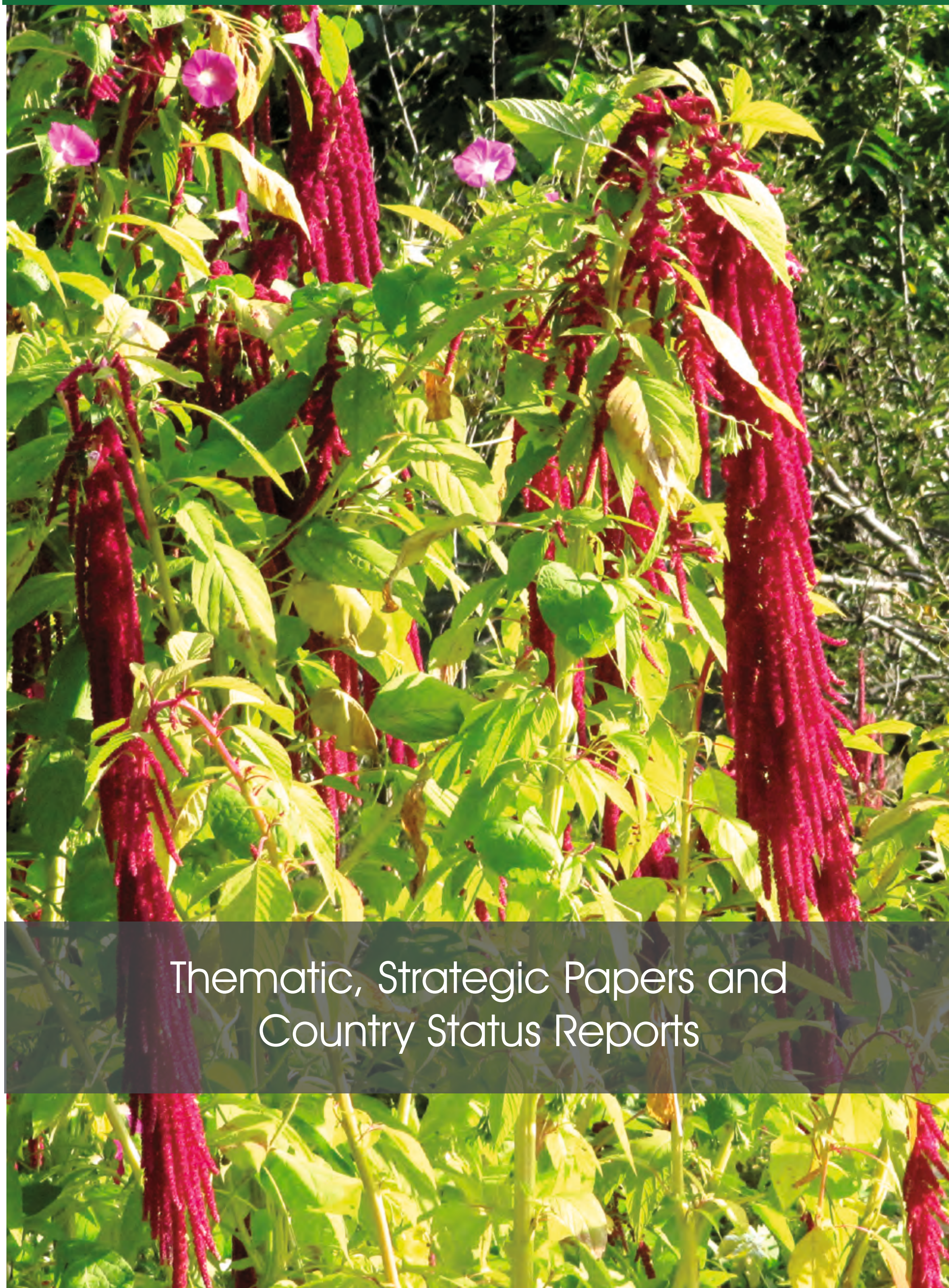
Regional Expert Consultation on Underutilized Crops for Food and Nutritional Security in Asia and the Pacific

Bangkok, Thailand, November 13-15, 2017



Thematic, Strategic Papers and Country Status Reports

APAARI – Asia-Pacific Association of Agricultural Research Institutions

APCoAB – Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources

World Vegetable Center

ICRISAT – International Crops Research Institute for the Semi-Arid Tropics

CFF – Crops For the Future

ICARDA – Science for resilient livelihoods in dry areas

Bioversity International

Department of Agriculture

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Foreword

APAARI under its programme on Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB), jointly organized a Regional Expert Consultation on "Underutilized Crops for Food and Nutritional Security in Asia and the Pacific" in collaboration with Council of Agriculture, Taiwan during November 13-15, 2017 at Bangkok, Thailand. The Expert Consultation was also sponsored by six other Institutions. Deliberations of Expert Consultation are being published in two parts: the first being "Proceedings and Recommendations" and the second on "Thematic, Strategic and Country Status Reports on Underutilized Crops of Asia-Pacific Region" for use more as ready reference. Content and style of presentations in the second publication have been retained as submitted by the contributors particularly with reference to reports of Thailand and Taiwan. The second publication consists of 9 thematic papers, 6 strategic papers and 16 country status reports. Two of the thematic papers (presented by Dr Benard, Mr Herriman) and one strategic paper (presented by Dr N.K. Krishna Kumar) were published earlier and have been reproduced with permission of the authors. Short bioparagraphs of all the presenters have been embedded in their respective papers/reports. Remaining participants contact details have been included in an Appendix. However, the editors put efforts to maintain continuity, uniformity and enhance understanding. Although, proceedings and recommendations are part of the first publication, however, if a country specific work plan needs to be developed, status and gaps presented in each country status report are extremely useful. Thematic and strategy papers have been planned to comprehensively cover aspects of underutilized crops (UUC). Analysis of these papers would help in generating new ideas to promote UUC.

The terms UUC, underutilized species (UUS) and neglected and underutilized species (NUS) have been largely used synonymously in both the publications. There are several listed crops in these reports that can be considered as UUC universally. However, some of the major staple food crops have been categorized as underutilized in certain countries. Considering the status and need in such countries, categorization presented by the countries is respected and retained. Learning lessons and success stories included in some of the country status reports will be of great help to other countries in the region. Leadership and relevant authorities in countries are expected to study both the publications while developing plans for their countries to enhance the nutritional, economic and environmental security by promoting UUC.

I am happy to state that APAARI with active support from members is committed to implement the recommendations made collectively by the experts and presented in the first publication to achieve SDGs 2, 3 and 13 in the Asia Pacific Region.

Ravi Khetarpal
Executive Secretary, APAARI

Acknowledgements

On behalf of APAARI and its programme APCoAB, it's a great pleasure to place on record appreciation to all the co-organizers, participants, service providers and staff who contributed in the successful organization of the 'Regional Expert Consultation on Underutilized Crops for Food and Nutritional Security in the Asia-Pacific Region' held at Bangkok from November 13-15, 2017. This document is the second publication emanating from the presentations made during Expert Consultation. We are extremely grateful to all the 16 countries, namely, Bangladesh, Bhutan, Fiji, India, Iran, Lao PDR, Malaysia, Nepal, Pakistan, Philippines, PNG, Samoa, Sri Lanka, Taiwan, Thailand and Vietnam for deputing the Heads and/or the representatives of their respective National Agricultural Research Systems (NARS), besides Subject Experts from various organizations. They have contributed in providing important thematic and strategic papers on underutilized crops and respective Country Status Reports in relation to the theme of the Expert Consultation. All the authors, as well as their co-authors, are sincerely thanked for providing very useful and comprehensive information, which has been encapsulated in this publication.

A few individuals need special mention for their unequivocal contribution for organization of the meeting and its outcome in form of this publication. Dr R.S. Paroda, Chairman, Trust for Advancement of Agricultural Sciences (TAAS), is very gratefully thanked for meticulously planning the Expert Consultation and sharing his deep insights during the deliberations. Able leadership provided by Dr Ravi Khetarpal, Executive Secretary, APAARI for implementation of the meeting and follow-up action, is thankfully acknowledged.

Thanks and deep sense of gratitude are due to the dignitaries present during the Opening Session – Dr Hiroyuki Konuma, Meiji University, Thailand, for delivering inaugural address and Drs Yusuf Zafar, APAARI, Thailand; Vincent Lin, COA, Taiwan; Suwit Chaikiattiyos, DOA, Thailand and Fenton Beed, WorldVeg, Thailand for gracing the occasion and their valuable remarks. Our sincere thanks are also extended to all the Co-Chairs, Rapporteurs, speakers and their co-authors, Panellists and the participants.

The valuable contributions of Drs K.S. Varaprasad, Anjula Pandey and Anuradha Agrawal is gratefully acknowledged who have not only worked as Rapporteurs/Facilitators during Expert Consultation and Co-Editors of this volume, but also as Reviewers, to improve the quality, coherence and content presentation of chapters; we highly appreciate their multiple tasks!

Administrative, logistic and technical support from Mr Vishwanath K. Sah, Ms Thansita Tanaphatrujira, Ms Celilu Bitong and Ms Tarathip Sanboonkrong, staff of APAARI Secretariat, is greatly appreciated and acknowledged.

The COA, WorldVeg, ICRISAT, ICARDA, CFF and Bioversity International are sincerely thanked for their generous financial contributions for organizing the Expert Consultation.

It is hoped that the present publication on thematic and strategic papers and country reports drawn from 16 countries of the Asia-Pacific Region, along with the Proceedings and Recommendations published in the first document, will draw attention of the policy makers, administrators, researchers, farmers and other stakeholders towards promoting the cultivation of underutilized crops.

Rishi Tyagi
Coordinator, APCoAB &
Co-Chair, Organizing Committee

The Organizers

The Asia-Pacific Association of Agricultural Research Institutions (APAARI)

The APAARI, with its headquarters in Bangkok, is a unique voluntary, membership-based, self-mandated, apolitical and multi-stakeholder regional organization in the Asia-Pacific region. It promotes and strengthens agriculture and agri-food research and innovation systems through partnerships and collaboration, capacity development and advocacy for sustainable agricultural development in the region. Since its establishment in 1990, APAARI has significantly contributed towards addressing agricultural research needs and enhancing food and nutritional security in the region. The close links, networks, partnerships and collaboration with stakeholders that APAARI has developed over the years, as well as its goodwill, authority and focus on results, make the Association an important actor in the region. The ultimate aim of APAARI is to help realising sustainable development goals in Asia and the Pacific. For more details, please visit: http://www.apaari.org

Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB)

The APCoAB was established in 2003 under the umbrella of APAARI. Later in 2017, it was renamed as Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB). APCoAB has the mission to harness the benefits of agricultural biotechnology bioresources for human and animal welfare through the application of latest scientific technologies while safeguarding the environment for the advancement of society in the Asia-Pacific region. For more information, please visit: http://www.apcoab.org; http://www.apaari.org/web/our-projects/apcoab/

Council of Agricultural Research (COA)

The COA, Taiwan is the competent authority on the agricultural, forestry, fishery, animal husbandary and food affairs in Taiwan. Its responsibilities include guiding and supervising provincial and municipal offices in these areas. Under the council, there are Department of Planning, Department of Animal Industry, Department of Farmers' Services, Department of International Affairs, Department of Science and Technology, Department of Irrigation and Engineering, Secretariat, Personnel Office, Accounting Office, Civil Service Ethics Office, Legal Affairs Committee, Petitions and Appeals Committee and Information Management Center respectively in-charge of related affairs. For more information, please visit: http://eng.coa.gov.tw

The World Vegetable Center (WorldVeg)

The World Vegetable Center, an international non-profit research and development institute, is committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious and health promoting vegetables. From its founding mandate in 1971 to support vegetable research and development in tropical Asia, AVRDC – The World Vegetable Center has expanded its focus to serve more continents, more countries, and more people. Today, Center researchers lead and participate in projects throughout Asia, Africa, Central America, and Oceania. We have 300 staff engaged in this spread of activities, and seek to partner with governments, nongovernmental organizations, universities, research institutes, and the private sector to promote prosperity for the poor and health for all. For more information, please visit: https://avrdc.org/

International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT)

The ICRISAT is a non-profit, non- political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics are home to over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture. ICRISAT is headquartered near Hyderabad, Telangana State, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR). For more information, please visit: www.icrisat.org/

Crops For the Future (CFF)

Since its inception, CFF has established partnerships with organizations around the world to improve food and nutrition security, health and incomes of the poor, and the sustainable management of fragile ecosystems. Crops For the Future Research Centre (CFFRC) was established in 2011 to provide research support for the global Crops For the Future organisation. CFFRC is a company limited by guarantee and without share capital. Its guarantors are the Government of Malaysia and the University of Nottingham in Malaysia.

In 2014, Crops For the Future and CFFRC combined their resources to form a single global entity - CFF. CFF now combines its research and development functions on underutilized crops (CFF Research) with Future Crop, an educational resource for underutilised crops and agricultural biodiversity. Both CFF Research and Future Crop will increasingly offer consultancy services to interested parties. For more information, please visit: www.cffresearch.org/

International Center for Agricultural Research in the Dry Areas (ICARDA)

The ICARDA is a global research-for-development organization. With envision thriving and resilient livelihoods in dryland communities of the developing world coming with robust incomes, secure access to food, markets, nutrition and health and the capacity to manage natural resources in equitable, sustainable and innovative ways. Since its establishment in 1977 as a non-for-profit organization, ICARDA has implemented research for development programs in more than 50 countries in the world's dry areas, spanning from Morocco in North Africa to Bangladesh in South Asia.

ICARDA combines scientific evidence and indigenous knowledge from dryland communities to address these challenges, which also have a considerable impact on emerging global issues of food security, land degradation and climate change. Our research aims to provide the evidence required to better position dryland issues firmly on the research and development agenda at national, regional and global levels. For more information, please visit: http://www.icarda.org/

Bioversity International

Bioversity International is a global research-for-development organization. We have a vision – that agricultural biodiversity nourishes people and sustains the planet. We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. We work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation. For more information, please visit the website: https://www.bioversityinternational.org/

Department of Agriculture (DOA)

The DOA was established since October 1, 1972 under the Revolutionary Decree No. 216 dated September 29, 1972 by merging the former Department of Agriculture and the Rice Department. The union was aimed to facilitate coordination among the Departments and officers as well as to streamline its function to enable a more efficient implementation of is mandates. The 15 pioneering units of the Department of Agriculture were the Office of the Secretary, Finance Division, Personnel Division, Planning Division, Rice Division, Field Crops Division, Horticulture Division, Sericulture Division, Rubber Division, Agricultural Engineering Division, Plant Pathology Division, Entomology and Zoology Division, and Agricultural Chemistry Division, a total of 95 research centres, stations and plant quarantine stations were then established throughout the country. For more information, please visit: www.doa.go.th/en/

Thematic Papers

Are Neglected Plants the Food for the Future?†

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ABSTRACT: Malnutrition and disease are closely associated and incidences of such diet-related diseases increase particularly in low and middle income states. While foods of animal origin are often unaffordable to low income families, various neglected crops can offer an alternative source of micronutrients, vitamins, as well as health-promoting secondary plant metabolites. Therefore, agricultural and horticultural research should develop strategies not only to produce more food, but also to improve access to more nutritious food. In this context, one promising approach is to promote biodiversity in the dietary pattern of low income people by getting access to nutritional as well as affordable food and providing recommendations for food selection and preparation. Worldwide, a multitude of various plant species are assigned to be consumed as grains, vegetables and fruits, but only a limited number of these species is used as commercial cash crops. Consequently, numerous neglected and underutilized species offer the potential to diversify not only the human diet, but also increase food production levels, and thus, enable more sustainable and resilient agro- and horti-food systems. To exploit the potential of neglected plant species, coordinated approaches on the local, regional, and international level have to be integrated that consequently demand the involvement of numerous multi-stakeholders. Thus, the objective of the present review is to evaluate whether neglected plant species are important as "Future Food" for improving the nutritional status of humans as well as increasing resilience of agro- and horti-food systems.

Key words: Fruits, malnutrition, orphan crops, underutilized species, vegetables

Introduction

Malnutrition, poor health, hunger and even starvation are still the world's greatest challenges. Currently, the FAO (de Silva, 2014) estimates that around 800 million people still suffer from food and nutrition insecurity, particularly in underprivileged population groups. According to the World Food Program (www.wfp.org/hunger/stats), poor nutrition causes nearly half (45%) of deaths in children under five – which accounts for about 3.1 million children each year. Worldwide, at least 120 million women in less developed countries are underweight (Blössner and de Onis, 2005). In addition, the Micronutrient Initiative reported that malnutrition reduced physical and mental development during childhood and weakened health and productivity of two billion people worldwide (Triantaphylides *et al.*, 2009). In this context, malnutrition is defined as deficiency of nutrition due to ingesting not the

Dr Benard Ngwene is a Scientist in the Department of Plant Quality, IGZ Großbeeren. He obtained a Ph.D. in Agricultural Science (Plant Nutrition). As a post-doctoral researcher, he worked on optimizing rhizosphere conditions for enhancing plant quality in some tropical neglected and underutilized species (NUS). He is coordinating the sub-project 'Impact of fresh and processed African indigenous leafy vegetables on human health' within the HORTINLEA project on rural and urban poor in Kenya, Ethiopia and Tanzania. His research interest includes food and nutrition security in the Global South, NUS (vegetables), soil fertility management, plant nutrient uptake and nutritional quality of plants.

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proper amount of nutrients by simply eating not enough food and/or by consuming nutrient-poor food in respect to the daily nutritional requirements (Blössner and de Onis, 2005). Consequently, the Sustainable Development Goals of the 2030 Agenda for Sustainable Development adopted by the United Nations in September 2015 (https://sustainabledevelopment.un.org/) still aims at having zero hunger as one of the Sustainable Development Goals by abolishing hunger and malnutrition (https://sustainabledevelopment.un.org/sdg2).

Malnutrition and disease are closely associated since malnutrition can be a contributing cause for diseases such as iron deficiency and anemia, iodine deficiency and mental impairments, as well as vitamin A deficiency and blindness (Ransom and Elder, 2003). Moreover, in recent years in developing countries, there has been a dramatic increase of chronic diseases including cancer, cardiovascular diseases, and diabetes as a cause of malnutrition based on unbalanced diet (e.g. http://www.afro.who.int/en/media-centre/world-health-day/2016.html). This worrisome development serves to highlight that new food strategies combined with health and nutrition educational programmes have to be initiated to better manage this interrelated food problem of malnutrition and disease.

Incidences of these diet-related diseases increase are particularly high in low and middle-income states (Yang and Keding, 2009). While foods of animal origin are often unaffordable to low income households, various neglected crops can offer an alternative source of micronutrients, vitamins, as well as health promoting secondary plant metabolites. Mainstreaming these crops into local food systems will therefore help in alleviating malnutrition, especially prevalent in rural communities, where farming is the main source of food and income.

Therefore, agricultural and horticultural research should develop strategies not only to produce more food, but also to improve access to more nutritious food. One promising approach is to promote biodiversity in the dietary pattern of these people. Development of products that are acceptable to the local people is one way of enhancing consumption of nutritious food and of boosting access to nutrition. It is important to note that diets are different all over the world and recommendations for food selection and preparation have to be matched with the local population's eating and cooking behavior.

Worldwide, a multitude of various plant species are assigned to be consumed as grains, vegetables and fruits, but only a limited number is used as commercial cash crops. Consequently, numerous neglected and underutilized species offer the potential to diversify not only the human diet, but also increase food production levels, and thus, enable more sustainable and resilient agro- and horti-food systems. Introducing these orphan species would increase the opportunity to produce nutrient-rich food as well as simultaneously enhancing the environmental capacity for future generations to supply themselves. Most of these neglected plants have a comparative advantage in marginal lands where they have been naturally selected to withstand stress conditions and can therefore contribute to low-input sustainable production systems (Thompson *et al.*, 2007). Considering current trends in weather alterations due to climate change and the vulnerability of agriculture and horticulture to these alterations, diversity in genetic resources will promote resilience of the agricultural and horticultural systems, as well as buffer social and economic shocks that might arise due to concentrating on fewer crops.

Thus, the objective of the present review is to evaluate whether neglected plants are important as "Future Food" for improving the nutritional status of humans as well as enhancing resilience of agro- and horti-food systems. To this end, this review will address the following three key questions:

1. Which potentials of neglected plants exist in different continents?
2. What are the benefits and barriers of establishing neglected plants along the food supply chain?
3. Which strategies could be used to bring neglected plants out of their niche role?

Methods

The results and discussions of the review are based on a workshop at the Potsdam Summer School of International Nutrition in October 2015 hosted by the Institute of Nutritional Science, University of Potsdam, and the Leibniz Institute of Vegetable and Ornamental Crops. Nearly 50 participants from 18 nations (Bangladesh, Brazil, Cameroon, Columbia, Costa Rica, Cuba, Ethiopia, India, Indonesia, Kenya, Nigeria, Philippines, South Africa, Togo, Uganda, Uzbekistan, Zambia, and Germany) attended the workshop representing a broad spectrum of experts from science and industry ranging from plant physiology, horticulture, food science, and human nutrition to food technology. Moreover, a balanced mixture of early stage researchers and senior scientists was in attendance. By using the World Café Method, the three above-mentioned questions were debated in six simultaneously running roundtable discussion groups each comprising five to six participants and one or two moderators. Afterwards the results were presented by the moderators. For the first round and question, the participants could choose a continent of their interest. Consequently, three tables discussed on Africa, two on Asia, and one on North and South America. For the second round, the participants were randomly selected, put in groups of five to six and worked on different steps of the food value chain, i.e. resources, production, storage, processing, trade and retail, and consumer. During the third round, strategies for bringing neglected plants out of their niche role were discussed for the following three areas of action: information and communication, technology, and trade and regulatory barriers. Two tables per area with randomly selected participants, put in groups of five to six, were allocated.

Potential of Neglected Plants in Different Continents

About 80,000 plant species are used for food and fiber as well as industrial and medical purposes (Kermali *et al.*, 1997). The number of edible plant species reported in the literature varies; however, about 10,000 appears to be a realistic number (Kunkel, 1984; Wiersema and León, 1999). To date, however, only four main crops, namely maize, potato, rice, and wheat, supply more than 60 per cent of the human's energy intake (FAO, 2010).

The drastic increase of the world's population in the last two centuries has driven up the need for food and increased food demand. This pressure initiated the distinct intensification in agriculture and horticulture practices and accelerated the loss in crop diversity. More recently, it has become clear that lack of diversity due to concentrating on fewer crops can have negative consequences for the human diet, which may cause malnutrition and diet-related diseases (Nakhauka, 2009). Since neglected plants are generally rich in nutrients and health-promoting compounds with preventive effects against malnutrition and some chronic diseases, they have a huge potential in improving nutrition and health in indigenous communities in many parts of the world. Therefore, diversifying the food chain to include these neglected species could be an effective tool to improve overall human nutrition and health. Thus, neglected plants are characterized not only by local importance; they also might have the potential to improve diet diversity on a more supra regional level.

Asia

The plant genetic resources in Asia accommodate a broad biodiversity as the Asian climate region comprising cool, temperate and tropical regions. In China alone, over 400 families, 3100 genera, and about 30,000 species are known (Chen and Zhang, 2001). Thus, an enormous diversity of plant species exists in this region (Larkcom and Douglass, 2007), but their potential is currently not fully exploited. Arora (2014) lists 778 underutilized species in the Asian-Pacific region, including 261 fruits, 213 vegetables, 55 root/tuber types, 34 nuts, 28 pseudocereals and millets, 14 grain legumes/pulses, 25 industrial crops and 148 others. During the Potsdam Summer School, certain species were named and discussed, of which bitter gourd, moringa, and ivy gourd were listed as neglected plants by the biodiversity international organization in 2013 (Padulosi *et al.*, 2013). Especially, bitter gourd and ivy gourd are eaten because of their health-promoting actions (Table 1). Moreover, there might be additional potential of other species in Asia not discussed during the Potsdam Summer School. Like all other neglected plants, these species have a great potential and could provide new or additional foods rich in minerals and/or vitamins that would ultimately contribute to improving human health. For example, date palms, sweet potatoes and lettuce are rich in carotenoids and serve as a source of pro-vitamin A as well as antioxidants (Table 1). Date palms and bitter gourds can essentially contribute to iron uptake in plant based diets. Finally, date palms and sweet potatoes are rich in dietary fibers (Arora, 2014).

Even if seaweed is beyond the scope of the present review it is worthwhile to note that it was mentioned as an interesting source for micronutrients, proteins, and fiber; and seaweed is regularly consumed in the Asian-Pacific region, has a huge biodiversity, complex composition, and broad range of nutritional and health beneficial compounds (examples are given in: Cardozo *et al.*, 2007; El Gamal, 2010).

Table 1. Examples of neglected plants in Asia and nutritional aspects discussed during the summer school

Species	Usage, nutritional/health aspects
Bitter gourd *Momordica charantia*	Consumed fresh, roasted, or as pickles. Known source of iron, helps to prevent cancer, diabetes, and diseases related to high blood pressure
Date palms *Phoenix dactylifera*	Fruits eaten raw or used in beverages, long shelf-life, known source of iron, carotenoids and fiber
Ivy gourd *Coccinia grandis*	Fruits are cooked and eaten as vegetable, consumption can reduce fever and blood sugar
Lettuce *Limnocharis flava*	Leaves are cooked or pickled and eaten as vegetable, rich in vitamin A
Sweet potatoes *Ipomoea batatas*	Tubers and leaves known source of fiber, starch, micro-nutrients and antioxidants

Africa

Addressing livelihood improvement options for rural communities in Africa requires also a broader focus on diet-relevant indigenous plant species. Of note is that Sub-Saharan Africa accounts for 9 per cent of the global population and has high food and nutrition insecurity, which is partly due to a lack of crop diversification (Bekunda *et al.*, 2010). The African diet partly comprises many different food products, including leafy vegetables and other indigenous crops, which contribute to a healthy diet. Apart from playing an important role in the African diet, indigenous African crops, most of which are neglected plants, also contribute to the local economy, provide environmental issues, and are an integral part of traditional medicine as leaves of certain neglected plants are used both as a food and a medical source (Table 2). Most of the plants used grow indigenously in the wild and/or are cultivated on a very small scale. Hence, production as well as availability is limited (Charles Aworh, 2015; Muhanji *et al.*, 2011; Tumwet *et al.*, 2014).

To exploit the full potential of these indigenous neglected plants for human nutrition and health, we have to understand how the plants are used in different communities as well as to determine which substances contribute to the associated health benefits. The plants are known by different names and serve different purposes in different communities. For example, *Gnetum africanum* cultivars are called *okazi*, *ukazi*, or *afang* in different parts of Nigeria, and the tough and slightly bitter leaves are used in soups or chewed with palm oil for medical purposes by the Efik people in South-eastern Nigeria (Ali *et al.*, 2011; Ingram *et al.*, 2012). Another good example of the multi-facetted utilizations of neglected plants is *Telfairiaoccidentalis* leaves. These leaves are used as food as well as a medical ingredient in many parts of West and Central Africa. For food, the leaves are boiled or blanched and mixed with different spices and other vegetables, and the final spinach-like product is then served as a main dish. For medicine, it is used to prevent some diseases (e.g. diabetes, anemia) or to support pregnant women towards lactating (Esuoso *et al.*, 1998; Oboh *et al*., 2006; Otitoju *et al.,* 2014).

Table 2. Examples of neglected plants in Africa and nutritional aspects discussed during the summer school

Species	Usage, nutritional/health aspects
Okazi / ukazi / afang *Gnetum africanum*	Leaves are used in soups, chewed with palm oil. Known source of minerals (iron), protein, fiber, flavone-glycosides, and stilbenes
Ugwu / ugu / pumpkin; *Telfairia occidentalis*	Cooked in soups and stews, and raw and blanched in smoothies. Used in traditional remedies to threat, e.g. diabetics, gastrointestinal disorders, and to support women towards lactating. Known source of protein, fat (seeds), and fiber, as well as saponins, tannins and phenolic acids
Utazi / otazi *Gongronema latifolium*	Used as leafy vegetable and spice for sauces, soups and salads as well as in traditional remedies, e.g. to maintain blood glucose levels. Known source of protein, saponins, tannins, and flavonoids
African nightshade *Solanum scabrum*	Leaves and young shoots are used as leafy vegetable and in soups. Used as medicinal plants to treat stomach ailments, e.g. ulcers, rich in β-carotene, calcium, iron, folate, vitamin E, alkaloids and protein
Uzazi *Piper guineense*	Raw, boiled, or blanched leaves for salads and soups as a spice. Known source of bioactive amides (e.g. piperine) and tannins
Waterleaf *Talinum fruticosum*	Leaves are used in soups or boiled as vegetables. Used in the treatment of cardiovascular diseases and obesity, rich source of vitamins, minerals, fiber, and proteins, flavonoids and alkaloids

North and South America

In the tropical regions of South America exist the most greatest plant diversity of any region today (Wilf *et al.*, 2003). Both in North and South America numerous neglected plants known from previous cultures of Incas, Aztecs, and native Indians still exist. One impressive example of these native plants is the *maca* root (*Lepidium meyenii*). *Maca* roots have been used by native Indians in Peru for nutritional and putative medicinal purposes. For the last 20 years, interest in *maca* has increased and scientific evidence has demonstrated that *maca* has nutritional, energizer, and fertility-enhancing properties (Gonzales, 2012). During the Potsdam Summer School, moringa and quinoa were categorized as neglected plants in all continents. However, in the last years, moringa and quinoa have gained great attention due to their secondary plant metabolites in both the European market and concomitantly in the agricultural sector of South America. In addition to these now rather popular crops, several still neglected fruits and vegetables indigenous in North and South America were also discussed during the Potsdam Summer School (Table 3).

Table 3. Examples of neglected plants in North and South America and nutritional aspects discussed during the summer school

Species	Usage, nutritional/health aspects
Arracachá *Arracacia xanthorrihza*	Roots consumed cooked and roasted, used for soups and puree. Young stems consumed fresh or cooked. Known source of carotenes, calcium, iron, and vitamin A
Cashew apple *Anacardium occidentale*	Fruits used for juice, syrup, liquor, beverage, and juice. Known source of fiber, calcium, phosphorus, carotenoids, vitamin B1, ascorbic acid, and tannins. Antioxidant activity due to the content of vitamin A precursors
Maca *Lepidium meyenii*	Roots consumed cooked or roasted, flour production and used for baking. Known source of fiber, iodine, calcium, phosphorous, zinc, magnesium, iron, vitamins B1, B2, B12, C and E, glycosides, and glucosinolates
Nance *Byrsonima crassifolia*	Fruits consumed fresh or cooked, used for beverages. Fruits known as a source of tannins, lipids, flavonoids, calcium and vitamin C. Bark reduces skin infections, gastrointestinal disorders, fever and has depressant effects on the central nervous system
Peach palm *Bactris gasipaes*	Fruits consumed fermented as beverage or the boiled mesocarp can be dried, sometimes smoked, stored for a long time and rehydrated later. Known source of fiber, carotenoids, flavonoids, vitamin C, E, A, B, and K, potassium, calcium, iron, magnesium, phosphorous, and zinc. Anti-carcinogenic, anti-diabetic, and prevents cardiovascular diseases

Arracachá was originally cultivated in the Andes and is still an important food in this region. The root is used as a culinary analog for potato, and can be roasted or boiled and is used in a broad range of dishes from starters to desserts (e.g. Arbizu *et al.*, 1997; Lim, 2015). Also young stems are consumed in fresh salads or as boiled vegetable. The processed roots are used as a thickener for baby food formula and instant soups (http://cipotato.org/roots-and-tubers/arracacha/). *Arracachá* roots should show intense amounts of calcium and iron, and especially yellow roots are a rich source of carotenoids (personal communication of Potsdam Summer School participants).

The cashew apple is a by-product of cashew nut production. Fresh fruits are directly offered at the local market or can be processed. The juice of the cashew apple is used for various kinds of beverages. In home-processing, and more rarely for commercial purposes, the highly perishable apples are preserved within syrup in glass jars (http://mvinayraj.com/index.php/my-articles/218-travails-of-cashew-cultivators-and-industy-workers-in-srikakulam-a-focus-on-cash-apple-to-supplement-economy).

Nowadays, some processes have been developed for converting the cashew apple into other products such as jam, syrup, chutney, and juice (de Abreu *et al.*, 2013). Cashew apple juice is described as a remedy for sore throat and chronic diarrhea. Fresh or distilled, it is thought to act as a potent diuretic and should have sudorific properties (Talasila and Shaik, 2015). Cashew apple brandy is applied as an ointment to relieve the pain of rheumatism and neuralgia (Morton, 1987) and the apples themselves have antibacterial (Kubo *et al.*, 1999), antioxidant (da Silva *et al.*, 2013; MeloCavalcante *et al.*, 2003), anti-inflammatory, and wound healing effects (da Silveira Vasconcelos *et al.*, 2015).

Maca belongs to the *Brassica* species and is native to the high Andes of Peru. It is used as a root vegetable as well as a medicinal herb. Scientific evidence of the medicinal properties of *maca* is still lacking. Just in one review only a few clinical trials were analyzed in which *maca* is promoted as a dietary supplement for several women´s health issues including menopause symptoms (Lee *et al.*, 2011). However, the clinical evidence and significance of these studies seem to be questionable. *Maca* has been promoted due to its assumed benefit for sexual performance as well as an aphrodisiac – for which there is also insufficient evidence (Ernst *et al.*, 2011). *Maca* is known to contain significant amounts of iodine and glucosinolates (Taylor, 2005) and iodine is important for thyroid metabolism and glucosinolates and their breakdown products have health-promoting effects on humans (Valentova and Ulrichova, 2003).

Nance or wild cherry is a large shrub or tree. The native distribution of the species is Central and South America and is limited to tropical and subtropical climates. The fruit can be eaten raw, cooked as dessert, or included in soups. Moreover, *nance* is also used for carbonated or fermented beverages known as chichi, a beer-like drink, and also a rum-like liquor is produced from nance fruits (Orwa *et al.*, 2009). The bark and leaves are used for medicinal purpose to treat skin infections and gastrointestinal disorders, or a bark infusion is applied to halt diarrhea, to act as a bactericide, fungicide, or antipyretic, and to promote menstruation (Caceres *et al.*, 1993; Caceres *et al.*, 1991; Martinez-Vazquez *et al.*, 1999). Furthermore, leaf and bark aqueous extracts shows depressant effects on the central nervous system (Morales Cifuentes *et al.*, 2001), and nance bark infusion is given as an antidote for snakebites (Bejar and Malone, 1993).

Peach palm is actually a palm tree native to South and Central America and is a limited exported crop. The fruits of peach palm range in color from yellow to red, depending on the variety (Graefe *et al.*, 2013). The fruit has been in use for centuries in South America. In the palm peach producing countries, palm peach is known for a great range of health benefits due to its bioactive compounds (Espinosa-Pardo *et al.*, 2014) and palm can be useful in treating diabetes due to the low glycemic index (Jimenez *et al.*, 2012), preventing macular degeneration due to the high content of vitamin A (Yumbya *et al.*, 2014), and increasing the HDL cholesterol (Carvalho *et al.*, 2013).

Benefits and Barriers of Establishing Neglected Plants Along the Food Supply Chain

Worldwide we are facing rapid urbanization, especially in Asia and Africa. At present, more than 50 per cent of the world population resides in cities, and even in less developed countries, a majority of people will be living in urban areas by at least 2017 as estimated by the United Nations (2010). For the year 2050, a further increase of the urban population is predicted of up to 70 per cent (United Nations, 2010). This rapid urbanization and simultaneously growing world population are challenging food supply chains by: (1) causing a loss in farmers and arable area; and (2) increasing number of consumers and consumer demands.

Globally, smallholder farmers produce the majority of the world's food (www.bioversityinternational.org). Thus, biodiversity of plant species used for human food – as highlighted at least by the potential of neglected plants – is one decisive tool for ensuring food productivity, and hence, food security not only for farmers, but also for the final consumer, regardless of the geographical location (Fanzo *et al.*, 2013). Mainstreaming the use of these neglected plants for human nutrition and health also means improving their production and linkages to value chains. However, popularizing the use of these neglected plants will provide more jobs, diversify income possibilities, as well as open new marketing options for the local community, commercial farmers, and the food industry.

In addition, leverage points within the entire food supply chain have to be identified (Fig. 1) to promote adequate usage of neglected plants (www.cgiar.org/our-strategy/cgiar-research-programs/cgiar-research-program-on-agriculture-for-nutrition-and-health/). Such leverage points include resource endowment via production, storage, processing, and retail to the consumer's expectations (Schreiner *et al.*, 2013).

Resources and Production

Among the first steps in creating a food supply chain for the delivery of a product to the market is the evaluation of existing resources. Neglected plants are characterized by adaptation to the environmental conditions of their regions of origin. Scenarios of global climate change predict increasing limitation of water resources, especially in arid and semi-arid regions. In these areas, reduced water availability is aggravated by the great seasonal and annual irregularity of precipitation leading to a further accentuation of the water shortage (Postel, 2006). Neglected plants have often a higher stress tolerance which enables them to survive, e.g. longer drought periods. This higher stress tolerance offers an advantage compared to staple crops since neglected plants often only need the existing

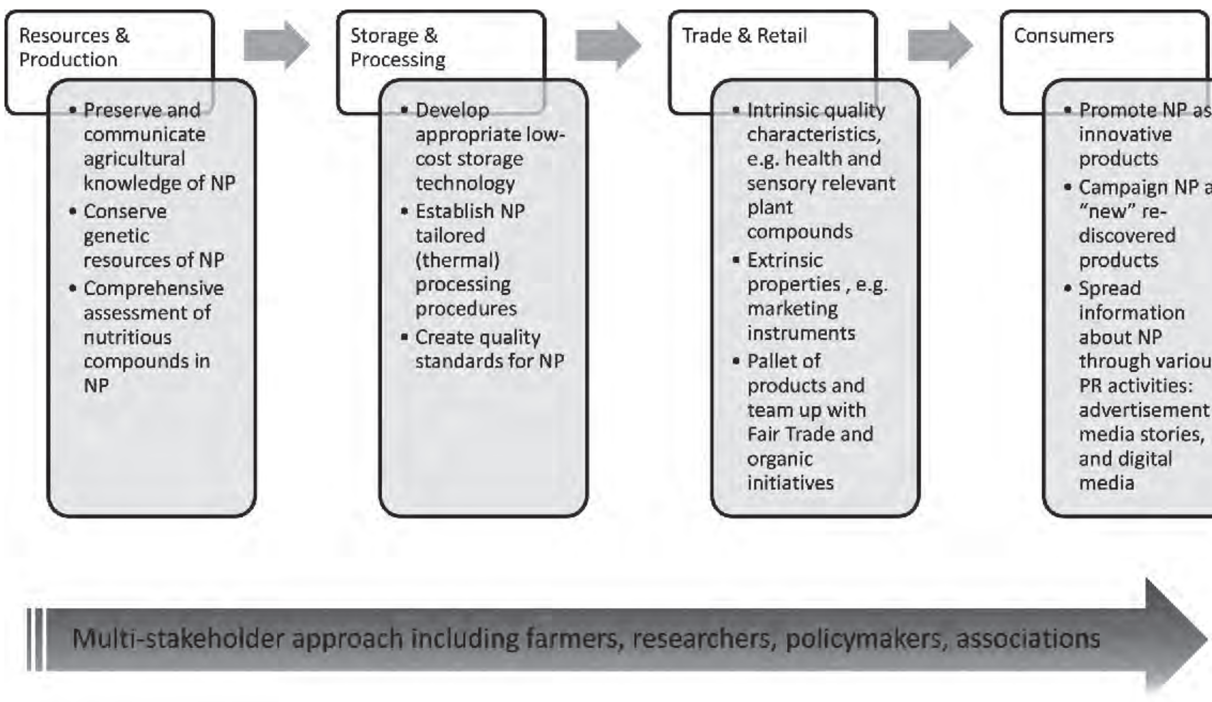

Fig. 1. *Leverage points of each level within the food supply chain of neglected plants (NP)*

local cultivation resources to which they are already adapted. Furthermore, neglected plants could be more tolerant to extreme weather conditions as a consequence of climate change, and it might be possible to cultivate them in more marginal areas. Another important resource is the agricultural knowledge about the characteristics and cultivation methods of these underutilized plants. Local farmers have the traditional expertise on how to grow these indigenous plants under field conditions with less cost-intensive tools. Unfortunately, the literature available about neglected plants has very little consistency, and in addition, neglected plants are scarcely addressed by research, conservation, and valorization activities. Providing this knowledge of local farmers to the international community is therefore of upmost importance to overcome our current lack of understanding. In the last few years, due to the rising attention in neglected plants, projects to record lists of neglected plants and acquire indigenous knowledge about their cultivation have been undertaken in several countries, e.g. an ethnobotanical study on underutilized plant species in the Shouf-Aley area of Lebanon (Noun, 2006) and the Bioversity International's African leafy vegetables programme in Kenya (Gotor and Irungu, 2010). Due to the limited research on neglected plants, production conditions, such as water and nutrient regimes, are often not yet investigated for these plants and might be of interest if such plants should be marketed. Moreover, to promote the cultivation of neglected plants and save their biodiversity, the genetic resources must be conserved *in situ* through use in their region of origin as well as *ex situ* in the form of germplasm collections to supply farmers and researchers with, e.g. seed material. About 7.4 million accessions of plant genetic resources are retained in about 1,750 individual gene banks worldwide and in over 2500 *ex situ* collections in botanical gardens. However, neglected plants remain underrepresented within these collections (FAO, 2010), emphasizing the importance of *in situ* conservation at the present time. Another limiting resource is the availability of arable land. The growing world population, currently at 7.3 billion, but expected to increase to 9.7 billion by 2050 (United Nations, 2015), will lead to increased food demand and cause competition for land between people's housing needs and farm land as well as between staple crops and neglected plants.

Storage

Neglected plants (mostly indigenous fruits and vegetables) are rich in nutrients, and thereby, possess a high potential for improving nutrition and health in many areas around the world, especially in rural communities where the dependency on self-produced foods is very high. However, to benefit from the nutritive potential of these plants, they should be consumed while the nutritive quality is still preserved. Poor storage can lead to loss of nutritive quality. Therefore, storage is quite an important factor to the exploitation of the potential of these foods for nutrition and health of consumers. Fruits and vegetables are generally harvested with very high-water contents of over 90 per cent, thereby making them very perishable. After harvest, a significant proportion may perish because of poor handling and marketing conditions (Habwe *et al.*, 2008). Moreover, storage technologies for these foods are scarce in rural communities (Lenné and Ward, 2010), and even if they are available, they are either too complex or unaffordable for the rural farmers. Since neglected plants are generally produced by small-scale rural farmers, low storage capacity and the unavailability of adequate transportation means are therefore main limitations to their marketing and consumption (Muchoki *et al.*, 2007). Under optimal storage conditions (temperatures close to 0°C and humidity of about 95%), leafy vegetables can be stored for between 10 and 14 days (Kanlayanarat, 2009). Storing fruits and vegetables at such low temperatures helps maintain their quality and prolong shelf-life by reducing metabolism and aging. Therefore, soon after harvesting, fruits and vegetables need to be stored and transported under low temperatures to maintain freshness and nutritive quality. Due to the lack of cold storage facilities among other factors, food losses are estimated to reach 50 per cent in many rural communities (Kitinoja *et al.*, 2011) where neglected plants are mainly produced. Subsistence smallholder farmers lack the resources to use modern cold storage buildings and/or refrigerated trucks for transportation, thus after harvesting their crops, simple storage methods, e.g. shading, are applied. Further, most public markets in these communities generally lack appropriate storage facilities and cooling systems. Alternative low cost technologies, such as on-farm evaporative coolers (Jain, 2007), modified atmosphere packaging (Sivertsvik *et al.*, 2002), and use of insulated covers over product crates (Wheeler *et al.*, 2015), have been proposed to reduce losses in product quantity and quality. Small-scale farmers, however, lack the know-how to apply these techniques and/or the financial resources to acquire them. With the help of agricultural extension services, which are available in many rural communities, along with financial support, some of these technologies can be applied to improve storability and prolong the shelf-life and supply of high quality neglected plant foods to consumers.

Processing

The processing of neglected plants is mainly based on traditional recipes with lots of interregional and interfamily variations. As cooling is often not possible for smallholder farmers, processing can extend the shelf life and concomitantly, the marketability (e.g. convenient products) and availability of neglected plants for longer periods after harvest (Kumar *et al*., 2013; Mishra *et al*., 2015; Sreeramulu *et al.*, 2013; Zerio-Egli *et al*., 2014). Moreover, anti-nutritional ingredients can be reduced by processing, e.g. oxalic acid in leafy vegetables or cyanogen compounds in cassava roots (Betsche and Fretzdorff, 2005; Chergui *et al.*, 2015). The partly enhanced bioavailability of nutritious compounds, e.g. carotenoids, or the development of species-specific flavors have been shown to lead to an enhanced acceptability of processed neglected plants (Eriksen *et al.*, 2016; Kinyuru *et al*., 2009; Reis *et al.*, 2015; Rodriguez-Roque *et al.*, 2016). However, cooking and other thermal processing have to be tailored to the neglected plant properties to avoid loss in health-promoting substances such as pro-vitamins A and C (Berni *et al.*, 2015; Martinez-Hernandez *et al.*, 2016; Rodriguez-Roque *et al.*, 2015). Processing of neglected plants can be done at home, e.g. fermentation, or directly on markets as street kitchens. Finally, the increased use of neglected plants can ultimately improve the livelihoods of low income families (Frank and Nelly, 2015; Toledo *et al.*, 2006).

Smallholder farmers and housewives can use traditional processing practices for preparing a limited number of dishes for their families or street clients, whereas international markets require the processing of higher quantities under certain quality standards of various quality management systems such as the International Food Standard or GlobalGap. Technological constrains are often linked to the non-monitoring of processing parameters, which can be unpractical under habitual home or market conditions. Thus, innovative, simple, and affordable technologies must be developed particularly for neglected plant products (Frank and Nelly, 2015; Oladele, 2011).

Trade and Retail

Innovative market approaches include identifying appropriate technical solutions in respects of quality preservation of neglected plants in terms of storage or processing. However, in addition to intrinsic quality characteristics, such as health and sensory relevant plant compounds, extrinsic properties are also decisive for the quality evaluation by the consumer, and hence, are crucial for the consumers' purchasing decisions (Schreiner *et al.*, 2013). Packaging, color, and price (e.g. Akdeniz *et al.*, 2013) or in a wider-ranging definition, marketing instruments, such as distribution, communication policies, and advertising (Richardson *et al.*, 1994; Scharf *et al.*, 2012), determine overall market success. Therefore, there is an urgent need to also develop such market strategies for neglected plants as new products and new demands are created (Padulosi *et al.*, 2013) associated with a previous identification of potential consumer groups or types (Koolman, 2014a). Thus, one strategy is that retailers offer recipes and sometimes even video tutorials on how to prepare the recommended neglected plant. Notably, retailers are more successful when they submit a pallet of products and team up with Fair Trade or organic initiatives (Eissing and Eissing, 2008) such as Baobab Social Business GmbH for *baobab* products (oil, powder, and sweets) or *Marula* Natural Products Trust for *marula* products (fruit pulp, essential and edible oil). Whatever marketing approach is chosen, it has to be tailor-made to the neglected plant and to the expected customer preferences and demands.

Consumer

To promote the consumption of neglected plants, the consumer is a very crucial stakeholder within the food supply chain. The consumer preferences and demands ultimately determine which fruit or vegetable will be purchased, and hence, which horticultural or agricultural produce will be established in the market (Schreiner *et al.*, 2013). Moreover, consumer preferences are also greatly influenced by social-political changes and are therefore very dynamic (Karmasin, 2007). However, despite the highly nutritious properties of neglected plants, these plants can be negatively perceived and attitudes to local and traditional food can be associated as food for the poor, thereby leading to rejection from the consumer (Fanzo *et al.*, 2013). One strategy to promote neglected plant consumption is to market them as innovative products. However, according to (Rogers, 2003) only certain groups of consumers, namely the innovators and early adopters, will be open-minded, and thus, firstly purchase the "new" rediscovered products. The majority of consumers will be hesitant in consuming neglected plants due to the lack of information about these fruits and vegetables and also having cultural diet barriers. Currently, little is known about these species such as where they come from, how they taste, how to process the plants, recipes, the nutritional values, health-promoting effects, etc. Furthermore, some neglected fruits and vegetables have an extraordinary morphology or appearance, or the product presentation at the point of sale is unprofessional, further leading to product rejection. Thus, impersonal public relation and marketing methods, e.g. advertising and media stories spreading information about these product innovations, are necessary since consumer acceptance will increase (Robinson, 2009). Collectively, these marketing tool and strategies should promote the key message that dietary diversity by these rediscovered neglected plants is a crucial element for the consumer's health status.

Strategies to Bring Neglected Plants Out of their Niche Role

To develop strategies for the promotion of neglected plants, barriers against mainstreaming these plants have to be first identified and then analyzed. These barriers are mainly attributed to (1) poor economic competitiveness of neglected plants compared to staple crops, (2) inefficiency in producing, storing, and processing of neglected plants, (3) no sound baseline data of the nutritional and protective properties of neglected plants, (4) disorganized or non-existing food supply chains, and (5) negative associations with poor rural lifestyle and low social status (e.g. Chweya and Eyzaguirre, 1999; Fanzo *et al.*, 2013). In addition, to better ensure the food supply chain, the most decisive action fields, namely information and communication, technology, as well as trade and regulatory barriers have got to be developed and implemented (Fig. 2).

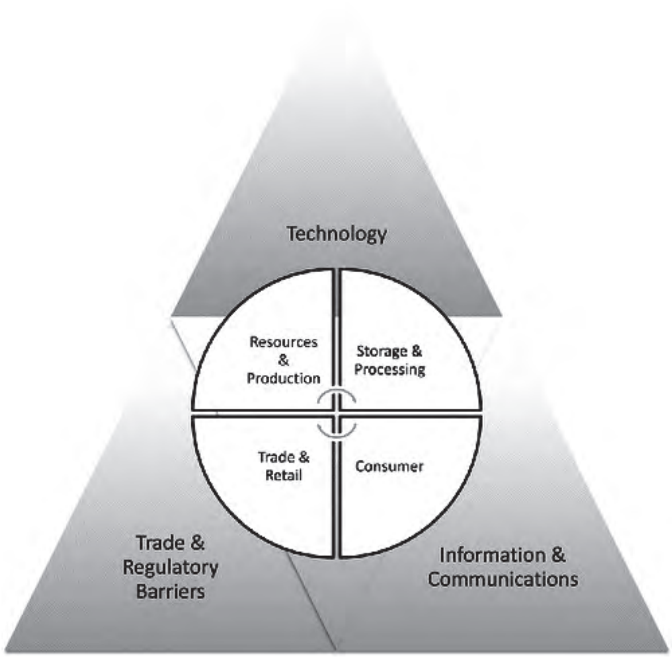

Fig. 2. *The food supply chain of neglected plants and their influencing areas of action*

Information and Communication

Improving the management of information and communication is a mandatorily requirement for enhancing the consumption of neglected plants. From a societal point of view, it is important to convince stakeholders and decision-makers, i.e. persons in charge of public welfare as well as prestigious individuals, to actively advertise these products in public. However, not only the neglected plants itself should be advertised, but also showing the preparation of a food from raw plant material in television, social-media, or public cooking courses could reduce prejudices and fears towards food security and nutritional quality. The advertisement of neglected plants in general and their products in particular is often based on information about the history of the plant, along with regional and botanical information, as well as their benefits for the consumer. It has to be underlined that to successfully market neglected plants the key message to convey is how the consumers or various potential target groups benefit from specific neglected plants. To achieve this marketing goal, specially tailored advertising for the different neglected plants is required (Koolman, 2014b).

Moreover, these campaigns emphasize the consumer's self-awareness of what one eats and how (traditional) food has to be prepared to contribute to a healthy diet. The reintroduction of traditional crops and enhanced identification with traditional values can be supported by the revival of cultural elements, e.g. the "Cassava Song", which was written in the 1980s by Flora Nwapa (1986), Nigeria`s first female novelist in modern time. The "Cassava Song" is a protest against the import of the staple crop rice and a plea to remain with the traditional African cassava crop. Finally, to better promote the consumption of neglected plants, especially with a view to attracting more young consumers, digital media should be increasingly used such as Facebook, Twitter, YouTube, or Instagram.

In addition to these societal aspects, policy supported extension services (e.g. governmental health initiatives, governmental campaigns to support and expand extension services to local farmers) should also be launched since health centers and diet-related health education is of central importance to any nation. Educating people on what a healthy diet is and how to eat healthily in their daily routine as well as which local plants can be used, may also help to strengthen a community's consciousness for their indigenous foods as well as for their own traditional diet. Further, educating consumers to consume indigenous plants in their daily diet, whether home-cooked or industrially processed, would generally raise their well-being in terms of health and finances.

Often the ecological and technological knowledge about neglected plants is lost or only limited information is available for smallholder farmers who mainly grow these neglected crops. Thus, training courses for local farmers, extension workers, and members of households for obtaining pertaining knowledge and skills necessary for production and household preparation of neglected plants should be conducted. Such training courses should include crop management, selecting varieties, and developing new products (Padulosi *et al.*, 2013). Moreover, in-depth high-level training on the benefits of traditional fruits and vegetables with a focus on neglected plants should be provided by partners from universities, private (seed) companies, and possibly NGOs from project countries. Another option is practical and module-based trainer-of-trainer programmes using seed kits, in which neglected plants are incorporated. This training will help farmers to establish their own garden and to produce good harvests of nutritious fruits and vegetables. Farmers will not adopt neglected plants unless an (strong) element of awareness is present among consumers, which also includes the farmers themselves. Finally, the organoleptic aspect also needs to be addressed as part of the training courses since the acceptance of fruits and vegetables with enhanced nutritional value will also depend on an acceptable taste and texture.

Technology

To improve the utilization of neglected plants they have to be characterized in respect to their properties, their cultivation requirements, and their processing applicability (Padulosi*et al.*, 2013). Commonly, as neglected plants are mainly cultivated on small-scale local smallholder farms, they are produced, stored, and processed manually using simple traditional techniques that are both time-consuming and labor-intensive (Eissing and Eissing, 2008).

Although neglected plants have a comparable lower yield, they are characterized by yield stability, low nutrient and water demand, and are also adapted to local pests. Collectively, these factors enable low cost production of these crops (Thies, 2000). However, for new crops to compete with already established ones, it is necessary to improve cultivation techniques, e.g. fertilizer use, adapted cropping systems, or natural pest treatments, as well as to use selected varieties or suitable seed storage bins (Padulosi *et al.*, 2013). This was demonstrated in the Slow Food Project "1000 gardens in Africa" (Padulosi *et al.*, 2013) and also shown in an Indian study by Ravi *et al.* (2010) where traditional millet cultivation resulted in a loss to several farmers due to low yield, whereas advanced techniques resulted in a 60 per cent yield increase.

After harvesting, simple storage methods, such as shading products or charcoal cooler storage facilities, are used. However, for improving the neglected plant's shelf life, alternative energy-saving techniques, such as on-farm evaporative coolers and appropriate modified atmosphere packaging, should be explored (Liberty *et al*., 2013; Yumbya *et al*., 2014). Several local preservation methods, e.g. blanching, air-drying, solar-drying, and fermentation, are already traditionally established (Muchoki*et al.,* 2010; Nguni and Mwila, 2007). However, these methods can cause dramatic nutritional loss as well as microbiological contamination (Habwe *et al*., 2008).Thus, to obtain nutritious products, value-adding processing should be developed. One example is millet-based malt which has the advantages of increased iron bioavailability and enriched with vitamins and calcium (Ravi *et al.*, 2010).

These adapted technologies to promote the local market for neglected plants are in strong contrast to the technologies necessary in establishing international value chains requiring state-of-the-art pre- and postharvest technologies. However, in respect to the potentially differing consumer preferences in the international markets, the product design, and hence, the processing and packaging style of neglected plants have to be developed to satisfy consumer demands (Koolman, 2014b). A pilot study with various neglected plants in Syria revealed that the non-appropriate taste, appearance, and packaging were the main constraints to reaching the international markets (Giuliani and Padulosi, 2005).

Trade and Regulatory Barriers

Neglected plants can contribute to livelihood improvement of smallholder farmers in different communities (Meaza and Demssie, 2015). However, their integration into production systems and different markets is a prerequisite (Wezel *et al.*, 2016). To bring neglected plants into regional, national, and international markets, one has to overcome different trade and regulatory barriers. This will require the involvement of numerous and various stakeholders who need to facilitate the marketing of these neglected plants through collaborative actions, e.g. creating regional networks of smallholder producers or partnerships between different actors along the value chain to enhance post-harvest handling and marketing (Latynskiy and Berger, 2016; Lowitt *et al.*, 2015). One of the main topics when talking about trade barriers is country borders that are linked to different law systems, traditions, and expectations of the consumers. The provision of certification standards based on an internal control system will contribute to break down such barriers (Preissel and Reckling, 2010). A step forward would be to strengthen efforts towards bringing neglected plants to the WTO agriculture agreement list and then to set standards for phytosanitary problems and trade conditions themselves to support the marketing of neglected plants. However, endangered plants cannot be sold. While making efforts to bring neglected plants out of their niche, all actors should also consider the fact that quite a number of these neglected plants may fall under endangered species and should be protected according to the 'Convention on International Trade in Endangered Species of Wild Fauna and Flora'. Overexploitation of such species due to market opportunities should be prevented to avoid biodiversity loss.

The trading documents for the new fresh or processed plant products should have precise labeling to simplify identification of the plant and to enhance traceability of the products by the consumers. Consequently, import and export bans should be reduced. The procedures for clearing import/export duties and for acquiring import/export certificates should be simplified and made easily accessible to the traders to grant fast export of the fresh plant materials that otherwise might perish. Therefore, the Ministries of Agriculture and the Ministries of Health of exporting and importing countries should collaborate to provide information on standards regarding product quality, phytosanitary, hygiene, and food safety. Of note is that limitations due to regulations, such as the Novel Food regulation (EU), and solutions, such as a notification procedure, should be available to traders. To effectively bridge these trade barriers, however, there needs to be a practical will to face barriers and find solutions from all stakeholders. All partners need to agree to commitments to strengthen the trade of neglected plants. This agreement should also extend to policy makers and government agents through lobbying to support smallholder farmers who will benefit from the marketing of neglected plants (Aju *et al.*, 2013).

Recommendations

To maximize the potential of neglected plants coordinated approaches on the local, regional, and international level have to be implemented, which ultimately requires a multi-stakeholder approach. This attempt has to be done under the umbrella of the global Sustainable Development Goals, especially in respect to Goal 2 claiming the abolishment of hunger and has to consider the sustainable establishment of supply chains, particularly for neglected plants and their products, as well as the sustainable livelihood improvement of the local population. Successful models for launching neglected plants into local, regional, and international markets are to be seen for the new superfoods such as *maca* roots and supplements (http://macarootreview.com), quinoa and their grain products, powdered baobab fruits (Bioversity International, 2014) and moringa products (www.kulikulifoods.com). There are also positive examples of newly launched food products in Europe, too. Rocket, formerly a niche product, is now available throughout European supermarkets and discounters. Thus, to maintain biodiversity for further successful development and launching of additional food products, germplasm preservation has to be taken into consideration.

Mostly the attractiveness of these neglected plant products is based on their numerous health benefits attributable to their nutritious compounds. However, consequently, as a result of the diverse attitudes and preferences of the various consumer groups, the products for local markets distinctly differ from products for the US or European market (Koolman, 2014b). Adjusting supply chains for neglected plants to consumer demands has to be complemented by appropriate technical solutions along the entire chain. Moreover, to achieve a sustainable livelihood for local smallholder farmers and households (as demanded by the Sustainable Development Goals), this supply chain development has to be embedded in both a local and international business development concept that encompasses areas of action for information and communication, technology, as well as trade and regulatory barriers. The participants of the Potsdam Summer School of International Nutrition in October 2015, representing not necessarily a representative panel but nevertheless symbolizing a particular voice of a range of developing countries, strongly agree with the recommendations of several organizations and associations (e.g. Bioversity International, Food and Agriculture Organization of the United Nations (FAO), Deutsche Gesellschaftfür International Zusammenarbeit (GIZ), International Fund for Agricultural Development (IFAD), Technical Centre for Agricultural and Rural Cooperation (CTA), and Crops for the Future (CFF) aiming at integrating neglected plants on the agenda of (inter)national research, agribusiness, and political programmes.

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Crops for the Future: Agricultural Diversification to 2017 and Beyond[1]

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ABSTRACT: Crops for the Future (CFF) is dedicated to research on underutilized crops and is working to lower the risks inherent in over-dependence on mainstream crops in a changing world climate with higher population, and to improve global nutrition through: research activities across the agriculture value chain; focus on sustainable landscapes; development of a Global Knowledge Base of underutilized crops; support for GAPAD targeting the UN 2030 Agenda for Sustainable Development; the DTP scholarship programme; community engagement initiatives and launch of the Forgotten Foods Network. By 2030, CFF will have contributed to the United Nations 2030 Agenda for Sustainable Development through a Global Action Plan for Agricultural Diversification (GAPAD) and achieved its vision and mission. The Vision for CFF is, "To be a world leader producing excellent, innovative research on underutilized crops that is responsive to societal demands." Present paper highlights on the current and future activities to achieve the mission towards global food and nutritional security.

Key words: Agricultural diversification, crops for the future, forgotten foods, nutrition, underutilized crops

Introduction

Our food systems are currently dominated by four crops – rice, maize, wheat and soybean – of which the three cereals provide over 50 per cent of plant-based human food (IPES-Food, 2016). Over the last 50 years, production of the three main cereals (rice, maize and wheat) has more than tripled in contrast to that of many other crops (Godfray *et al.,* 2010), so that food systems have become relatively more dependent on a few crops. Reliance on a few crops to not only feed but nourish the growing global population, in the changing climates of the future, is also a major threat to ensuring global food and nutritional security, in particular in sub-Saharan Africa.

As detailed by the GLOPAN Foresight Report (GLOPAN, 2016), deficiencies in key vitamins and minerals pose a very serious constraint to human health and economic development. It highlights that healthy diets comprise a diverse variety of fruits and vegetables, wholegrains, fibre, nuts and seeds, whilst limiting free sugars, sugary snacks and beverages, processed meats and salt. It highlights that healthy diets comprise a diverse variety of fruits and vegetables, wholegrain, fibre, nuts and seeds, whilst limiting free sugars, snacks and beverages, processed meats and salt. This Report, together with the Global Nutrition Report (IFPRI, 2014) and the Kigali Declaration on Biofortified Nutritious

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[1]Much of the text was originally published by CFF under the headings of 'Dietary Diversification for Enhanced Human Nutrition: The Role of Underutilized Crops' and 'CFF Roadmap 2030: Delivering the Vision'.

Foods (HarvestPlus, 2014), highlights the need for multiple complementary strategies to address key micronutrient deficiencies.

Many plants contain higher concentrations of vitamins, mineral nutrients and phytometabolites than found in cereals, so that consumption of a diverse range of plants is beneficial to human health (Boedecker *et al.,* 2014). Fruits, vegetables and other plants rich in minerals and vitamins can be grown in diverse cropping systems to complement the major crops, thereby improving diets and human health. Smallholder producers in both rural and urban areas frequently grow a mix of plants to enhance their diets. Women play a vital role in producing such plants and as urbanization increases, the peri-urban production of crops such as vegetables, fruits and herbs increases in importance.

Dependence on a small number of cereal crops has led to increasing concerns about human diets being energy rich but nutrient poor (Stadlmayr *et al.,* 2011; Toledo and Burlingame, 2006). Micronutrient deficiencies are now recognized to be more widespread than energy/protein malnutrition with at least 1.5 billion people likely to be affected by one or more micronutrient deficiency (GBD, 2016). Such deficiencies exist in populations even where the food supply is adequate in terms of meeting energy requirements but are most prevalent in areas where the diet is monotonous and lacks diversity, a situation that is the norm in many developing countries. The most vulnerable groups are women and children of all communities, and displaced individuals, such as those escaping persecution and discrimination in war-torn countries (Kennedy *et al.,* 2003).

Combinations of actions are needed to secure better diets because different populations within a country can only be reached by different methods. The GLOPAN policy brief on Biofortification (GLOPAN, 2015) outlines one such promising strategy to enhance the availability of vitamins and minerals for people-whose diets are dominated by micronutrient-poor staple food crops. A complementary and equally valid strategy is that of dietary diversification through the increased consumption of a variety of whole foods.

Food based solutions (for diversifying both agriculture and nutrition) have immense potential to alleviate hidden hunger. Diversification of the diet, to include foods from a range of sources, in particular from underutilized species, is one such approach. It can be implemented by all population groups, especially subsistence farmers in both rural and urban settings, who have the skill and capacity to diversify their production to include a range of fruits, vegetables, nuts and berries.

A refocusing of global food policies is needed to ensure quality not quantity of food produced with the aim to achieve nutritional security rather than food security. Momentum is building amongst the key players- Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO)- to enable this shift in focus. This new emphasis coincides with the FAO proposed 'Year of Forgotten Foods', which follows on from the 2016 International Year of Pulses. Policy makers at FAO and globally recognize that field bean, lentil and chickpea are among the plant species that will help achieve the Sustainable Development Goals (FAO.org, 2017).

Crops for the Future

Crops for the Future (CFF) is the world's only organization dedicated to research on underutilized crops. Its purpose is to diversify agriculture beyond the world's major crops. By 2030, CFF will have contributed to the United Nations 2030 Agenda for Sustainable Development through a Global Action Plan for Agricultural Diversification (GAPAD) and achieved its vision and mission.

The Vision for CFF is, "To be a world leader producing excellent, innovative research on underutilized crops that is responsive to societal demands." The Mission of CFF is, "To develop solutions that diversify agriculture using underutilized crops." CFF is to be developed over three phases. Phase One (2012-2017) is now coming to a close. The goals for Phase One were for CFF to establish internal resources, form an alliance of partners and initiate a value-chain approach for research on underutilized crops from their genetics to potential markets. In Phase Two (2018-2023), CFF will deliver research outcomes to stakeholders around the world. Its research will also become financially self-sustaining through prototype products, external support and global partnerships. CFF activities will align with the targets of GAPAD. Finally, in Phase Three (2024-2029), CFF will help to transform agriculture for good and demonstrate how underutilized crops contribute to the United Nations 2030 Agenda for Sustainable Development via GAPAD.

Why Underutilized Crops?

Underutilized crops comprise the multitude of species that are currently largely neglected by major research and funding bodies. They include cereals, grains, legumes, fruits, vegetables, flowers, roots, seeds and nuts. Interest is growing in the potential for these crops to contribute to food and nutritional security and improved livelihood options for subsistence farmers, a large proportion of who are women.

Some of these underutilized species can yield under a range of soils and climates that are hostile to, or unfavourable for, production of the more common staple crops. For example, millet species typically yield in marginal soils and climates in India and African countries (Handschuch and Wollni, 2016; Jukanti *et al.,* 2016). This is of obvious benefit for the changed climate expected over the coming decades. Some yield of a diverse range of nutrient-rich plants is nutritionally superior to no yield of a current staple crop.

Nutritional Benefits from Consuming Underutilized Crops

Consumed together with staples, underutilized species can complement and diversify the diet with a range of micronutrients and bioactive compounds essential to health. These include:

Amino acids - the essential amino acids of animal-sourced proteins more closely match the profile of essential amino acids required by humans. To achieve the same intake of essential amino acids from plant-based foods requires a combination of cereals and legumes found in all cultures. Examples include rice and beans in Africa, *tortilla* and beans in Mexico, and rice and *dal* in Asia.

Phytochemicals - these are bioactive non-nutritive plant compounds including carotenoids, alkaloids, nitrogen containing compounds and organosulphur compounds that are present in fruits, vegetables, grains and other plant foods. Evidence for the efficacy of these phytochemicals in promoting health (or preventing disease) is patchy and often anecdotal, but it strongly points to health benefits conferred by consuming a diverse range of whole plant-based foods, rather than taking plant-derived supplements or extracts (Liu, 2004).

Vitamins - consumption of a range of green leafy vegetables together with red, orange and yellow fruits and vegetables all contribute to vitamin A consumption via β-carotene. The absorption of β-carotenes and vitamin A are enhanced by the presence of small amounts of fat or oil in the diet-achieved through the consumption of oilseeds, oily fruits and nuts.

Minerals - humans require at least 18 essential minerals many of which come primarily from plant sources. Deficiencies of zinc, calcium, and selenium are evident in regions where either the diet is monotonous or based on a limited range of foods from mineral poor soils.

Anti-nutritional Factors

Besides these beneficial components, plants may also contain compounds that are detrimental (and occasionally toxic) to health. These include:

Digestibility inhibitors - the presence of chelators such as phytates and oxalates in the diet, primarily from green leafy vegetables, can reduce the bioavailability of minerals including calcium, iron and zinc (Gibson *et al.,* 2010). Furthermore, protease inhibitors such as tannins and trypsin inhibitors, commonly present in the seed coats of grains, legumes and seeds reduce the digestibility of proteins.

Toxins - these include alkaloids, cyanogens, goitrogens, carcinogens, hemagglutinins, protease inhibitors (tannins, trypsin inhibitor, phenolic compounds) amongst others. Cyanogenic and other toxic compounds are present in many foods, making them dangerous to consume without proper processing. Simple household processing techniques including soaking, heating, roasting, germination and fermentation are used to denature or destroy anti-nutritional compounds such as cyanogens, protease inhibitors and phytates (Gibson *et al.,* 2000).

Need for Research on the Nutritional Potential of Underutilized Species

There is a compelling need to research on currently underutilized plants to determine what they contain and how the benefits can be delivered while minimising any deleterious contents. Moreover, very little is known about the effects of agronomic practice (planting, growth, fertilizer application, irrigation, and harvest) processing and storage on the accumulation (and potential disappearance or sequestration) of minerals and their bio-availability.

This knowledge is essential if the full benefits from a more diversified, plant-based diet are to be gained. There are systematic general differences between plant families in the mineral nutrients that they contain (White *et al.,* 2012). For example, the seeds of most cereals have lower concentrations of zinc and iron than seeds of legumes (Gregory *et al.,* 2017). Also, because of differences in the way nutrients are transported inside the plant, tissues such as tubers, fruits and seeds are frequently poorer sources of zinc and iron than the leaves. Leafy vegetables are particularly rich sources of many mineral nutrients. However, the concentration in plant tissues is also considerably affected by the environment in which the plant is growing. Specific plants contain specific nutrients which may benefit human diets, especially if the diet is diversified by the inclusion of one or more of these lesser known species.

The CFF Response to Global Challenges

Humanity must feed more people on less land in changing climates. Our food systems depend on a few `major' crops grown in exporting countries. Whilst such crops have reduced the risk of widespread famine, hunger and malnutrition still inflict human suffering. We must put nutrition at the heart of our food systems and diversify our diets. We must also use landscapes that are too harsh for major crops to provide sustainable livelihoods from currently underutilized species.

Major crops will continue to feed humanity. But, by themselves, can they nourish 8.5 billion people in a hotter, riskier world? For our nutritional security, we must evaluate 'underutilized' crops that, until now, have received little attention. In our changing climates, some could be '*Crops of the Future*'. The question is, which crops?

CFF has closely mapped its plans to the United Nations 2030 Agenda for Sustainable Development, through world-class research that contributes to specific Sustainable Development Goals (SDGs). CFF is focusing efforts where it can achieve the greatest impact by leveraging on knowledge, capabilities and global partnerships. To this end, in its establishment phase, CFF has built physical facilities, partnerships and internal resources directed at improving knowledge of underutilized crops.

The CFF headquarters were completed in 2015. These include facilities to support world-leading research on the effects of climate change on crop yields and nutritional content. CFF also has a Field Research Centre as a testing ground for new and diverse cropping systems and an Aquaculture Research Centre for development of fish feeds. CFF has assembled a multidisciplinary team of multinational staff dedicated to deliver, coordinate and support research on underutilized crops.

CFF research links genetics, crop selection and field studies with nutritional and sensory evaluation and market testing of novel products from underutilized crops. It has established a global evidence-base for underutilized crops. Working with global partners, CFF shows how underutilized crops can deliver sustainable and economically viable agricultural systems, meet the challenges of changing climates, enhance food and nutritional security and improve livelihoods.

CFF publications cover social sciences relating to farmer adoption of innovative practices, genomics and computational science. As well as being of world quality, CFF research is developing 'future foods' and digital applications that allow end-users to select diversification options according to their needs.

Global Partners for Agricultural Diversification

CFF has links with over 50 partners represented in 300 global locations. These include the Association of International Research and Development Centers for Agriculture (AIRCA), a consortium of leading agricultural research centres, national and international agencies, universities and private companies. These partners provide access to world-class scientists who bring skills and ideas as well as collaborations to extend the breadth and depth of CFF's global ties.

Global Action for Agricultural Diversification

In September 2015, the United Nations announced the 2030 Agenda for Sustainable Development to end poverty fight inequality and tackle climate change. In December 2015, CFF secured the signature of leading scientists and research institutions for the Declaration on Agricultural Diversification. The declaration calls for a Global Action Plan for Agricultural Diversification (GAPAD) to transform agriculture for good. CFF provides Secretariat services to GAPAD.

CFF Current Activities

CFF research focuses on food and nutritional security, adaptation to climate change, the sustenance of biodiversity and development of the bio-economy to promote livelihoods. CFF research shows how underutilized crops can add value to food and non-food systems. Its research aims to unlock new knowledge and deliver emerging innovations and technologies for underutilized crops. To maximize impact and increase the wider adoption of underutilized crops, CFF delivers 'exemplars' of how research on particular underutilized crops can be translated to other promising species and systems.

CFF research addresses three societal challenges:

- *Global Knowledge System* - CFF is delivering a trusted and interactive global evidence-base for underutilized crops. This will link databases and models to provide growers, researchers and policy makers with state-of-the-art knowledge on the potential of particular underutilized crops for current and future climates.
- *Food and nutritional security* - working with its global partners, CFF evaluates underutilized species as food-security crops for changing climates. It is developing nutritious and affordable products from underutilized crops to diversify diets. Research evaluates the composition, content and functionality of ingredients and develops techniques to maximize nutritional benefits. CFF research has also shown that insects fed on underutilized crops can replace fishmeal in aquaculture feed. This technology can be leveraged to develop novel feed ingredients for livestock and poultry. CFF will work with investors to scale-up prototype products from underutilized crops to full commercialization at local, regional and global scales.
- *Sustainable landscapes* - CFF is evaluating how sustainable landscapes can include underutilized crops to satisfy commercial and environmental interests. This approach will provide a model for productive landscapes that use underutilized crops for livelihoods and food security in contrasting environments.

The Forgotten Foods Network

The Forgotten Foods Network (FFN) was launched on November 3, 2017 by His Royal Highness the Prince of Wales at CFF headquarters in Malaysia. FFN is a global initiative that collects and shares information on foods, recipes and traditions that are part of our common heritage. Forgotten foods are those that were once popular but have now been displaced by a modern global diet based on processed ingredients from a few crops. Forgotten foods can come from neglected crops, fruit and vegetables, animals and even insects as well as traditional varieties of the major staple crops. By exploring our own culinary histories and traditions we can help identify and celebrate the world's forgotten foods. Through the FFN, CFF is enabling the discovery and sharing of foods that can transform the way we eat now and nourish us in climates of the future.

The Doctoral Training Partnership

In 2013, CFF and the University of Nottingham, Malaysia Campus (UNMC) launched the Doctoral Training Partnership (DTP) CFFPLUS joint scholarship programme - the largest single commitment ever made to support research studentships on underutilized crops. Round One of the DTP (fully funded) has recruited 33 students. Round Two (fee scholarships only; partner institutes cover consumables and stipend) has recruited 16 students. The total contribution "in kind" by partner organisations is RM 3.8 million. Global partners include: The Ministry of Higher Education (Sri Lanka), Musim Mas (Indonesia), MOSTI (Malaysia), and Brazil Government (Brazil). Of the 49 candidates from 15 nationalities supported by the CFF-UNMC DTP, 12 have already completed their degree.

The gender and discipline breakdown of the CFF-UNMC DTP scholarship students is shown in Table 1.

Table 1. Discipline breakdown of the CFF-UNMC DTP scholarship students

Gender	Faculty of Arts and Social Science	Faculty of Engineering	Faculty of Science
Male	1	2	28
Female	1	5	12
Total	2	7	40

The DTP candidates have 29 publications to date in different disciplines, including the following examples:

- Developing improved germplasm resources for underutilized species – a case for bambara groundnut
- Dietary mineral supplies in Malawi: spatial and socioeconomic assessment
- Approaches for scientific collaboration and interactions in complex research projects under disciplinary influence
- Co-pyrolysis of rice husk with underutilized biomass species: a sustainable route for production of precursors for fuels and valuable chemicals
- Image based 3D canopy reconstruction to determine potential productivity in complex multi-species crop systems

Conclusions

Drawing together all the key issues, it is clear that providing food and nutritional security for an estimated 8.5 billion people by 2030 in an increasingly hot and riskier world can no longer rely solely on three major cereals. At present, over 50 per cent of all plant-based food consumed globally relies upon these three crops – which generally fail to perform in harsh environments, but, additionally, even when bio-fortified, cannot provide all of the micro- and macro-nutrients essential to overcome malnutrition. There is therefore a very compelling case for complementing these staples by drawing on the vast diversity of underutilized crops that include species adapted to all environments, including the harshest. Attention must be shifted towards policies and food systems that support the quality of food as well as its quantity. This is as important in developed countries where diseases of over-consumption (of calories) occur as it is in countries where under-nutrition and hunger continue to be serious threats to economic development. Agriculture and nutrition policies must also consider the rural-to-urban shift, and the need to provide quality diets in urban and peri-urban areas. Increased consumption of underutilized plants is one potential solution that addresses this shift in focus.

CFF is working to lower the risks inherent in over-dependence on mainstream crops in a changing world climate with higher population, and to improve global nutrition through: research activities across the agriculture value chain; focus on sustainable landscapes; development of a Global Knowledge Base of underutilized crops; support for GAPAD targeting the UN 2030 Agenda for Sustainable Development; the DTP scholarship programme; community engagement initiatives and launch of the Forgotten Foods Network.

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Underutilized Plant Species in Asia-Pacific Region

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ABSTRACT: Underutilized plant species in Asia-Pacific region have been discussed in light of many important global initiatives taken in past two decades to enhance their utilization. This group of species has been dealt under documentation, prioritization, popularization and research & development issues with emphasis on crops of the region. Some of the points that need special attention include documentation of information on endemic and lost crops, prioritization for areas/crops and methods of use, linkages through sharing of knowledge and research and development in collaborative manner, involving full spectrum of disciplines for enhanced food and nutritional security.

Key words: Asia-Pacific Region, documentation, popularization, prioritization, value addition

Introduction

During the history of human civilization man has been exploring plant wealth to meet with day-to-day needs for survival which in turn has resulted into identification of many useful plants used for food and nutrition. Presently with increased population pressure and other anthropocentric changes, there is growing realization of the need to enlarge or diversify the food basket to realise potential of promising underutilized species for food and nutritional security in the global context (Zeven and de Wet, 1982; Kunkel, 1984; Arora, 1985; Zohary and Hoff, 1992; FAO, 1996; Padulosi, 1999; MSSRF, 1999; Evy, 2000; Padulosi *et al.,* 2002). The Asia-Pacific region is one among the geographical regions holding rich ecological, ethnic and cultural diversity with many economic plants used directly or cultivated to meet human needs. Four regions of high diversity namely, Chinese-Japanese, Indochinese-Indonesian, Australian/Pacific and Indian region (consisting of West Asia, South Asia, Southeast Asia, East Asia and the Pacific) are located in this region; eight out of the 17 mega-biodiversity countries namely Indonesia, Australia, China, India, Malaysia, Papua New Guinea (PNG), Philippines and Thailand are also located here (Mittermeier *et al.,* 1997; APAARI, 2006). To tap the potential of underutilized resources (NAS, 1975; Paroda *et al*., 1988; van der Maesen, and Somatmadja, 1991; Bhag Mal *et al*., 1997; Martin *et al*., 2001; Smart and Haq, 1997; Arora *et al*., 2006), this region of developing countries has an important role of enlarging the food basket for food and nutritional security. Greater emphasis was laid on increase in use of underutilized crops and crop wild relatives in breeding programmes, through establishing effective and functional seed systems for farmers' access (FAO, 2010).

Transition from "Underutilized plant species" to "Underutilized Crop Plants" (neglected and underused crops) has taken place through domestication of plant species that have been used for centuries or even millennia for various uses for food and agriculture particularly when staple crops have not

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performed well. The benefits of these species are manifolds: (i) contributing to poverty alleviation through employment opportunities and income generation, and sustainable livelihood, (ii) adding nutrients to diet for low income group people, (iii) adapted to fragile environments and can contribute to the stability of agro-ecosystems, especially in the arid, semi-arid, mountains and tropical forests, (iv) meeting with wider scope of crops for new market demands, and (v) assisting development through value addition.

There has been an upsurge in research and development (R&D) activities associated with diversification of underutilized plant species and their suitability for different agro-ecosystems, specifically focussing on the needs of rural farmers in marginal agro-habitats with limited livelihood options and the policy implementation. This has been emphasised through several global platforms such as the Convention on Biological Diversity (CBD) and the FAO International Technical Conference on Plant Genetic Resources for Food and Agriculture held in Germany in 1996 (ref. Activity 12: promoting development and commercialization of underutilized crops and species); Global Plan of Action (GPA); the Global Forum on Agricultural Research (GFAR) (Padulosi *et al.,* 2002), the International Symposium on "Underutilized Plants for Food, Nutrition, Income and Sustainable Development", in Tanzania from 3-7 March, 2008 and the 3rd International Conference on Neglected and Underutilized Species - for a Food-Secure Africa (NUS, 2013), held in Ghana from 25-27 September there was thrust on policy implications (Hall *et al*., 2013).

The terminology used to address this group too has evolved with process of 'crop domestication' from wild, to wild economic plants, poor man's crop, protected species, semi-domesticates, potential crops, less-known species, neglected, local/traditional, under-exploited/under-utilized, under-developed, orphan, lost, promising, crops for future and alternative plant species. These crops have been known to human beings in restricted/ limited pockets, narrow regions and their value (potential, nutritional, agro-ecological) has been fully utilized and known by the communities/ areas. Despite their potential value realized they remained hidden or unknown to other parts of the globe. There are multiple reasons of unrecognized nutritional/potential/economic value viz., ignorance for food value, unacceptability for taste by younger generation or social value, lack of produce to meet with pace with modernization in agricultural practices, and change in dietary habits. Due to this they have either been poorly researched, less recognized for their nutritional value, had poor consumer preference/awareness and therefore continued with a tag of 'poor people's crops'. Over the period of time many of them are likely to face dwindling status of 'vanishing crops/lost crops' (FAO, 2010).

Useful Diversity of Underutilized Plants in the Asia-Pacific Region (APR)

Regions such as APR are rich in ethnic, ecological, cultural and species diversity, with a wealth of ethnic knowledge (Bhag Mal *et al*., 1997). Successful food systems effectively draw on locally available food, food variety and traditional food culture. This involves concerted efforts in research, public policy, promotion and required action in support of multi-sectoral and community-based strategies, linking rural producers and urban consumers with traditional and underutilized food systems. Paucity of agronomic and nutritional information, negative public perception towards traditional foods, policies not recognizing sufficiently their important role in food security and health programs and lack of markets are few important aspects which need attention. Reassessment with respect to their nutritional traits, culinary value, adaptation to climate change, production and use to enhance their values to outside world has led to increased global attention to crops like soybean, kiwi fruit, quinoa and oil palm.

Likewise, while the value of these species as hardy staple crops under climate change is well recognized, it is essentially required to give attention to underutilized cereals/pseudocereals, millets, legumes, fruits, vegetables and medicinal plants to promote more balanced diets for good health. In several instances they have provided alternative food security, furnishing raw materials for direct or indirect use and harvest for market (Arora and Pandey, 1996). While most farmers grow underutilized crops for their subsistence use, many households get significant income from them, comparable with that from sale of common agricultural commodity. Examples of such crops which fetch a good price in India, include *Glycine max* (black soybean, locally called 'Kala bhat'), *Eleusine coracana*, *Echinochloa crus-galli*, *Macrotyloma grandiflorum* ('kulthi') and *Perilla* sp. Wild economic species like *Allium stracheyi*, *A. humile* ('jamboo') and *Cleome viscosa* ('jakhiya') are under large-scale cultivation in high altitude areas of Uttarakhand in India and *Allium perzwaliskianum* ('jimbu') in Nepal as wild harvest.

Bringing Useful Species into the "Food Crops Chain"

Some important initiatives in India have facilitated in identification and induction of underutilized species into the food chain. For example, the All India Coordinated Research Project (AICRP) on Underutilized Crops and Underexploited Plants (now renamed as AICRP on Potential Crops) by Indian Council of Agricultural Research (ICAR), India, is continuously working with objective to identify new plants for food, fodder and industry and activities include germplasm collection, characterization, evaluation and conservation, development of high yielding varieties for different farming systems, and promotion for cultivation (Joshi *et al.*, 2002). Prioritized crops include amaranth (leaf, grains), buckwheat, chenopodium (leaf, grain), adzuki bean (grain), faba bean (pod), winged bean (grain, pod), job's tear (grain), *kankoda* (green fruit) (Singh and Thomas, 1978). Another initiative has been the AICRP on Ethnobiology by the Council of Scientific and Industrial Research (CSIR), India, with ~9,000 taxa used by the tribals (including ~4,000 edible types). In addition, documentation of over 1,200 taxa of wild edible plants of India, including 130 domesticated species and potential domesticates (~200) of Indian gene centre (Arora and Pandey, 1996; Pandey and Arora, 2004; Pandey, 2015 unpublished) has also helped in popularization of the underutilized species.

Despite all the benefits known of this group of crops, their inclusion into the food chain has been a slow process and only very few have reached to required levels. For the APR, over 770 taxa from various groups under cultivated underutilized and less-known species (with overlapping of the category) are pseudocereals and millets (22), grain legumes/pulses (14), root/tuber types (55), vegetables (213), fruits (261), nuts (34), industrial crop (25), others (148) are listed below (Table 1).

Table 1. Distribution of underutilized plant species in the Asia-Pacific region*

Pseudocereals/millets: Buckwheat, foxtail millet, proso millet (all of Chinese origin), in China, Korea and Japan, and in the Hindu Kush Himalayas-Indian sub-continent; *Echinochloa* species (3 spp.) with Japanese barnyard millet having diversified in Japan, China and peninsular India; Job's tears/*adlay* (*Coix lacryma-jobi*) in China, Korea, Japan, Philippines, Indo-China and northeastern India; the soft-shelled cultivated type (var. *mayuen*) possibly got domesticated in the Indo-Chinese region; *raishan* (*Digitaria cruciata* var. *esculenta*) domesticated in northeastern India, Meghalaya. *Panicum sumatrense,* little millet of Indian origin, peninsular region, *Brachiaria ramosa, Urochloa panicoides* and *Setaria glauca* in Tamil Nadu, Andhra Pradesh, India); introduced crops- finger millet, an old African introduction, in South Asian-Indian subcontinent in particular, Himalayas. Grain amaranth-dual purpose; kodo millet (*Paspalum scrobiculatum*) in drier peninsular tracts of India
Legumes: Widely distributed *Vigna* species of Asian origin, *V. mungo*/black gram in South Asia, particularly India and Nepal; *V. umbellata* rice bean in East Asia-South and Southeast Asia; *V. angularis*/adzuki bean confined to East Asia and in the Hindu Kush Himalayas; *Vigna aconitifolia*/moth bean, western India in Rajasthan, Deccan penisular *Lathyrus sativus*/grass pea, with more cultivation in central India, and elsewhere in Bangladesh; *Vigna trilobata* a minor cultigen domesticated in parts of Tamil Nadu in South India; *Macrotyloma uniflorum*/horse gram in South India, Western and Central Himalayas in India and Nepal. *Psophocarpus tetragonolobus*/winged bean is considered to be of South Pacific/ Papua New Guinea origin, diversity in the Philippines, Thailand, Indonesia, Indo-China and northeastern-Southern India and Sri Lanka. Myanmar-grown for grain and green pods and for edible tubers. Exotic-legume *Vicia faba* of West Asian origin, in India in the Himalayas, and in China. *Phaseolus coccineus*, *P. lunatus*, in backyards or homegardens in diverse tropical to temperate habitats, for local consumption.

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Root and Tubers: *Alocasia, Amorphophallus, Canna, Coleus, Colocasia, Dioscorea, Helianthus, Ipomoea, Maranta, Flemingia/Moghania, Pachyrhizus, Stachys, Tacca* and *Xanthosoma* usually consumed after boiling, rarely raw; after peeling off the outer skin e.g. *Moghania vestita* and *Pachyrhizus erosus.* rhizomatous and bulbous types - *Allium, Curcuma, Zingiber* used in soups and curries, after boiling/cooking, or often eaten raw as salad e.g. *Allium* species, indigenous (*Alocasia, Colocasia, Dioscorea*) and exotic species (*Canna, Coleus, Maranta, Pachyrhizus* and *Xanthosoma*) in humid tropical areas (subsistence farming, and in home gardens, backyards); cold, temperate regions have only limited diversity such as of *Arracacia, Lathyrus, Sium* and *Ullucus* mainly distributed in the Chinese-Japanese, Indo-Chinese-Indonesian and the Hindustani/Indian region; Pacific region- rich in taro/*Colocasia* and *Xanthosoma.* The Chinese-Japanese region limited diversity in starchy tuberous- *Alocasia, Colocasia,* etc. but with more diversity in *Xanthosoma*; South China- *Amorphophallus harmandii* while *A. konjac*, sporadic in Japan and the Philippines. Variability occurs in *Dioscorea japonica. Eleocharis dulcis* variability in South China-Pacific Islands, and southwards in the Indo-Burmese region and in Southeast Asia. widely distributed is *Stachys affinis* domesticated in China, and Japan, also grown in Eastern Europe; *Sagittaria sagittifolia.* Indo-Chinese-Indonesian and the Indian regions: *Alocasia, Colocasia,* Asiatic *Dioscorea* spp., *Tacca* and *Amorphophallus. Alocasia cucullata, Amorphophallus paeoniifolius* and *Moghania vestita* (domesticated in Eastern Himalayas/ northeast region in Meghalaya) and in Southeast Asia for *Dioscorea.* wider distribution in South and Southeast Asia- *Alocasia macrorrhiza, Coleus parviflorus, Colocasia esculenta, Dioscorea alata, D. bulbifera, D. esculenta* and *D. pentaphylla.* limited variability prevails in *Cyrtosperma chamissonis* in Pacific Islands in *Pueraria montana* (domesticated here as a tuber crop); *Tacca leontopetala* - sporadic distribution - Asia-Pacific with limited local diversity.
Vegetables: *Amaranthus, Allium, Asparagus, Atriplex, Basella, Brassica, Chenopodium, Phytolacca, Pisonia, Polygonum, Portulaca, Rumex* and *Tetragonia*; fruits-*Abelmoschus, Benincasa, Coccinia, Cucurbita, Luffa, Momordica, Solanum* and *Trichosanthes;* pods of *Canavalia, Dolichos, Mucuna, Vigna,* and among the exotic types, *Cyclanthera, Sechium, Sicana, Scorpiurus* - all tropical American introductions; *Sechium edule* represents a secondary centre of diversity in the Eastern Himalayas/northeast region of India, Indo-Chinese region. Some cucurbit fruits are eaten raw e.g. *Cucumis.* Bamboos - young culms of *Bambusa, Cephalostachyum, Dendrocalamus, Phyllostachys* and *Sinocalamus* species are boiled/fermented and made into soup or eaten as vegetable; pickled/preserved. Tropical, sub-tropical and temperate areas: *Allium, Amaranthus, Chenopodium, Brassica, Chrysanthemum, Cynara, Phytolacca* and *Rumex* among leafy types and *Cyclanthera* and *Sechium* among fruit-types; bamboos, rich diversity occurs in humid tropical areas, with the exception of a few species of *Phyllostachys, Sinocalamus* and others, which also occur in colder climates. Chinese-Japanese, Indo-Chinese-Indonesian and the Indian gene centre, within the Asia-Pacific region. **The Chinese-Japanese region:** *Allium odorum, Angelica kiusiana, Brassica* spp. *especially alboglabra, parachinensis, pekinensis, Chrysanthemum segetum, Lactuca denticulata, Malva verticillata* and *Viola verucunda;* among the bamboos confined to China are *Bambusa beecheyana, Phyllostachys aureosulcata, P. dulcis* and *P. nigra* and *Sinocalamus edulis* wider distribution extending to East/Southeast Asia is represented by *Ipomoea aquatica* and *Nasturtium indicum;* the Japanese region, more diversity occurs in *Aralia cordata, Cryptotaenia japonica, Bambusa multiplex, Chrysanthemum morifolium, Brasenia schreberi, Lactuca sativa,* and *Veronica anagallis-aquatica;* China and Japan as cultigens, particularly bamboos like *Chimonobambusa quadrangularis*, *Phyllostachys bambusoides* and *P. pubescens,* and leafy types - *Brassica napobrassica, Chrysanthemum coronarium, C. sinense, Lactuca indica* and *Phytolacca acinosa*. China, Japan and Korea and sporadically in East/Southeast Asia, *Actinidia polygama, Lycium chinense* and *Lactuca* spp. The Indochinese-Indonesian and the Indian regions are more variability in *Basella alba* occurs in South Asia, particularly in Sri Lanka and in India (mainly in southern and the eastern region) extending further to Bangladesh. *Pentaphragma begoniaefolium* and *Pisonia alba* are more confined to Malaysia, while *Sauropus androgynus*-Indonesia. wider distribution also occurs in *Houttuynia cordata, Hydrolea zeylanica, Enhydra fluctuans, Emilia sonchifolia, Sesuvium portulacastrum* and *Wolffia globosa*; *Ipomoea aquatica*. As compared to the above types, *Amaranthus* species are more important, and much variability in these occurs in the Himalayan region in South Asia, and in humid tracts, for *A. dubius, A. tricolor* and *A. viridis*. *Tetragona tetragonoides* native of Australia and New Zealand and cultivation extending to East Asia; *Talinum triangulare* is confined mainly to Sri Lanka. Immature fruits are consumed as vegetable, in South Asia: *Abelmoschus esculentus, Momordica dioica*, *M. cochinchinensis*, with wider distribution of *M. charantia,* and in *Lagenaria siceraria, Luffa acutangula*, *L. aegyptiaca* and *Trichosanthes cucumerina*; South and Southeast Asia is *Moringa oleifera* East Asia-the Pacific in home gardens. *Abelmoschus manihot* is East Asia, - Philippines and Southeast Asia, Indonesia, and as far as in the Pacific/PNG region cultivated bamboo species occurs in South/ Southeast Asia; *Cyclanthera pedata* and *Sechium edule* (wider but sporadic distribution in the former, and a secondary centre in the Eastern Himalayan region for the latter); limited diversity occurs in West Asian species such as *Allium kurrat* and *A. fistulosum;* and of the Mediterranean species, *Allium porrum* and *Scorpiurus vermiculata*.

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Fruits: Tropical/sub-tropical: *Annona, Artocarpus, Averrhoa, Baccaurea, Carissa, Cordia, Citrus, Chrysophyllum, Cynomitra, Diospyros, Durio, Emblica, Elaeagnus, Elaeocarpus, Flacourtia, Ficus, Garcinia, Grewia, Lansium, Litchi, Mangifera, Manilkara, Morus, Musa, Passiflora, Phoenix, Nephelium, Salacca, Salvadora, Sandoricum, Spondias, Syzygium, Tamarindus* and *Ziziphus.* **Temperate/sub-temperate:** *Actinidia, Crataegus, Fortunella, Fragaria, Hippophae, Malus, Myrica, Physalis, Prunus, Pyrus, Punica, Rhodomyrtus, Ribes, Rubus* and *Sorbus.* Indo-Chinese-Indonesian, Hindustani/Indian and the Chinese-Japanese regions with several prominent species from the central and south American regions- *Annona, Passiflora, Pouteria and Physalis.* The Chinese-Japanese region in *Actinidia callosa, A. rubicaulis, Prunus mume, Citrus* spp., *Crataegus cuneata, C. pentagyna, Duchesnea filipendula, Malus asiatica, M. spectabilis, Poncirus trifoliata, Prunus cantabrigiensis, P. cerasifera, P. salicina, Ribes longeracemosum, Pyrus prunifolia, P. pyrifolia, P. sinensis, Vitis amurensis* with *Malus halliana* introduced in Japan and *Diospyros lotus* in the Himalayan region. *Citrus* (bred types/selections, with distinct identity) occurs in Japan and several cultigens, viz. *C. canaliculata, C. funadoko, C. glaberrima, C. hassku, C. iyo, C. leucocarpa, C. mediglobosa* (also occurring in the Philippines), as also in *Fortunella japonica* and *Stauntonia hexaphylla*. confined/localized in the Philippines, viz. *Artocarpus camansi, A. odoratissimus, Citrus mitis* (also in Japan), *Dracontomelon edule, Garcinia dulcis and G. lateriflora* (also in Java) and *Garcinia binucoa* (introduced into the Pacific), and *Syzygium cumini.* China and Japan- *Prunus mume, Chaenomeles speciosa, Citrus* spp., *Fortunella crassifolia, F. hindsii, F. margarita, Malus micromalus, Prunus salicina* and *Pyrus sinensis*. *Crataegus pentagyna* occur both in China and Korea, whereas *Actinidia callosa, Citrus junos, Crataegus cuneata, Chaenomeles sinensis* and *Macrocarpium officinale* in China, Korea, and Japan; south Asia- *Artocarpus heterophyllus, A. lacucha, Aegle marmelos, Carissa congesta, Citrus indica, C. macroptera, C. pseudo-limon, Chaerospondias axillaris, Dovyalis hebecarpa, Elaeocarpus floribundus, Emblica officinalis, Feronia limonia, Flacourtia ramontchii, Garcinia indica, G. gummi-gutta, Grewia subinaequalis, Manilkara hexandra, Morus* spp., *Spondias oleoides, S. pinnata, Salvadora persica, Syzygium cumini, Rhodomyrtus tomentosa, Rubus ellipticus and Ziziphus mauritiana*. In southeast Asia, diversity occurs in *Artocarpus rigidus, A. integer, Averrhoa carambola, Baccaurea dulcis, B. motleyana, B. racemosa, Bouea macrophylla, Citrus hystrix, Diospyros discolor, Durio oxleyanus, D. zibethinus, Dimocarpus longan, Feroniella lucida, Flacourtia rukam, Garcinia cochinchinensis, G. mangostana, Lansium domesticum, Litsea calophylla, Mangifera caesia, M. foetida, M. odorata, Nephelium lappaceum, N. rambutan*, *Salacca edulis, Spondias dulcis, S. laosensis, Stelecocarpus burahol, Syzygium aqueum* and *S. malaccense.* Indonesian region-Java, viz. *Garcinia dulcis, G. lateriflora*; the Philippines- *Dracontomelon edule* and *Syzygium cumini*, and *Pometia pinnata* and *Triphasia aurantifolia*, also occurring in the Pacific Islands, wider distribution within south and southeast Asia- *Artocarpus heterophyllus, Averrhoa bilimbi, A. carambola,* and several species/varieties in *Citrus, Garcinia, Manilkara, Musa, Syzygium, Ziziphus* and *Mangifera*.
Nuts: *Castanea, Corylus, Juglans, Pinus* and *Pistacia* are mainly concentrated in cold/temperate regions of West, South and East Asia. Overall, this diversity is more confined to the Hindustani/Indian region for both sub-tropical and temperate types, and in humid tropical types in Indo-Chinese, Indonesian and the Australian Pacific region; Chinese-Japanese region in China for *Prunus/Amygdalus tangutica, Castanea mollissima, Corylus chinensis, C. sieboldiana* and *Juglans ailantifolia*; in China, Japan and Korea - *Corylus heterophylla*; Indo-Chinese-Indonesian- *Terminalia* spp., and in *Gnetum gnemon/melinjo; Anacolosa frutescens galonut;* and *Canarium ovatum/pilinut*. *C. ovatum* was domesticated in the Philippines and *G. gnemon* in the Indonesian region. Indian region–*Terminalia catappa* in south India, *Buchanania lanzan* in central India, and in *Pinus gerardiana, Juglans regia* (walnut) in the western Himalaya; Papua New Guinea/South Pacific Islands *Canarium* several species, *Terminalia kaernbachii*. Australian region- *Macadamia*, a native domesticated nut, now introduced elsewhere; *Macadamia ternifolia* grown commercially. Polynesian nut- *Inocarpus fagifer,* a domesticate of this region; limited diversity in *Barringtonia* spp. Exotic types- the paradise nut/*Lecythis zabucajo* a tropical American introduction; fleshy-nuts, kernels *Euryale ferox*, *Nelumbo nucifera* and *Trapa natans* and other species; diversity in *Euryale/ makhana* nut in eastern India, and for others, both in India and China and sporadic elsewhere.

**Source: Modified from Arora (2014)*

Approaches for Mainstreaming Underutilized Crops

Documentation

Documenting the identified species for the region by drilling into data at regional level, appears to be the starting point, especially on nutritional aspects, climate change, needs of region *viz-*

a-viz outside world. Analysis of the diversity in underutilized plants of this region shows that good efforts have been done in past four decades in different areas to document immense knowledge. However, due to ignorance of their value, many of the important underutilized crops have been lost. Furthermore, it has been realized that at least 15-20 per cent of the useful diversity known in the region is still undocumented, or scattered or segregated in several inaccessible knowledge resources.

Several publications have greatly contributed to highlight major thrust on research and development aspects of underutilized species as per needs of national programs within the regional as well as global perspective (FAO, 1996; Monti, 1997; Williams and Haq, 2002; IPGRI, 1998-2000; 2002; Gundel *et al.,* 2003; GFU, 2005; CGIAR, 2005; IPGRI/GFU/MMMRF, 2005; Jaenicke and Hoschle-Zeledon, 2006; Bala Ravi *et al.,* 2006). Publications by National Academy of Sciences, USA (1975), FAO/ RAPA (Bhag Mal, 1994) on grain legumes and pseudocereals, monographic works on selected underutilized species by Bioversity International and Institute of Plant Genetics and Crop Plant Research in Gatersleben, Germany; tropical fruit species in Asia under ADB Project (IPGRI, 2003, Bhag Mal *et al*., 1996; Bhag Mal*,* 2007); publications ICUC by PROSEA (Pulses, 1991: Fruits 1992; Vegetables, 1996), and pulses, vegetables, and cereals/pseudocereals (Williams, 1993; 1995) have largely focused on this group.

An exhaustive document by Arora (2014) on the underutilized plants of this region documented the wealth of selected species and precisely focused on nutritional value, medicinal proprieties, value as known in the area (ethnobotanical/ local data), prioritized crops among selected diversity and the R&D activities. Research data have indicated that species with multiple uses, high shelf-life of produce, ease of storage/conservation and processing for use, with medicinal use, were adopted by people easily; and currently species with high marketability have directly entered in commercial chain (like *Momordica dioica*, *M. cymbalaria*, *Moringa oleifera*). Documentation of knowledge on cultivation/ conservation practices, probable areas/climatic analogues suggested for future cultivation, methods of use as recorded from original data, and methodology to generate awareness appears essential to accelerate the process of acceptance among users. Chinese chives (*Allium tuberosum*) was introduced from China to various parts of the globe including adjoining regions; diverse uses have been reported in adjoining parts of India (North-eastern region) where it is consumed as salad, soups and green vegetable. Wider adaptability to hills as well as plains of Indian region suggested its cultivation in areas during season when onion is scarce (Pandey *et al.,* 2014; Deokota and Chetri, 2016).

Documentation of diverse species consumed by human beings (Pareek and Arora, 1998; Paroda and Bhag Mal, 1989; Peter, 2007; Quah *et al*., 1996; Rogers, 1997; Vielmeyer, 1990) are several examples of plants used in this region. New species of *Manihot* from Brazil (crop wild relatives of cassava/manioc/tapioca) with potential to improve cassava crop by diversifying it for drier climates with biotic resistance to viruses; and nine new species of *Mucuna* used in the treatment of Parkinson's disease named across South East Asia and South and Central America and 28,187 new species recorded for medicinal use (https://www.kew.org/about-our-organisation/press-media/press-releases/the-state-of-the-worlds-plants-report-2017) has opened new dimension for use of these at global level.

Information on lost/vanishing crop diversity at regional levels can facilitate prioritization process and can attract the attention of government/ NGO/ social activist to enhance the impetus on support system. In the past, tribal farmers of Indian peninsula (Bastar, Chhattisgarh) were growing 11 crops (mostly small millets and pseudocereals) in the same field whereas in southern India's Kolli hills nearly 30 varieties of millets were grown together for many centuries. Now with higher dependence of local communities on rice, maize, etc. has resulted in very sparse cultivation of this crop. In Sub-Saharan Africa which is endowed with over 1,000 types of leafy vegetables and fruits rich in micronutrients, gradual replacement by exotic vegetables was reported. Several less-known vegetable melons in parts of India are depleting at a fast rate; cultivation of other ones like *satputia* (*Luffa hermaphrodita*), known for nutritional value has remained in restricted pockets of Nepal, Laos and India (eastern part, Odisha, Maharashtra in tribal belt) (Pandey, 2017 under publication).

Prioritization

Criteria for prioritisation of underutilized crops and policy for promoting specific species for a region may vary with local, national and regional needs. Primarily, the species should meet demand, acceptability by people, have low risk, free of negative properties (ill-effects on human health), adapted to areas recommended for cultivation, easy and safe to establish with less inputs, fast growing, produce high yield and good quality product; and such species/crops should be compatible with land use (von Maydell, 1989; Padulosi *et al*., 2002). Table 2 provides some prioritized list of crops for the APR region, based on criteria enumerated hereafter.

Table 2. Prioritized underutilized plant species for the Asia-Pacific region*

Crop Group	Crop	Genus/Species
Pseudocereals	Amaranths	*Amaranthus* spp.
	Buckwheat	*Fagopyrum esculentum*
	Chenopods	*Chenopodium* spp.
Millets	Finger millet	*Eleusine coracana*
	Proso millet	*Panicum miliaceum*
	Foxtail millet	*Setaria italica*
	Kodo millet	*Paspalum scrobiculatum*
Grain legumes	Rice bean	*Vigna umbellata*
	Adzuki bean	*Vigna angularis*
	Faba bean	*Vicia faba*
	Moth bean	*Vigna aconitifolia*
	Horse gram	
Tubers	Taro	*Colocasia esculenta*
	Giant taro	*Alocasia* spp.
	Greater yam	*Dioscorea alata*
	Elephant foot yam	*Macrotyloma uniflorum*
Vegetables	Hyacinth bean	*Lablab purpureus*
	Sweet gourd	*Momordica cochinchinensis*
	Cho-cho	*Sechium edule*
	Horse radish tree	*Moringa oleifera*
	Kangkong	*Ipomoea aquatica*
	Garden cress	*Lepidium sativum*
Fruits	Bread fruit	*Artocarpus altilis*
	Longan	*Dimocarpus longan*,
	Durian	*Durio* spp.
	Rambutan	*Nephelium lappaceum*
	Mangosteen	*Garcinia mangosteena*
	Carambola	*Averrhoa carambola*
	Seabuckthorn	*Hippophae rhamnoides*
	Khirni	*Manilkara hexendra*
	Karonda	*Carissa congesta*
	Khejri	*Prosopis cineraria*

**Adapted from Arora (2014)*

Ecology provides the range of probability to select the plants for food, while culture decides the tradition and ethics of a society on what and how to eat, and preserve natural resources. Expected success of any species of exotic origin needs proper study on 'Ecocrop' database (Sunil and Pandravada, 2015). While selecting a crop factors that need consideration are food habit, resources available, time for cooking, ease of processing, preserving methods (short shelf-life and difficult to store/process for day-to-day use are not accepted) and most importantly opinion of women folks who are the ultimate users. Plants with multiple uses will be accepted over those with limited use, expensive market over cheaper, nutritional over staple use. Local people, NGOs, middle man, marketing person and R&D scientists need to be linked.

On the basis of relative importance of underutilized species over 80 taxa were prioritized for APR (Arora, 2014). Over 100 vegetables are sold in urban markets of South East Asian countries like Indonesia, Malaysia, Philippines, Thailand, Vietnam, also some in PNG (Siemonsma and Kasern, 1994). More important, widely grown ones are *Abelmoschus esculentus, Allium fistulosum, Amaranthus* spp., *Apium graveolens, Benincasa hispida, Brassica juncea, B. oleracea-broccoli, B. rapa* and *patchoi*, *Ipomoea aquatica, Luffa* spp., bitter gourd, bottle gourd, banana flower, cayota/chow-chow, snake gourd and winged bean. Some minor types gaining importance to varying degrees in the above countries (not in PNG) include *Basella alba, Chrysanthemum coronarium, Lactuca sativa, Rorippa* spp. and *Sauropus androgynus.* Other species in selected regions are *Asparagus*: Malaysia, Philippines; *Lactuca indica, Limnocharis flava, Archidendron jiringa*: Indonesia, Malaysia, the last also in Philippines; *Meliantha*: Thailand and Vietnam; *Solanum torvum*: Malaysia and Thailand. Country-wise localised species are in Indonesia: *Hydrocotyle sibthorpioides*; Malaysia, Thailand: *Cleome viscosa*; Thailand: *Neptunia oleracea;* PNG: *Abelmoschus manihot*/abika, *Rungia klossii, Polyscias* spp., *Saccharum edule*/pitpit. In a study undertaken in Nepal based on relative importance of 49 underutilized plant species employing a Relative Importance (RI) technique, 22 species were identified for multiple purpose use, which were designated as future potential species (*Ficus semicordata, Debregeasia longifolia, Girardinia diversifolia, Hydrocotyle nepalensis, Garuga pinnata, Aloe vera* and *Pyrus pashia*) for the region (Kunwar *et al*., 2012).

Some crops have remained so neglected that they have been considered as lost. High priority must be given to forgotten crops that were once very popular but are vanishing from cultivation currently. *Fagopyrum esculentum*, *F. tataricum*; amaranth and minor millets, *Setaria italica* and *Panicum miliaceum* are forgotten crops, whereas others like amaranth (*Amaranthus caudatus*) only grown in kitchen gardens in hills and valleys of Kashmir, including Ladakh and Jammu provinces (Sultan and Singh, 2013). High priority must be accorded to lost crops of a region.

After UN declared 2015 as the 'International Year of Quinoa', the whole world became aware of its nutritional value resulting in its enhanced awareness and use. Similarly, value of finger millet, amaranths, buckwheat, rice bean which are nutritionally very rich, good potential for food and nutritional security, health and income generation for local communities, was highlighted for adoption to marginal and degraded lands and suitability to low input agriculture. There are emerging concerns in promoting these underutilized plant species which have been receiving due emphasis by Bioversity International and International Centre for Underutilized Crops (ICUC) in particular (William and Haq, 2002; Padulosi *et al*., 2002; Jaenicke *et al.*, 2006; Abeyrathne *et al.,* 2006; Dawson and Jaenicke, 2006; Barry, 2007; Danies *et al.,* 2007; Dawson *et al.,* 2007).

Underutilized crops available in a region and intended area where it is needed for introduction requires proper study. Species introduced from other region(s) were comparatively better recognized, selected consciously or otherwise, depending on the need of the society and better acceptability for use for food or nutrition value. *Phaseolus* species, including *rajmash* (kidney bean) and others were introduced in India long back and have got great acceptance in Indian cuisine due to high nutrition, taste, types and variants such as *kashmiri rajmash*; others such as *P. coccineus* and *P. lunaris* have remained in sporadic state of cultivation. Prioritization based on nutritional parameters can make the market opportunities better with added products to many folds and can have competence with the major crops. The use of modern science to improve their productivity, value addition/popularization through agro-industries needs visualization of new opportunities.

In identifying crops with the status of health food, it was observed that species with diverse uses were better for harnessing the opportunities for improving for newer products/valuation. Sprouted form, protein rich flour mixed with others grains, baked/roasted products can be developed. Recently a very ancient desert crop of Mexico known since Mayan and Aztec civilization, *chia* (*Salvia hispanica*) known for seeds used as energy booster by folklore cultures and enriched concentrated food (rich in omega-3 fatty acids, carbohydrates, protein, fiber, antioxidants and calcium) gained popularity for cultivation and consumption. Vitamin A content of many underutilized and underexploited leafy vegetable species is comparatively higher than the well-established vegetable crops such as spinach; nutritional value of the Himalayan chenopod grains, (*Chenopodium* spp.), is superior to that of most major cereals. Use of buckwheat known since ages under cultivation has gained new dimension of its use as a gluten-free and safe diet recommended for people suffering from celiac disease and gluten sensitivities. It is a grain that is making a 'comeback' after its fall due to health benefits, especially in naturopathy (trace minerals - manganese, magnesium and copper; source of vitamins - B6, pantothenic acid, niacin, folate, thiamin and choline); and use as boiled kernels/groats, noodles and Ume Paste, Japan soba noodles (Japanese buckwheat noodles). Similarly, fox nut/makhana (*Euryale ferox*) a wild/ semi-cultivated aquatic species in India, Korea, China, Japan and Russia primarily cultivated for its edible seeds has value superior to dry fruits such as almonds, walnut, coconut and cashew nut in term of sugar, protein, ascorbic acid and phenol content. It has become a commodity of high export value due to its multiple benefits, use in fast food and ready to cook food.

Popularization, Awareness Generation and Value Addition to Enhance Use

Capparis decidua (known locally as *ker* in India), has been a regionally important popular arid zone fruit, since three decades. Realization of its value addition in form of pickle in recent times, has led to use in multi-fruit pickles which is not only sold in Indian markets, but also exported. Earlier *Allium stracheyi* was a totally neglected species growing in higher altitude ranges of Indian Himalayas; now large scale cultivation is being done due to its great demand in urban markets and fetching good price (sold in urban markets from INR 1,000 - 2, 000 per 250g). In Nepal, Bhutan and adjoining areas, wild species of *A. przewaliskianum* is collected through participatory approach and sold. *A. tuberosum* a potential species with very high adaptability and potential uses was known since its introduction but remained less-known in India. Now ICAR (Directorate of Onion and Garlic), India, is monitoring a pilot project and farmers of major North eastern hill region of India are growing on a large scale, after harvest of paddy (Pandey *et al.,* 2014). Large numbers of such crops or species are in the markets and require better value addition by intervention of organizations/ institutes through R&D approach (Kermali *et al*., 1997). Many of the underutilized natural flavourants, colourants like *Hibiscus sabdariffa*, *Bixa orelana*, *Curcuma* sp. and other natural colourants can not only enhance their marketability but nutritive value as well.

Going Along the Trends of Modernization

With changing food habits and life styles there is a need to create more awareness about nutrition efficient food diet and products full of nutrition (e.g. antioxidants, fibre rich and vitamins). Foods that are ready-to-use, favored by youth and tasty, are easy to popularize and get accepted than conventional food items. Small-scale industry and home science departments can join hands with women stakeholders and work in preparing chips/flakes of tapioca and *Artocarpus*, pickles, multi-grain biscuits, cakes, tamarind candies. Roasted seeds of *Glycine max* and *Vicia faba* with different flavours are in high demand due to acceptance by the younger generation. Recently one of the underutilized vegetable in India, *Momordica dioica* (*kakrol*) was costlier than bitter gourd, used as naturopathic vegetable in diabetic control.

Research and Development Efforts

Documentation of data, prioritization (scoring of the priority and grading based on adaptability of crop, acceptability, marketability, value addition, popularization), networking in the past facilitated approach towards Research and Development endeavour. Role of international organizations such as Bioversity International (formerly International Plant Genetic Resources Institute, IPGRI), International Centre for Underutilized Crops (ICUC), Food and Agriculture Organization of the United Nations (FAO), Global Forum on Agricultural Research (GFAR), and the Global Facilitation Unit (GFU) on underutilized species has play a major role in this direction. Involvement of other organizations for funding/ major donor agencies such as the German Federation Ministry for Economic Cooperation and Development (BMZ), International Fund for Agricultural Development (IFAD), Consultative Group on International Agricultural Research (CGIAR); and in Asia-Pacific region, the Asian Development Bank (ADB) and Australian Centre for International Agricultural Research (ACIAR), Ausaid and Nzaid (ACIAR, 2001) have tremendous support to carry out these activities. Besides, better networking among international, regional and national programmes (AVRDC- vegetables; IPGRI and ICUC- tropical fruits) with emphasis on making national agricultural research systems (NARS) has played a supportive role to meet challenges of food security and poverty reduction and contribute towards agricultural sustainability.

Euryle ferox (*makhana*) has moved from wild/semi-wild to cultivation and large scale commercialization through involvement and efforts of locals and scientific community. In India, ICAR has succeeded in developing a technique for field cultivation of *makhana* normally grown in low land ponds in parts of Bihar, Odisha, Assam and West Bengal, now possible to grow in low farmland and inter-crop with other crops and exports. With launch of '*makhana* popping machine' high quality popping output, less wastages and high export value has enhanced the economic potential.

Priority Species: Choice/identification of priority species for R&D would vary depending on several factors, particularly the needs of the national programmes and wider development role of such species at regional/ sub-regional levels (MSSRF, 1999, 2002; Williams and Haq, 2002; Arora *et al*., 2006). Further prioritisation among the neglected underutilised species was emphasised largely to focus on selected groups (Hall *et al*., 2013). The following criteria will serve well in ascertaining the choice of these species: National programmes recognizing species/crops of importance and committed to promote their R&D and evaluation; identification and development of promising selected varieties suited to diverse agro-climates/ecosystems; multiplication and supply system if in place, as also infrastructure for the supply of planting material, post-harvest technology application to meet R&D needs; diversification and value addition technology available; market outlets/channels exist-linking farmers to markets.

Networking and Partnership: The two leading organizations engaged in this activity for promoting underutilized species are Bioversity International (formerly IPGRI) and International Centre for Underutilized Crops (ICUC), and 'Crops for the Future' (CFF); their efforts over the past two decades have been successful particularly in addressing/providing thrust on conservation, and use of underutilized tropical fruits (IPGRI, 2003; ICUC, 2006).

Participatory research should be actively pursued among stakeholders in areas such as constraint with respect to production to consumption, evaluation of material with farmers and local NGOs, strengthening seed supply system, educating farmers and involving them in promoting participatory plant breeding activities (Padulosi *et al.,* 2002). There is thus need for development of sustainable linkages between organizations, farmers, and consumers. Efforts are required to address constraints through strong networking and coordination. Significant progress has been achieved by IPGRI managed networks/coordinated programmes (APAARI, 2007). Assessing the impact of such improvement/ promotion process through appropriately addressing conservation and utilization aspects, agronomic aspects, policy-level decisions and strong monitoring is desired (MSSRF, 1999, 2002; IPGRI, 2002; FAO, 2010).

Conclusions

The choice for the priority species for R&D needs has been suggested with emphasis on native/ endemic diversity. Inter-disciplinary approach with need-based focus in meeting the growing demands to promote and assess this diversity includes: use of biotechnology, ethnobotany and documenting indigenous knowledge, diverse uses and conservation. The greater need for partnership/networking at national, regional and international level for realizing the full potential of underutilized species has been stressed to address the Sustainable Development Goals (SDGs).

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Grasspea: A Neglected but Important Pulse Crop for Nutritional Security of Low-Income People

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ABSTRACT: Grasspea (*Lathyrus sativus* L.), a multi-purpose and climate smart important pulse crop which can be grown under harsh edapho-climatic conditions with low cost of cultivation. Traditionally, its seeds and twigs are used for human consumption and green fodder and plant residues as animal feed. It has a great potential for cultivation in areas where other crops cannot be grown due to adverse growing conditions. The crop has a specific production niche in South Asia, where it is grown as a relay crop in rice field, thus no tillage operations are required which reduces its cost of production. Grasspea is largely grown in Bangladesh, India, Nepal and Ethiopia and to a lesser extent in China, West Asia, Southern Europe and the Americas on about 1.5 million/ ha area. It provides an excellent opportunity for sustainable agriculture and nutritional security to the low-income people of South Asian countries. Despite its numerous advantages, grasspea has an ambivalent reputation. Its plant parts contain, β-N-Oxalyl-L-α, β-diamino propionic acid (β-ODAP), which causes an irreversible neurological disorder to humans and animals. Despite its importance in food and farming systems, grasspea crop is still under-researched except a few breeding efforts.

Key words: Future action, grasspea, introduction, nutritional security, pulse

Introduction

Grasspea (*Lathyrus sativus* L.) is among more than 52 crop species regarded as nutritionally enriched but under-researched/underutilized. It is important in food and farming systems of South Asia and some Sub-Saharan countries. Many countries of Asia (India, Pakistan, Bangladesh, Nepal and China), Middle East, Africa (Ethiopia, Ghana, Sudan, Niger, Ivory Coast and Mauritania) and Southern Europe (France and Spain) cultivate grasspea for both human consumption and livestock feed use.

Grasspea is mainly eaten as *dal* (concentrated soup) and used as *besan* (flour), as adulterant in varying proportions in chickpea and pigeonpea for food preparations, and its twigs as leafy vegetables. It is commonly believed that the recipes become tastier with the blending of chickpea and grasspea flour. It is also preferred for its good fodder and straw quality. Farmers feed their animals on paddy straw and grasspea straw, which being rich in nutritive value, serves as a good supplement to nutritionally poor paddy straw, since under rainfed situation growing of other quality fodder is not feasible. Grasspea being a leguminous crop fixes atmospheric nitrogen, improves soil carbon and organic matter, thus collectively improves soil health and provides sustainable production systems.

Because of its easy and low-cost cultivation, and resistance to drought, flood, salinity, diseases and insect pest attack, farmers are attracted to grow this crop. When other crops fail due to adverse conditions, grasspea can be the only available food source for the poorest section, and sometimes is a survival food in times of drought induced famine. It is predominantly grown as a relay crop, popularly

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known as *utera,* in rice field, which is a well-established rice-based cropping systems and farmers do not have a better alternative under such a harsh rainfed conditions. It is also grown as mixed and intercrop with other rabi crops, thus minimizes risk of total crop failure. It is a rich source of protein (up to 34%) and contains essential micronutrients, thus provides nutritional security to its consumers. Grasspea plant has a profuse and penetrating root system, therefore, can be grown of many soil types and conditions of soil including saline and nutrient deficient soils where other crops can hardly sustain. This hardiness together with its various properties makes this crop suitable for adverse agro-climatic conditions (Campbell *et al.,* 1994). It also helps in fixation of atmospheric nitrogen (approximately 108-125 kg/ha nitrogen) to the soil, hence meets its own requirement and the nitrogen demand of succeeding crop and plays important role in sustainable farming system (Peoples *et al.,* 2008).

Despite these advantages, relatively little research efforts have been directed to improve grasspea. Its improvement work was initiated at the International Center for Agricultural Research in the Dry Areas (ICARDA), New Delhi, India in 1989. The main reason behind the slow progress has been the side effects due to excessive consumption of grasspea that can lead to a neurological disorder in humans and domestic animals (Jackson and Yunus, 1984), by the presence of a neurotoxic non-protein amino acid β-N-oxalyl-L-, α-diaminopropionic acid (ODAP) contents. To combat neuro-lathyrism, many governments of endemic countries has banned grasspea production and made substitution by the best alternative crops. Under climate change, with serious concerns about sustainability of agricultural production and food security worldwide, interest in the under-utilized crops such as grasspea has been renewed in many countries. The main research objectives are to develop low-toxin/toxin-free, high yielding varieties with resistance to biotic and abiotic stresses and adapted to various cropping system niches.

Production Regions

Worldwide, area under grasspea is assessed at 1.5 m ha with annual production of 1.20 tons, mainly in South Asia and Sub-Saharan Africa. In South Asia alone, it is grown on 0.92 m ha area with 0.63 tons production with productivity of 687 kg ha^{-1} grain yield (Rahman *et al.,* 2008). During 1994-2004, the grasspea area in South Asia decreased from 1.38 to 0.92 ha, with corresponding decline in production from 0.85 to 0.63 ton. During the period, however, the productivity has increased from 588 to 691 kg ha^{-1}. In India, grasspea area declined drastically from 930,000 ha in 1996 to 601,500 ha in 2008. During this period, the production declined marginally from 420,000 to 384,800 tons as yield increase from 455 to 640 kg ha^{-1} compensated the area loss to some extent. Nepal has recorded sharp decline in grasspea production from 17,340 tons in 1995–1996 to 4,335 tons in 2008-2009 because of decline in area from 30,780 to 5,870 ha. The ban on the trade of grasspea seeds in India and Nepal has been the main reason behind the drastic reduction in its cultivation. In Bangladesh, grasspea still occupies the first position among the pulse crops and its production has increased from 181,000 tons in 1995-1996 to 304,000 tons at present. Similarly, in Ethiopia, area and production have increased steadily from 75,950 ha and 80,430 tons in 1996 to 159,731 ha and 202,126 ton in 2009, respectively. These increases are attributed to the fact that grasspea cultivation has found preference in difficult areas where other crops have generally failed due to prevailing harsh climatic conditions. In India, it is cultivated primarily in Bihar, Maharashtra, West Bengal, Assam and Chhattisgarh (Khandare *et al.,* 2014). The majority of the area (~70%) is shared by Chhattisgarh and Vidarbha region of Maharashtra, a rice-growing region where supplemental irrigation is available only for rice (Dixit *et al.,* 2016). Thus, water is not available for subsequent winter crops. Hence, grasspea is the only alternative for a crop following rice. Grasspea withstands unfavorable conditions including excessive moisture at sowing, which is often followed by moisture stress at later growth stages. It is favored for cultivation in such areas owing to its hardy nature and low costs of cultivation.

Utilization

The most common use of grasspea is to prepare *dal,* and nearly 25 per cent of consumers adopt conventional measures to detoxify grains before consumption. Considerable awareness was found among rural people about the toxic effects of grasspea consumption. It is used in many ways for human and animal consumption (Yadav, 1996) as shown in Table 1. Grasspea cultivation maintains the soil fertility by fixing high nitrogen and maintaining poorly drained land better than any other crop therefore, it is also utilized for soil health.

Table 1. Different uses of grasspea

Product	Usage
Leafy vegetable	Young leaves (vegetative parts) plucked and sold as green leafy vegetable. Also is rolled and dried for off-season use
Green pods	Green pods are eaten directly and whole pods are cooked and eaten as vegetable
Dried grains (Dal)	Grains are split to make *dal* and consumed with rice
Flour	Flour used to prepare pancake like preparations
Feed	Ground split grain/ flour used as feed for lactating animals or for bullock at time of heavy field use
Fodder/forage	Used as forage from the young vegetative stage to maturity

Production Constraints

Plant population: It is mainly grown under relay cropping, thus appropriate plant population is major bottleneck for productivity increase.

Suitable varieties: Farmers are using traditional varieties, resulting in low yield. Only few varieties have been developed and further research on development of low toxin varieties and location specific agronomic practices is underway.

Lack of good quality seed: Supply of seed is always less than the demand. More efforts are required for quality seed production at formal and informal sources.

Poor yield: In relay cropping, its cultivation faces two different situations *viz*., excessive moisture at sowing and stress at growth and reproductive stages resulting in low yield.

Non-use of fertilizers: Farmers do not use fertilizers, as application of fertilizer in relay system is difficult in standing paddy crop and/or farmers are reluctant to use fertilizers.

Genetic Resources

The genetic diversity of the genus *Lathyrus* is of immense significance, particularly for rainfed cropping systems in many countries (Yadav, 1996) as a resource for the improvement of *L. sativus*; the genus is largely underutilized and under-researched. Several species are cultivated for food, feed, and fodder, as well as for ornamental purposes (Sarker *et al.,* 1997), but there is potential for further exploitation of the *Lathyrus* genepool. Therefore, collection, conservation, characterization, genetic diversity assessment and utilization of the genus *Lathyrus* is a priority. There is an urgent need to actively conserve the genetic diversity of the genus using both *ex situ* (gene banks) and *in situ* (natural habitats) techniques. ICARDA holds the largest collection of about 3,000 accessions of cultivated and wild species which are being shared with national programmes. Besides, Bangladesh maintains 1,792, and India conserves about 2,600 accessions, among major countries holding grasspea germplasm.

The genus *Lathyrus* includes 160 species, some of which have economic importance as food, fodder and ornamental crops (mainly *L. sativus, L. cicera* and *L. odoratus*, respectively) (Vaz Patto and Rubiales, 2014), chiefly located in Europe, Asia and North America, extending to temperate South America and Tropical East Africa. The primary center of cultivation is in southern Asia, particularly in Bangladesh, China, India, Nepal, Pakistan and also in Ethiopia, with more limited production in southern Europe and West Asia. Due to the potential the genus has as a food, feed and fodder crop, as well as its extensive cultivation of ornamental species, it is necessary to collect and conserve all available cultivars, landraces as well as the wild species of genus *Lathyrus*. Table 2 provides a list of those species known to be historically or currently cultivated.

Table 2: Historic or current cultivated *Lathyrus* species

Species	Use	Status	Distribution
L. annuus	Pulse, fodder	Rare	Europe, N. America
L. aphaca	Fodder	Rare	India
L. blepharicarpus	Pulse	Historic	Near East
L. cicero	Pulse, fodder	Rare	S. Europe, N. Africa
L. clymenum	Pulse	Rare	Greece
L. gorgoni	Fodder	Historic	Middle East
L. hirsutus	Forage	Common	USA
L. latifolius	Horticulture	Common	Europe
L. ochrus	Pulse, fodder	Rare	Greece, Middle East
L. odoratus	Horticulture	Common	Widespread
L. pratensis	Forage	Rare	S. Europe, N. Africa
L. rotundifolius	Horticulture	Common	Widespread
L. sativus	Pulse, forage	Common	Widespread
L. sylvestris	Forage	Rare	S. Europe, N. Africa
L. tingitanus	Fodder	Rare	N. Africa
L. tuberosus	Tubers	Rare	W. Asia

Research on Genetic Improvement

To improve the yield potential of grasspea a lot of efforts need to be done for enhancing food security in harsh environments, feed for livestock and crop for soil health. Regardless of the availability of low toxin lines, listing of grasspea as a toxic plant and the banning of seed sales in some countries, has limited funding for crop development. The major grasspea improvement research has been conducted in India, Bangladesh, Australia, Ethiopia and at ICARDA. Previous research showed that germplasm from South Asia contained relatively high amounts of ODAP (0.7–2.4%) whereas, those from North Africa, Syria, Turkey, and Cyprus had significantly lower quantities of ODAP (0.02–1.2%) although no accessions were found to be free of the ODAP.

ODAP content is a polygenic trait and is highly influenced by genotype, environment and their interactions (Hanbury and Siddique, 2000). Germplasm accessions with low ODAP have many undesirable agronomic traits such as late flowering, low yield and susceptibility to biotic and abiotic stresses. In order to combine low ODAP with high yield, appropriate phenology and stress tolerance, breeding programmes have been undertaken mainly at ICARDA, India, Ethiopia, Bangladesh and Australia. This has resulted in the development of several high yielding varieties with low ODAP (<0.1%) in different countries: Australia (Ceora, Chalus); Bangladesh (Barikhesari-1, Barikhesari-2, Barikhesari-3, Barikhesari-4 and Binakhesari-1); India (Ratan, Prateek, Mahatiwara, Nirmal); Nepal (Clima Pink, 19A, 20B); Chile (Luanco, INIA); Kazakhstan (Ali-Bar); Ethiopia (Waise); Poland (Derek, Crab) and Turkey (Gurbuz-1).

Cropping System and Agronomic Practices

In India, understanding its ability to grow under harsh conditions, it is generally grown in three farming systems i.e. sole crop in fallow where irrigation water is not available; relay system in which seeds are broadcasted before harvest of paddy; and mixed cropping with linseed or chickpea. In relay cropping it is very easy to cultivate without much efforts but very difficult to boost up productivity. In Bangladesh, it is mostly grown as a relay crop in low lying areas in *aman* rice fields. Broadcast sowing with high moisture in standing rice field, 3-4 weeks before harvest. At some places it is grown as sole crop. Fertilizers and pesticides are not used in its cultivation (Sarwar *et al.,* 1996). In Nepal, the adoption of grasspea is in marginal areas like water logged lowland rice areas where other winter crops like wheat, oilseeds or other legumes cannot grow. It is mostly sown in relay condition with late maturing rice fields. No additional chemical fertilizer or insecticide is used in its cultivation but it plays an important role in increasing the cropping intensity.

Attempts in Technology Up-scaling

ICARDA, with financial support from National Food Security Mission-Pulses (NFSM-P), Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture (GOI) operated a project on enhancing grasspea production for safe human food, animal feed and sustainable rice-based production systems in India. With national partners, from Indian Council of Agricultural Research (ICAR)/ State Agricultural Universities (SAUs) and Non-Governmental Organizations (NGOs), ICARDA implemented the project in the states of Assam, Bihar, Chhattisgarh, Uttar Pradesh and West Bengal. Major focus was for replacement of indigenous high toxin grasspea varieties available with farmers with low toxin and high biomass varieties through farmers' participatory approach and enhancing fodder and straw yields through production of these varieties to support nutritional feed and fodder, where only paddy straw is available as cattle feed. Another objective was establishing grasspea as a second crop in specific niches like rice-fallows to break mono-cropping, thus increasing cropping intensity and income of farmers. The varieties provided were Nirmal, Ratan, Prateek and Mahateora along with improved agronomic practices. In order to provide seed at right time, 12 seed hubs were developed, to ensure regular supply of seed. The results of improved technological intervention brought out that the grasspea yield could be increased up to 41 per cent, if proper agronomic practices are followed. Crop was also successfully established in rice fallows, covering more than 1000 ha of land.

In India, during last few years of technology dissemination, improved grasspea varieties have been provided to 13,000 farmers in 868 villages in five states of India. More than 21 tons of quality seeds have been produced. In capacity development, a total of 11,000 farmers including 4,867 women farmers were trained on improved production practices, storage, value addition and physico-chemical detoxification. With all these interventions, it is expected that grasspea area will be increased substantially and will be available in daily diet of the people of Bangladesh and India to meet nutritional requirement.

Conclusions and Future Strategies

Grasspea is a food, forage and fine green manure crop. Its multiple beneficial properties and various uses make it suitable for introduction in problem soil areas. It provides ample opportunities to diversify and intensify the existing cereal-based cropping systems manage the risk of unpredictable weather and increases the profitability and sustainability of agriculture under the climate change scenario. Global attention is needed to embark on its genetic improvement using conventional and bio-technological interventions, and integrated crop management research to make this survival food available and safe for human consumption.

Several actions that can be made to improve the grasspea cultivation are given below:

- ***Expansion of growing area****:* grasspea area has decreased due to many production constraints. Keeping in mind its importance and easy cultivation, area can be increased in new niches, like rice fallows in eastern India, Bangladesh and Nepal.
- ***Quality seed production****:* seed is considered as a key element in crop production, and it is the material used to establish a new crop each year, and the quality of the seed determines how efficiently that is flourished. Presently, grasspea seed is produced as in informal seed sector, in

which the farmers obtain seed by saving a part of the crop directly sowing the following season or buying from neighbours or local traders. The seed quality may not be suitable. Good quality seed should be multiplied and disseminated to the farmers, through programme extension.

- ***Further investigation:*** although several studies on grasspea have produced good results, there is a need to study further on its agronomy and breeding. Its place in crop rotations should be comprehensively investigated, and the seeding rate and fertilization ought to be studied. The breeding efforts should be focused on greater yield and nutritive value. After identification of the suitable parental lines, the relevant crosses may be made in order to incorporate the desirable plant characteristics.

At present, grasspea is an under-researched crop. Concerted research efforts are warranted to develop improved production technologies along with varieties with low-toxin content. There appears to be a great potential to expand its cultivation area and improve its production. Besides, grasspea can be successfully grown in Pakistan, Ethiopia and China for human consumption and animal feed. Among South-East and Pacific regions, long-duration grasspea varieties with high biomass can be introduced in Fiji, Vietnam, Thailand and other countries of interest for fodder purpose.

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Nutritionally Rich Underutilized Vegetables - Recapturing Vegetable Phytonutrients for Healthier Diets

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ABSTRACT : Vegetables contribute to good health by providing phytonutrients like: (1) essential nutrients including macronutrients (protein, carbohydrates, fat) and micronutrients (vitamins and minerals); and (2) health-promoting phytochemicals (such as flavonoids, carotenoids, terpenes, glucosinolates, and phytosterols) to the human diets many of which are not available through other foods. Certain regionally or locally important traditional vegetables are nutritionally rich, health-promoting and adapted to extreme stresses such as flood, salinity, drought and pests. However, breeding of traditional vegetables has been neglected and production and marketing has declined over the years. Consequently, many vegetable value chains depend on a few globally important vegetables, and the nutritional values of the improved crops are not necessarily better than before. It is possible that the health benefits of vegetable consumption may have been limited due to the modern diets with fewer crop types, lower varietal diversity and imbalanced phytonutrient profiles. The paper highlight on: thinking of breeding for nutritional traits and ways of promoting underutilized crops, and proposed nutrition-sensitive vegetable breeding programme and using need-based and evidence-based dietary strategy to prioritize and promote greater production and consumption of phytonutrient-rich underutilized crops.

Key words: Breeding, diversity, intakes, phytochemicals, traditional vegetables

Introduction

The triple burden of chronic undernutrition, micronutrient deficiencies, and obesity (root cause of diet-related non-communicable diseases) is rampant in the tropics. Efficient, well-managed and sustainable food systems are essential to end hunger and malnutrition as well as to protect the environment. Sound food systems enable access of all people to sufficient, affordable, diverse, nutritious and safe diets to help achieve food and nutrition security (HLPE, 2017; Global Panel on Agriculture and Food Systems for Nutrition, 2016).

Healthy diets include diverse foods from the key food groups (starchy staples, legumes and nuts, animal products, fruit and vegetables) that are enjoyable to eat, fulfill daily nutrient requirements, and contain health-promoting substances such as fiber and antioxidants to help maintain health. Vegetables are highly diverse in terms of species and varieties as well as the essential and bioactive phytonutrients contained in them. Agricultural, socio-economic and health benefits of vegetables including those traditional and indigenous to specific regions are many: diversification and more resilient cropping systems, increased job opportunities, especially for women, and better incomes and livelihoods for smallholders. Many people consume monotonous, insufficiently nutritious diets because they lack access to or cannot afford a broader range of nutritious foods with limited awareness of healthy diet importance.

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Although 5,500 plants are known to be human food (Willis, 2017), human diets are based on just three crops - rice, maize and wheat that provide 60 per cent of the world's food energy intake and 15 crops make up 90 per cent of the energy supply (FAO, 1995). Crop diversity contributes to dietary diversity and favorable anthropometry outcomes in middle and low-income countries (Jones, 2017). Modern food systems emphasize efficiency, low cost and convenience (McCullough *et al*., 2008). Production and consumption of traditional vegetables have declined over time due to the consequences of globalization, urbanization and trade involving larger quantities of a few commodities.

Development and marketing of new crop varieties, including vegetables, is increasingly dominated by private seed companies and selection has emphasized traits linked to higher productivity such as high yield and disease resistance, and quality traits important to market acceptance such as size, color, shapes, shelf-life, and others. Nutritional quality is often a "hidden" trait not easily discerned visually that requires laboratory analysis to quantify and usually not an important factor in market success; consequently, increased nutrient content is rarely an objective in breeding programmes and nutrient levels are rarely monitored in new varieties. Some recent studies have provided evidence for decreased nutrient content of new varieties compared to older or heirloom varieties (Bash, 2015; Ceccarelli, 2015; Christinck and Weltzien, 2013; Davis *et al.*, 2004; Fu, 2015). Most phytochemicals taste bitter, sour, or astringent at various degrees from unnoticeable to mild and strong. Humans have many types of receptors to taste bitterness and diversity (Drewnowski and Gomez-Carneros, 2000). However, a major consideration in consumers' preference has been "sweet taste" leading to higher sugars, and protein contents and lower phytochemical concentration and diversity (Yang, 2018, unpublished data).

In the last two decades, HarvestPlus – biofortification seeks to improve nutrition and health for poor populations by developing and scaling high-nutrient varieties of staple foods (Bouis *et al*., 2011; Nestel *et al.*, 2006). Tremendous impacts on enhanced nutrient intakes and health in Africa are evident (Bouis and Saltzman, 2017; de Valença *et al*., 2017). For vegetables the advantages of "genetic and phytonutrient diversity" and the disadvantage of "lower consumption rate and seasonality" require that improved nutrition from vegetable breeding should be different from but complementary to staple food biofortification. Unlike staple crop biofortification which measures nutrition impact directly from the production and consumption of a single crop and is feasible due to its high consumption rate, the nutrition impact from vegetable breeding should be examined from collective, aggregated and synergetic perspectives.

Nature provides diverse plant foods rich in phytonutrients for human consumption and health. Vegetables contribute to good health, as they provide phytonutrients including: (1) essential nutrients such as macronutrients: protein, carbohydrates, fat; and micronutrients: vitamins and minerals; and (2) health-promoting phytochemicals (such as flavonoids, carotenoids, terpenes, glucosinolates and phytosterols) to the human diets, many of which are not available from other foods. Essential nutrients are "essential" to human for body function and growth, and insufficient intakes will result in nutrition related disorders, like Kwashiorkor, night-blindness, and anemia from protein, vitamin A and iron deficiencies, respectively. On the other hand, over consumption of energy-dense food with low nutrition quality can lead to overweight, obesity and various dietary related chronic diseases, such as type 2 diabetes, cardiovascular diseases and cancers (Astrup *et al*., 2008; Drewnowski and Specter, 2004). Health-promoting phytochemicals are not "essential" for house-keeping function and growth, but they are bioactive and critical to help the human body in fighting infectious, degeneration and chronic diseases and maintain good health (Dillard and German, 2000; Leitzmann, 2016; Liu, 2004; Rodriguez-Casado, 2016).

Functional properties of bioactive phytochemicals have been characterized *in vitro* and *in vivo* the past decades. Leitzmann (2016) reviewed nine main functional effects (anti-carcinogenic, anti-microbial, anti-oxidative, anti-thrombotic, immunomodulatory properties, anti-inflammatory, influence on blood pressure, cholesterol-lowering effects, modulate blood glucose levels) of selected bioactive phytochemicals (carotenoids, phytosterols, saponins, glucosinolates, polyphenols, protease inhibitor, monoterpenes, phytoestrogens and sulfides). The report suggested that one bioactive phytochemical could contribute to several of different health effects depending on the dosage, actions in food matrix and experimental conditions. Health benefits of bioactive phytochemicals are more evident with whole foods rather than nutraceutical supplementation (Liu, 2003, 2004, 2012; Rahal *et al.*, 2014; Romagnolo and Selmin, 2017; Slavin and Lloyd, 2012; World Cancer Research Fund/ American Institute of Cancer Research (WCRF/AICR, 2007; Yahia, 2009). Evidence of the associations between disease prevention and vegetable consumption are positive, but sometimes with weak causal linkages the results were inconsistent among dietary patterns consumed by different populations. It is possible that the health benefits of phytonutrient intake from plant foods, particularly from fruit and vegetables may have been limited from the modern diets with fewer crop types, lower varietal diversity and imbalanced phytonutrient profiles.

Phytonutrient Intake - Country Status

Estimated phytonutrient intake at the regional level were reported using FAO food balance sheet data instead of consumption surveys (Murphy *et al.*, 2014; Tennant *et al.*, 2014). The top food sources and their per cent share of consumption are summarized in Table 1. The selected phytonutrients (carotenoids, anthocyanins and quercetin) are abundant in many different fruit and vegetable crops, however the top food sources were concentrated to two-five crops, indicating low diversity of plant foods and phytonutrients in current diets.

Table 1. Top food sources of selected phytonutrients and the per cent share of the intake amount

Region	β-carotene (%)	Lutein/zeaxanthin	Lycopene	Anthocyanidins	Quercetin
Americas and Australia	Carrots and turnips (28%); Lettuce and Chicory (25%)	Lettuce, Chicory (36%); Cabbage, Brassicas (17%)	Tomatoes (73%); Watermelons (21%)	Lettuce, Chicory (24%); Bananas (12%)	Onion (46%); Lettuce, Chicory (16%)
Western Europe	Carrots, Turnips (42%); Cabbage, Brassicas (16%)	Cabbage, Brassicas (35%); Lettuce, Chicory (14%)	Tomatoes (66%); Watermelons (18%)	Grapes (17%); Currants (16%)	Strawberries (62%); Raspberries (28%)
Asia	Cabbage and others Brassicas (28%); Spinach (20%)	Cabbage and others Brassicas (41%); Spinach (33%)	Watermelons (54%); Tomatoes (32%)	Lettuce, Chicory (26%); Bananas (24%)	Bananas (27%); Strawberries (22%)
Southern Africa	Cabbage, Brassicas (38%); Carrots and Turnips (17%); Plantains (11%)	Cabbage, Brassicas (66%); Spinach (6%)	Tomatoes (74%); Mangoes, Guavas (16%); Watermelons (3%)	Bananas (63%); Cabbages, Brassicas (14%)	Bananas (65%) Pineapples (10%)
Taiwan	Sweet potato leaf (20%); Carrot and products (14%); Spinach (11%)	Sweet potato leaf (36%); Spinach (17%); Water spinach (14%)	Tomato and products (63%); Watermelon and products (31%); Papaya and products (5%)	Radish (41%); Bananas (18%); Grapes and products (12%)	Tea (55%); Sweet potato leaf (10%); Spinach (6%)

Source: Murphy et al. (2014); Tennant et al. (2014)

Phytonutrient intake at country level using consumption data were reported for diets in the US, Korea and Taiwan (Lee *et al.*, 2013; Murphy *et al.*, 2012; Pan *et al.*, 2018), and the comparisons among the three countries were made by Pan *et al.* (2018). The study indicated that phytonutrient intake profiles of the three diets were very different and skewed to specific classes of phytochemicals attributed from a small group of plant foods. For instance, American diets provided higher lycopene from tomato and its products, higher quercetin from onion, but was low in several types of carotenoids mainly derived from green leafy vegetables. Taiwan populations consumed more lutein, a non-provitamin carotene important for eye health, and quercetin from green leafy vegetables, but less red antioxidants, such as lycopene and anthocyanins. Korean diets contained less phytonutrients in general. These are important messages for better understanding of dietary gaps, developing need-based and evidence-based dietary strategies, and identification of important food items to fill the dietary gaps. Unfortunately, such information on phytonutrient intakes for most countries are scarce and this limits our understating of dietary gaps and further research on its nutrition and health implications.

Phytonutrient intake is calculated from consumption surveys and phytonutrient profiling data. Due to the wide diversity of plant foods with varying consumption patterns among regions, the complexity of sampling the plant foods, and high laboratory analytical capacity required for phytonutrient analysis, information on phytonutrient contents are not available for many plant foods, particularly those traditional and underutilized vegetable and fruit species. Consequently, phytonutrient intake cannot be calculated, even when consumption data are available.

Efforts Made

The World Vegetable Center has collected and preserved genetic resources of over 65,000 vegetable accessions including principal crops - tomato, peppers, cucurbits, legumes and 400 different species from tropical Africa and Asia, many of which are underutilized. Ample genetic diversity for nutrient content exists in many global and traditional vegetables, offering scope for breeding. A worldwide gap-analysis of selected traditional vegetables is needed to deepen our understanding of the distribution of genetic diversity and where future collection is needed to adequately preserve genetic diversity.

Breeding programmes at the World Vegetable Center aim at development of high performance lines adapted in tropical climates. WorldVeg breeding programmes have selected for higher levels of beta-carotene, lycopene, and flavonoids in tomato, high methionine in mungbean, and carotenoids in pepper (Dhillon *et al.*, 2017; Hanson *et al*,. 2014; Hanson *et al*., 2006; Hanson *et al*., 2004; Hanson and Yang, 2004; Luoh *et al.,* 2014; Nair *et al*., 2013; Yang and Ojiewo, 2013). Even when nutritional traits are not breeding targets, the nutritional quality of the improved lines of tomato, peppers, pumpkin, bitter gourd, mung bean, vegetable and grain soybean and several traditional vegetables (such as amaranth, cowpea, African nightshades, eggplants, and kale) are monitored by nutrition laboratory analysis to safeguard against nutrient reductions in new lines. Nutrition-sensitive vegetable breeding could be promoted through regional vegetable research networks, Asian and Africa Seed Associations and other platform such as the Global Partnership for Plant Breeding Capacity Building from FAO-Nutrition which is advocating the integration of plant breeding into global nutrition agenda.

Nutritional values (nutrients/anti-nutrients/promising bioactives) of accessions representing more than 200 species were evaluated by the Nutrition Laboratory at the World Vegetable Center (Luoh *et al*., 2014; Yang *et al*., 2006; Yang *et al*., 2008). We also characterized the phytonutrients of selected plant foods in collaboration with Academia Sinica in Taiwan to investigate the phytonutrients intakes from different dietary patterns and detect the biomarkers in relation to diet-related pathogenic pathways such as metabolic syndrome and diabetes. Experience and knowledge on how to grow traditional vegetables were accumulated from the past 15 years of work in Asia and Africa through projects involving conservation and evaluation of germplasm, vegetable breeding, and promotion of the production and consumption of traditional vegetables.

Conclusions

Future research should explore local food systems from a dietary perspective, evaluate dietary patterns of different populations at community and regional levels, particularly for plant food diversity and phytonutrient intake, identify dietary gaps and investigate the possible implications for nutrition and health. This information would be crucial for developing dietary strategies and designing programme including advocacy for nutrition-sensitive vegetable breeding and for crop prioritization (including traditional vegetables), subspecies and varietal diversity to address the dietary gaps and how these actions could be leveraged in a sustainable way.

Issues relating to recapturing vegetable phytonutrients for healthier diets are raised:

- What are the dietary gaps for different population groups and the components of the food system responsible for the identified gaps?
- What are the nutrition and health implications from these gaps?
- Can we recapture the diversity and phytonutrients (both essential nutrients and bioactive compounds) in our diets?
- How can we do things differently in plant breeding and promoting traditional vegetables, so that our current efforts to enhance availability, affordability and utilization of vegetables can be combined or balanced with greater diversity of crops, varieties and phytonutrients addressing the triple burdens?

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Wild Edible Plants in Asia-Pacific: A Case Study with Bastar Tribal Pockets in Chhattisgarh, India

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ABSTRACT: The Asia-Pacific Region (APR) is agriculturally diverse and very rich in plant genetic resources, including those of wild edible plants, less-known food plants and underutilized species. Being culturally, ethnically and ecologically very diverse, several wild edible plants available in the forest areas and underutilized species under subsistent agriculture are used by native farmers. Wild edible plants and underutilized species with a great potential in the APR have been synthesized under different categories *viz.*, roots, tubers, cereals, millets, pulses, vegetables, fruits and nuts. Plant parts such as roots, rhizomes, tubers, leaves, shoots, young twigs, flowers, fruits, seeds, etc. are used as food by the tribal peoples throughout the globe. A case study is presented on wild edibles and medicinal plants diversity available in the undivided Bastar tribal pockets in Chhattisgarh, India, based on diversity observed during extensive exploration expeditions undertaken during 1981-1989 (first author) and also up to 2017 (others) especially in the forests and some highly protected areas. Out of major forest and village areas explored, the forest and some protected areas such as Abujhmarh, Kanger Ghati, Bijapur forest, Bailadilla hills, Binta forest, Bhejji forests, Mardoom forests, Dantewada forest, Bhopalpatnam forests, Sukma forests and Keshkal-Kanker forests were observed with maximum diversity of tubers, fruits, vegetables, grain legumes and medicinal plants.

Key words: Abujhmarh plateau, Bastar plateau, underutilized species, wild edible plants

Introduction

During the course of civilization humans started domesticating wild species; however, a large population still depends on the wild varieties of plants to fulfill their food and other requirements. Even today, forests provide a large number of edible products from wild plants. The wild vegetables are preferred over the cultivated types as they grow naturally, provide better taste and nutrition. Tribal people believe that some of the seasonal wild vegetables are good for health and also provide immunity. The nutritional value of traditional leafy vegetables is considered higher than several conventional vegetables as they contain antioxidants which offer protection against many chronic diseases. Their increased use contributes to enhancing people's health and economic and social status. FAO (2004) reported that wild food is a part of diet rural population not only during periods of food shortage but also on a daily basis, and the daily consumption of wild products contributes to overall nutritional well-being. The wild and underutilized species have great potential. Investigating these species is likely to uncover new ways in which these could be used more effectively. They may be rich in minerals or vitamins, and can provide new or additional foods, contributing to food security. They might be marketed in new ways as novel food and help raise income for those that gather, grow and process them or they may enhance environmental services by filtering and processing toxic substances, preventing soil erosion and restoring degraded soils. Several of the wild and underutilized species grow primarily in the centre of origin. Overall, many of these are considered as wild harvest/minor crops in terms of their production and market value though these assume high priority/importance to feed the rural poor.

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Food and Agriculture Organization (FAO, 2004, 2009, 2010) in its state of food insecurity in the world reports estimated that around one billion people use wild plants in their diet. These plants constitute an essential component in diet bringing household food security of many ethnic communities.

The Asia-Pacific Region (APR), consisting of 39 countries, is agriculturally diverse and very rich in plant genetic resources, including those of wild edible species. Several useful plants have been domesticated in the region and are considered important from economic development and food security point of view. Being culturally, ethnically and ecologically very diverse, several wild edible plants available in the forest areas are used by the natives of this region for generations and still rely directly on this diversity of plants, for food and medicine. Four diversity rich areas namely, Chinese-Japanese, Indochinese-Indonesian, Australian-Pacific and Indian region located in this region and hold this diversity. Wild edible species genetic resources located in tropics, sub-tropics, Mediterranean and temperate regions of the world are making an increasingly important contribution to production of food, medicines, and raw materials (Heywood, 1999). The tribal belts are more often considered as the centre of diversity and origin of many of these plants (Maheshwari *et al.*, 1986; Patale *et al.,* 2015). Due to the advent of modern civilization, the life style and culture of the aboriginals are gradually changing to the urban pattern. Most of the plants, however, are gathered from the wild; many are depleted and some are endangered, both by over-exploitation and by loss of their habitats. Many useful plants associated with tribal people have already disappeared due to impact of climate change/habitat change. Many more species have attained the category of endangered plant (Ladio and Lozada, 2004; Sthapit *et al.,* 2012). In search of the potential domesticates, a critical screening is essential. Wild species like *Macadamia ternifolia* (macadamia nut tree), *Actinidia chinensis* (kiwi fruit), *Simmondsia chinensis* (jojoba), with other wild useful species are recent domesticates (Pandey and Arora, 2004). Due to rapid decline of traditional knowledge about wild economic plants (WEPs) and increased reliance on processed food, documentation and evaluation of the traditional knowledge related to the diversity, usage, and status of WEPs is greatly required, and emphasis has been increasing during the last two decades. Some studies on ethno-medicinal plants have been conducted. Research and development activities to tap these assets for economic development and sustainability have also remained at the bottom. The rich diversity of WEPs is extremely useful in screening of newer germplasm source for the present and for posterity.

Studies have been focused on surveying WEPs genetic resources, their nutritional values, chemical compounds, use and knowledge. Local people have knowledge on how to gather and use them as food items (Dhir, 2015). It has been observed that these days greater attention is being played on WEPs diversity in managing risk, building resilience and supporting household subsistence (Mahapatra *et al.*, 2012). Over 7,000 species of WEPs have so far been documented worldwide (Grivetti and Ogle. 2000). About 1,000 species were reported from Americas, 1,200 from Africa; 400 from Kenya; 700 from Tanzania; 150 from Eastern Madagascar; 110 from Swaziland; 349 from Nepal; 300 from Cameroon; 105 from Uganda; 123 from southern Yunnan in China; while 3,000 tropical fruits worldwide were reported as unexploited/underexploited (Jin *et al.*, 1999; Goode, 1998; Mugnozza, 1996; Styger *et al.*, 1999; Maduka, 2004; Pauline *et al.*, 2004; Rathore, 2009; Acharya and Acharya, 2010; Marwat *et al.*, 2011; Paull and Duarte, 2011; Sthapit *et al.*, 2012; Lapeña *et al.*, 2014, Dangol *et al.*, 2017). Very rich diversity of wild edible fruit species have been reported from Nigerian lowland rainforest (Etukudo, 2000; Adekunle and Oyerinde, 2004). Similarly, in Ethiopia, richness of WEP species is enormous (Redzic, 2006) and over 180 edible fruit species were reported to be consumed in Ethiopia (Demel and Abeje, 2004; Addis *et al.*, 2013; Getachew *et al.*, 2013). In India, it is estimated that about 3,900 WEPs are used by tribal as food; 800 are new claims and at least 250 are worthy of consideration for development as alternative sources of nutritive food which can be used as new crop in future (Singh and Arora, 1978; Umesh Chandra *et al.*, 1994; Anonymous, 1995; Samant *et al.*, 2001; Angami *et al.*, 2006; Hebbar *et al.*, 2010; Mahapatra *et al.*, 2012; Ekka and Ekka, 2016; Niveditha, 2017).

Wild species used by mankind occur in all bio-geographical regions and habitat types. In each region communities have learned to make use of the plant diversity, no matter how harsh the environment (Styger *et al.*, 1999). The global indigenous tribal population of approximately 300 million people belongs to about 5,000 distinct indigenous cultures worldwide, living in various climates from the Arctic Circle to the tropical rain forests. Indigenous peoples, as per World Bank policy brief, have been observed as 'still among the poorest of the poor' (Vicente and Patrinos, 2011). Although they contribute only 5 per cent of the world's population, and account for 15 per cent of the world's poor. Of the estimated 370 million indigenous peoples in some 75 countries across the world, an estimated 70-80 per cent is concentrated in Asia and the Pacific region alone (Ahmed *et al.*, 2007) because this region represents diverse biodiversity-rich habitats and rich ethnic and cultural diversity (Vishnu Mittre, 1981). Besides, unique and rich wild flora, it is also rich in wild economic plants wealth including useful/edible species, most of them belongs to underutilized category. These natives are still dependent on indigenous wild, semi-domesticated and domesticated diversity largely of edible less-known, underutilized and other economic plants for their daily needs of food, feed, and shelter and health care. The number of species within the mega-biodiversity countries of the Asia-Pacific region has been analysed and estimated in document by Arora (2014).

In India, broadly the tribal communities are located in three distinct zones: i) North and North-eastern zones in the mountain valleys and eastern frontiers of India; ii) central zones of older hills of plateau; along the dividing line between the peninsular India and the Indo-Gangetic plains; and (iii) Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. Interestingly, the tribal dominated tracts of India are still the storehouse of such material, information and indigenous knowledge to unfold the multiple uses of the plants. Thus, native plant genetic wealth, by and large, preserved by different ethnic tribes who still live in isolation, are culturally distinct from the urban communities and the local inhabitants. The selections for useful species are made from the plants that grow in their natural vegetation zones/floristic areas/ natural habitats as wild types. Both unconscious and conscious selections are evident in the evolution of desired types (Arora, 1981; 1998). The choice and spread of locally economic types of known potential value and the plant part used may vary with different tribals (Pandey and Chandra, 1993). Besides using potential material from wild, the tribals hold such species/resources as the protected types in their backyards, kitchen gardens and marginal lands. These are morphologically alike their wild types having more towards wild types with several promising attributes. The prolonged use of wild plants has played an important role in socio-economy of mankind to the extent that some of them have become a part of their rituals and ceremonies (Vishnu Mittre, 1981). Among the edible types, the semi-domesticated/domesticated diversity is represented by over 150 species (Arora and Pandey, 1996) and over 500 important potential species still awaiting domestication (Arora and Pandey, 1996; Pandey and Arora, 2004). The Indian sub-continent harbors a wide spectrum of life forms, with rich cultural and ethnic diversity. There are about 53 million tribal people belonging to over 550 tribal communities of 227 ethnic groups spread over 5,000 forest villages and have distinct social and cultural identity. Their life style may differ from forest hunting, primitive hill cultivation (shifting, artisan, pastoral and cattle breeder and urban industry worker types. They occupy about 18.7 per cent of total area of the country and are spread mainly in the states of Madhya Pradesh, Odisha, Bihar, Gujarat and Rajasthan. High ethnic diversity prevails in distinct pockets of North-eastern region, part of western Himalayas, central India and the western and the eastern peninsular tracts and in the island regions of the country. Considering the importance of WEPs to household food security, it is essential that the social-ecological system should be appropriately protected, managed, and valued to check their over-exploitation. At global level, fragmented information is available on WEPs and their local use in North-western Argentina (Ladio and Lozada, 2004a); Guatemala (Nerea Turreira-Garcia 2015); Pakistan (Shaheen *et al.*, 2017); Spain (Guillermo *et al.,* 2017), etc. but their documentation was ignored earlier by extension workers, policy-makers and economists, hence gathering systematic knowledge on these received little recognition by the developed communities (Scoones *et al.*, 1992). The reasons for this neglect was attributed to:

- lack of information about the extent of their use and importance in rural economies (economic value);
- lack of reliable methods for measuring their contribution to farm households and the rural economy and world market for products;
- irregularity of supply of wild plant products;
- lack of quality standards;
- lack of storage and processing technology for many of the products;
- meager attention by national agricultural and biodiversity conservation policies/programmes on research and development

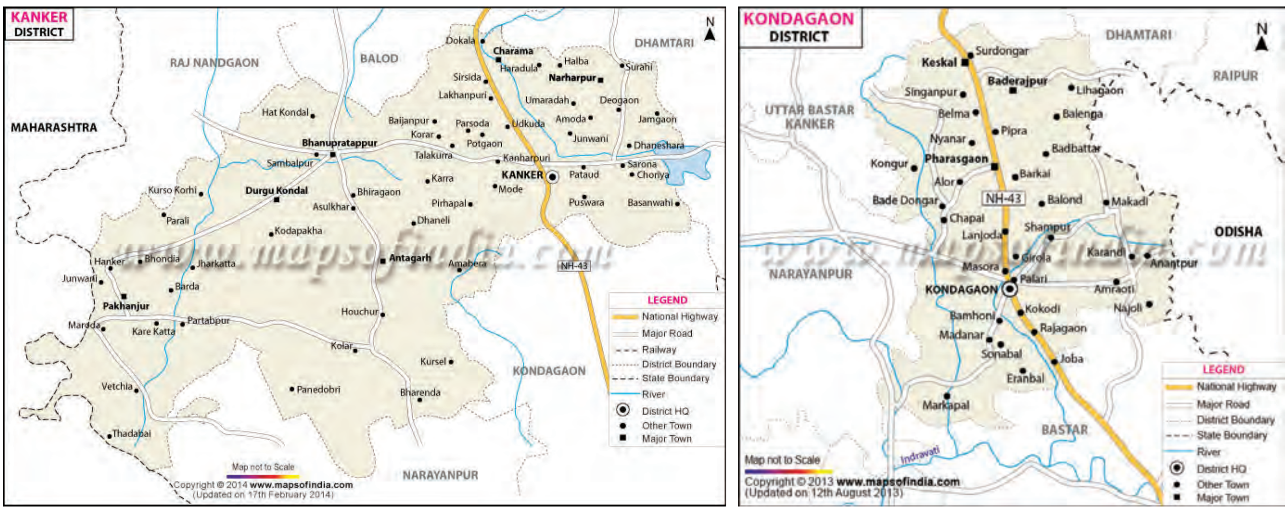
Wild Edible Plants: A Case Study of Bastar Region of Chhattisgarh

Amongst the several diversity rich regions/ agri-diversity hot-spots, tribal rich regions of India, Bastar region in Chhattisgarh is one which deserves special attention where involvement of the authors in undertaking exploration expeditions (10), carrying out the ethnobotanical studies and collection and conservation of WEPs especially in vegetables, fruits, less known economic species could enrich genetic resource wealth. The authors have contributed a great deal in the areas in past two decades. The information given below is only some glimpses on significant points that have been summarized. Keeping the importance of these reasons in study area, a need was felt to:

- inventorise wild edible plants;
- determine the aspects of preservation, marketability and conservation;
- systematic documentation of indigenous knowledge regarding the identity and use of wild foods by rural communities;
- evaluation of nutritional components of priority species;
- integration into the agricultural system and sustainable conservation and management; and
- assess threats on the wild edible plant species and recommend the possible management scenarios for their conservation.

The Bastar region was traditionally known from ancient times for its rich floristic diversity and find mention as the Dandakaranya in the epic Ramayana, and as part of the Kosala kingdom in the Mahabharata (Singh, 2013). In the state of Chhattisgarh, this region is located between 17°46′ and 20° 34′ N latitude, and 80°15′ and 82°15′ E longitude with a range of altitude between 250-1,200 m above sea level with the highest Bailadilla hill range (1,276 m) and comprises part of the eastern plateau, mainly southern part of Chhattisgarh state (Fig. 1). Despite being influenced by various neighboring and national cultures, the region has maintained its unique identity. The region also has been declared a National Agricultural Biodiversity Heritage Site (Singh and Varaprasad, 2008). Historically, Bastar was a vast kingdom, before formation of Chhattisgarh. Current seven districts of Bastar (the then undivided Bastar) happens to be the largest tribal belt spread over an area of 39,171 km^2 of the state of Chhattisgarh. Before creation of Chhattisgarh state in the year 1999, it was even larger than the area of whole of Kerala state and some other countries like Belgium, Israel etc. with a scant population, rich with all kinds of natural resources, and some of the most dignified human cultures.

Presently, the region includes seven southern-most districts namely, Bastar, Kanker, Dantewada, Bijapur, Sukma, Kondagaon, and Narayanpur and is bounded by Koraput district (Odisha) in the east, Gadchiroli district (Maharashtra) in the west, Nirmal, Nizamabad district (Andhra Pradesh) in the South, and the Durg and Dhamtari districts of Chhattisgarh in the North. Topographically, this region is predominantly the land of hills, green jungles, waterfalls and a tribal community that has managed to maintain its distinct identity and traditions. The Bastar region is a hot sub-humid eco-region with



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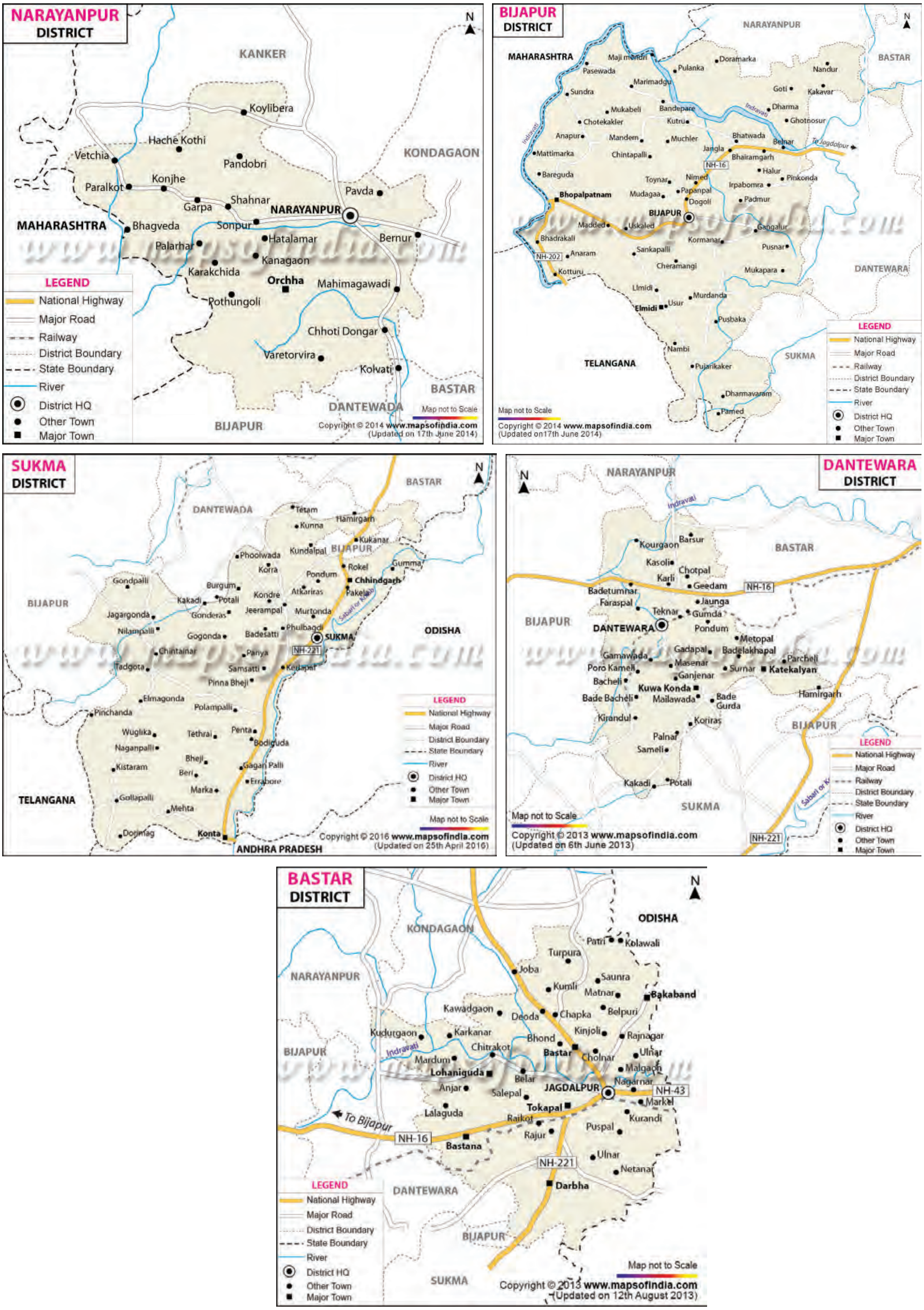

Fig. 1. *Districts of Undivided Bastar (Kanker, Kondagaon, Narayanpur, Bastar, Bijapur, Dantewada, Sukma)*

reddish, calcareous, and neutral to slightly acidic soils. The climate of the area is characterized by hot summers and cool winters which receive an annual rainfall of 1,200 to 1,600 mm, of which 70-80 per cent is received between July and September. Summers are relatively cooler in comparison to adjoining plains and temperature fluctuates from about 3°C to 47°C. The tribal people of the region still lead a very primitive/nomadic life and rely most on the forest based resources.

Very little is written about the wild edibles of Bastar region. Grigson (1949) who wrote an ethnobotanical account of *Marias* of Bastar, has mentioned only a few well known WEPs. Elwin (1947) has mentioned about a dozen native species consumed by the *Muria* community and Roy and Rao (1957) about their dietary habits. Further, the local people/tribals have identified a large number of alternative sources of food and medicine (around 1,200 plant species), many of which are being used in their regular diet also during food scarcity (Jain, 1963, 1964; Nanda and Shaw, 2008; Banik, 2012; Banik *et al.,* 2014; Chakravarty *et al.,* 2016; Ekka and Ekka, 2016). Within the forests, the special habitats occur like undulating and rocky slopes, dry plateau, riverine and bamboo brake but due to the destruction of the natural habitats in the last two decades, the scenario has changed considerably and many potential/valuable economically important species disappeared.

Globally, Bastar region is known for its rich biodiversity and natural resources. The forests are dense like the Amazon forest, which covers about 851,867 ha of area and serve as the source of various important wild useful plants. The region has been placed in the Deccan biogeographical area and the forests have been categorized under three major types: Tropical semi-evergreen, Tropical moist deciduous and Tropical dry deciduous forests. These forests are mainly dominated by several useful tree species like *Terminalia alata*, *Shorea robusta*, *Stereospermum chelonoides*, *Dalbergia paniculata, Butea monospema, Tectona grandis*, *Pterocarpus marsupium*, *Terminalia bellirica*, *T. chebula*, *Haldina cordifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Butea monosperma*, *Cassia fistula*, *Diospyros melanoxylon*, *D. chloroxylon, Soymida febrifuga, Terminalia arjuna, Bauhinia retusa, Tamarindus indica, Sterculia urens*, *Careya arborea*, *Pongamia pinnata*, *Albizzia lebbeck, Azadirachta indica.* Shrubs and herbs include *Buchanania lanzan*, *Achyranthes aspera*, *Rauvolfia serpentina*, *Vitex negundo, Cucurma angustifolia*, *Asaparagus racemosus*, *Andrographis paniculata*, *Justicia adhatoda, Evolvulus alsinoides, Acorus calamus* and *Woodfordia fruticosa* including a large number of wild economic species. Other notable wood species constituting a significant chunk of the middle canopy of the forests are *Pterocarpus marsupium*, *Terminalia tomentosa, Anogeissus latifolia, Madhuca longifolia* var. *latifolia*, *Emblica officinalis*, *Cleistanthus collinus* and *Dendrocalamus strictus* (Umesh Chandra, 1991; Jha and Khanna, 2005; Khanna *et al.*, 2005). Sal (*Shorea robusta*) and teak (*Tectona grandis*) are the two major tree species found all over the region.

Bastar is considered a 'Hot-Spot' for most of the tropical and sub-tropical useful plants, especially in the Abhujhmarh hills, Kanger Ghati, Antagarh-Pakhanjore, Binta and Mardoom forests, Bailadilla forest, Barsur forest, Bhairamgarh, Pamed, Dantewara, Bhopalpatanam, Machkot forest, Darbha forest, Sukma, Kondagoan, Keshkal-Kanker forests which are the places of maximum number of wild edible plants. The whole of undivided Bastar is dealt here in 10 segments to describe the topography and region-wise availability of wild edible plants as below:

Keshkal-Kanker-Pharasgaon Area: Pharasgaon, on way to Keshkal and Kanker forest areas, Narharpur, Charama and river banks etc. are dominated by most of the climbers like *Dioscorea* spp., wild and cultivated *arvi* (*Colocasia* sp.), *jangli suran* (*Amorphophallus companulatus*), *semal kand* (*Martynia annua*), *peepri mool* (*Piper longum*) etc. Lemon grass (*Cymbopogon citratus*), Palmarosa (*Cymbopogon martini*), *Char/chironji* (*Buchanaia lanzan*) are also in abundance in this area.

Bhanupratappur-Antagarh-Pakhanjore Areas: Antagarh forest, Koeilibeda and Bande forest. It has a typical flora comprising of *sal* trees *(Shorea robusta)*, *dhawra (Anogeissus latifolia), arjun* (*Terminalia arjuna*), teak (*Tectona grandis*), bamboo etc. The topography of this northern region is more plains than the hills. Hence, the location is rich *inbhui-nimb (Andrographis paniculata), gorakhmundi (Sphaeranthus indicus), bhaskatiya (Solanum surattense), satyanasi (Argemone mexicana), indrayan (Citrullus colocynthis*), *dudhi (Euphorbia hirta), nagbel (Aristolochia indica), dokarbela (Vitex* sp.), *Mucuna purita* and some tubers like *Dioscorea* sp., *jangli haldi (Curcuma amada), jangli bhindi (Abelmoschus ficulneus), keu kand* (*Costus speciosus*)*, jangli suran* (*Amorphophallus* sp.), *jangli arvi* (*Colocasia* sp.) etc. This area can be considered as *in situ* diversity centre for *Colocasia and*

Zingiber spp. *Chlorophytum* spp. are rare in this area, only *C. tuberosum* is found in some pockets. The typical species of *Dioscorea* like *sikka kanda* (*D. rotundata*), *dori kand* (*D. sinensis*), *surenda* (*D. pentaphylla*) and *baichandi* (*D. hispida*) are well represented in the area.

Abujhmarh-Narayanpur-Dhaudai-Gudadi Areas: This inaccessible tribal belt is situated in the central-western extending towards South-western adjoining Telangana state and boundaries of Maharashtra state. Abujhmarh hills, hillocks of Bastar and parts of Geedam/Dantewada are the most protected and prohibited parts because the specific tribal race *Abujhmaria*, are native of this region. Their main food source are roots, tubers, minor forest produces and hunting wild animals, thus forest based economy prevails. Due to protection act operative in this area, many endangered/rare species of tubers and medicinal plants are still available. Tribals of this region are solely dependent on these species for their health and nourishment. Surveying or entering into this region requires special permission by the District Collector. However, traders are strictly prohibited. Based on several intensive surveys/explorations undertaken by ICAR-NBPGR from 1989-2008, the general biodiversity of medicinal and tuber species could be gathered (Table 1). Medicinal species are abundantly available in the region, such as *Acorus calamus*, *Andrographis paniculata, Chlorophytum tuberosum, C. arundinaceum, C. borivillianum, Citrullus colocynthes, Costus speciosus, Curcuma angustifolia, Curcuma* spp., *Disoscorea alata, D. bulbifera, D. dumetorum, D. pentaphylla, D. trifoliata, D. esculenta, D. hispida, Gloriosa superba, Hemidesmus indicus, Plumbago zeylanica*, *Ricinus communis, Smilax macrophylla* and *Urginea indica.*

Table 1. Selected wild edible taxa available in different habitats of Bastar region

Botanical name	Local name	Parts used	Season of availability	Availability area(s)
Amaranthus paniculatus	*Jangali choulai*	Leaves	July-Aug.	Forest and fallow lands
A. viridis	*Purpuri bhaji*	Leaves and seeds	Rainy-winter	Kitchen garden and fallow land
Amorphophallus campanulatus	*Suran*	Corm	Oct-Nov	Kitchen garden and forest
Annona squamosa	*Sharifa*	Fruits	Oct.-Nov.	Community forest/Kitchen garden
Actinoscirpus grossus	*Keshur kand*	Tuber	Oct.-Nov.	
Bambusa arundinacea	*Kareele*	Young shoot	June-July	Conserved in kitchen gardening
Bauhinia variegata, B. purpurea	*Koliari bhajee*	Young leaves, flower buds, young pods	March	Conserved as living fence and naturally grown in forest
Caryota urens	*Salphi*	Pulp of plant	April-June	Kitchen garden
Cassia fistula	*Amaltas*	Fruits	April-May	Community forest
Cassia tora	*Chench bhajee*	Leaves	July-Aug.	Kitchen garden and forest
Celosia argentea	*Siliari bhajee*	Leaves	July-Aug.	Forest and fallow lands
Coccina grandis	*Kundru*	Fruits	Rainy- winter	Field border
Cordia myxa	*Bohar bhaji*	Young fruits/leaves	April-May	Kitchen garden
Costus speciosus	*Keukand*	Tuber	Dec.-March	Kitchen garden
Cucumis callosus	*Kacharia*	Fruits	Sept.-Oct.	Fallow land
Curcuma angustifolia	*Teekhur*	Tuber	Dec.-March	Kitchen garden
Dioscorea bellophylla	*Nagarkanda*	Tuber	Dec.-March	Kitchen garden
Emblica officinalis	*Amla*	Fruits	Feb.-March	Community forest
Ficus racemosa	*Gular*	Fruits	March-April	Surrounding of villages
F. religiosa	*Pipal*	Fruits	April-June	Surrounding of villages
Madhuca longifolia var. *latifolia*	*Mahua*	Flowers, fruits	March- April	Community forest
Moringa oleifera	*Munga*	Leaves and fruits	March	Kitchen garden and forest fringes
Solanum virginianum	*Bhejri*	Leaves and fruits	October	Forest fringes
Tamarandus indica	*Imli*	Fruits	April-June	Community forest

Jagdalpur-Kondagaon Areas: The surveyed areas of this part of Bastar include Bhanpuri, Baniyagaon, Benoor and some other small interior forest villages on way to Kondagoan. The medicinal species available are *Asparagus* sp., *Amorphophallus* sp. and *Cucurligo orchiodes*. The typical strain of *safed musli* (*Chlorophytum borivillianum*) having leaves which are dark green on upper surface and pinkish blue on lower surface, is observed in interior forests near Baniyagoan which is never seen in any place of Chhattisgarh. The taste of tuber is very sweet and sticky but thin and medium in length. The typical strain of reddish brown *Mucuna pruriens* var. *pruriens*is is also recorded in this region. The other herb, shrub and tree medicinal plants are similar to other areas, but in less to moderate in occurrence.

Kanger Ghati-Teerathgarh-Kotumsar: The areas of Kanger Ghati include Teerathgarh forest, Kotumsar, Kailasgupha, Darbha forest, Koling, Majhpal and adjoining forest areas. It has a typical flora comprising *sal* trees, *tendu*, *dhawra*, *arjun*, teak, bija, bamboos and various ferns etc. Hence the zone is rich in medicinal climbers and tubers like *Dioscorea* spp., *nagbel* (*Aristolochia indica*), *dokarbela* (*Vitex* sp.), *datte lata* (*Ampelocissus indica*) and also *brahmi* or *mandukparni* (*Centella asiatica*) etc. The other medicinal species abundantly occurring are *ama haldi* (*Curcuma amada*), *jangali adark* (*Zingiber* sp.), *jangli bhindi* (*Abelmoschus ficulneus*), *keu kand* (*Costus speciosus*), *teekhur* (*Curcuma angustifolia*), *indrayan* (*Citrullus colocynthis*), *jangli suran* (*Amorphophallus* sp.), *Colocasia* sp., *bada gunj* (*Abrus precatorius*) and *kewanch* (*Mucuna pruriens* var. *pruriens*) etc. Hence this area can be considered as diversity hot-spot for *Dioscorea, Amorphophallus, Colocassia, Curcuma* and *Zingiber* spp., suitable for *in situ* conservation programme. However, *Chlorophytum* species are rare in this area, and only *C. tuberosum* is occurs abundantly. The typical species of *Dioscorea* (*D. rotundata*, *D. sinensis*, *D. pentaphylla*, *D. ovata*) D. *hispida*) are observed in abundance. Wild germplasm of *Dioscorea*, *Colocasia*, *Amorphophallus* and *Centella asiatica* are important species in this area hence, may be conserved in this location.

Chitrakot-Mardoom-Binta Areas: This includes areas of Chitradhara, Karanji, Lohandiguda, Chitrakot forest area, Mardoom and surrounding forests, Binta and Bhejji forests etc. These areas are dominated by climbers like *Dioscorea alata, D. bulbifera, D. dumetorum, D. pentaphylla, D. trifoliata, D. esculenta, D. hispida*, and herbs and shrubs, *viz.*, *bhui-nimb,* wild brinjal (*Solanum* sp.), *Vaibidang* (*Embelia ribes*), *peng beej* (*Celastrus paniculatus*), *Asparagus* sp., wild *arvi* (*Colocasia* sp.), wild *suran* (*Amorphophallus companulatus* and *A. poinifolious*), *anantmool*, *buchh*, *jangli arand*, *semal kand*, *baghnakkha* (*Martynia annua*) etc. are noted in abundance. Among location specific species *peng beej* (*Celastrus paniculatus*), white and red *gunj* (*Abrus precatorius*), asparagus having extra white tubers, wild *bael* (*Aegle marmelos*), *bada surenda* and edible sweet *arvi* (*Colocasia esculenta)* are also noted in this region. Wild *Aegle*, *Dioscorea Solanum* spp. *Andrographis paniculata, Celastrus paniculatus* etc. are noted specific to this location and hence, can be conserved in this area.

Dantewada and Bailadila Hills Areas: This area includes the forests and villages of Dantewada, Bailadila hillocks, Balood, Kawalnar forest. The flora is rich in medicinal herbs, especially tubers. The typical abundant tuber species are *Costus speciosus*, *Dioscorea esculenta*, *D. alata*, wild and edible *kewanch* (*Mucuna pruriens* var. *pruriens* and var. *utilis*), *kali haldi* (*Curcuma caesia*), black fruited Benjamin fig (*Ficus benjamina*), *pipramool* (*Piper longum*), *giloi* (*Tinospora cordifolia*), *teekhur* (*Curcuma angustifolia*), *safed musli* (*Chlorophytum arundinaceum*), *aonla*, *baila adrak* (*Alpinia galanga*), *patal kumhra* (*Pueraria tuberosa*) and *bhui-nimb* (*Andrographis paniculata*). Beside these, some herbal plants like *anantamool* (*Hemidesmus indicus*), *gorakhmundi* (*Spilanthus indicus*), *bhui aonla* (*Phyllanthus niruri*) and *badi duddhi* (*Euphorbia hirta*) are also observed in abundance. Hence, efforts should be concentrated for their *in situ* conservation in this area.

Barsur-Bijapur-Bhopalpatnam-Usoor-Pujarikanker Areas: This region includes the most typical forests like Barsur hillocks, Tular cave and surrounding forests areas, Pamed Sanctuary, Bhopalpatnam Forest and river banks of Indrawati River, Mahanadi river, Tarlaguda, Bhadra Kali, Usoor and Pujarikanker etc. having dense forest dominating by *sal*, *tendu*, *beeja*, *siyari*, bamboo etc. The medicinal species abundantly observed in this area are *kalihari* (*Gloriosa superba*), various *Dioscorea* spp., viz., *dori kanda* (*D. sinensis*), *kuliha kanda* (*Dioscorea hispida*), *sikka kanda* (*D. rotundata*), *jangli suran* (*Amorphophallus* sp.), *safed musli* (*Chlorophytum borivillianum, C. arundinaceum*), *bhilawa* (*Semecarpus anacardium),* *ram datun* (*Smilax macrophylla*), *ratanjot* (*Jatropha curcas*), *dokar bella* (*Vitex* sp.), wood apple, *Asparagus* sp., *mainhar, tikhur (Curcuma angustifolia), jangli adrak*, *jangli haldi*, *kali musli* (*Curculigo orchioides*), white *gunj* (*Abrus precatorius*), *marodphali* (*Helicterus isora*), *gulu* tree (*Sterculia* urens) etc. Beside these, various orchids, *brahmi* (*Bacopa monnieri*), ferns and mosses are also available in riverbanks and most forests of Bastanar surroundings. Marodphali (*Helicterus isora*) and *Dioscorea* species are elite germplasm of this location.

Niyanar-Machkot-Gupteswar-Tiriya Areas: The areas include Kurandi forest, Nangur, Gupteswar forest, Tiriya forest. River valley possesses *sal* (*Shorea robusta*), *tendu* (*Diospyros melanoxylon*), *palas* (*Butea monospema*) and some other trees. The important diversity noted in this area are *jangli suran* (*Amorphophallus* sp), *pipramool* (*Piper longum*), *Chlorophytum tuberosum, C. arundinaceum*, *Dioscorea* spp., *lal gunj* (*Abrus precatorius*) etc. However, occurrence of *Rauvolfia serpentina, Plumbago zylenica, Jatropha curcas, Colocasia* sp. and other herbs of shade loving nature are also noted. *Rauvolfia serpentina* and *Amorphophallus campanulatus* have sturdy and excellent plant type in this region. *Piper longum*, *sarpgandha*, *jangli suran*, *kalihari* was abundantly observed in Gupteshwar and river valleys of this place hence, they may be conserved under *in situ* in these pockets.

Sukma-Konta Region: This region includes forest and forest villages of Sukma, Chhindgarh, Gadiras and forests on way to Konta have been intensively surveyed for plant diversity. The typical features of this area are dry and hot climate forests rich with *tendu*, *sal*, *palas*, *arjun* and *sagaun* trees in abundance. Among medicinal flora, *Pueraria tuberosa*, *Dioscorea* spp., *Tinospora cordifolia*, *Chlorophytum* sp., *kewanch* yellow and red fruit type (*Macuna pruriens* var. *pruriens*) and white and red *gunj* (*Abrus precatorius*), bhui-nimb (*Andrographis paniculata*), *Asparagus* sp., *nagbel*, *nagbala* etc. are in abundance. Most of the edible and wild legumes are in abundance in this location. *Tinospora cordifolia, Pueraria tuberosa, Gloriosa superba* and *Abrus precatorius* may be conserved under *in situ* considering suitability of climate for these.

Tribes of Bastar

Indigenous tribal communities have wisdom, knowledge and traditional know-how through words of mouth for a long time and, thus they play a vital role in environmental management and development. The Bastar region has been regarded as one of the regions that is predominantly (70-98%) inhabited by tribal communities which represents about 26.76 per cent of the total tribal population of Chhattishgarh. About 98 per cent population reside in villages and grow crops under rainfed conditions. *Gond, Bhunjia, Baiga, Abhujhmarhia, Maria, Dandami Maria, Bison Horn Maria, Parghi, Muria, Halba, Bhatra, Parja, Dhurvaa, Dorla, Dhanwar, Kol, Korwa, Rajgond, Bhaiyana, Binjwar* and *Munda* are the major tribes of this region. Among these, *Gonds* constitute the largest population, known for their unique *Ghotul* system of wedding. Abujhmarh hill, hillocks of Bastar and parts of Dantewara is the most protected and prohibited parts inhabited mostly by the specific tribal race *Abujhmarhia,* native of this region. Their main food sources are roots, tubers, minor forest produces and hunting wild animals. They lead semi-nomadic life, practicing shifting cultivation (Roy, 1989; Umesh Chandra, 1991). These people are living close to the nature since many years, acquired unique knowledge about the use of the living biological resources. Most of the tribes prefer living in isolation with their own way of life, customs, traditions, moral values, religious rites, taboos, legends and myths, have different food habits, speak different dialect, but are able to retain their unique practices and traditional way of life even today. To speak about the tribal culture in Chhattisgarh, each tribe possesses its own rich history and culture. Their various forms of dance, music, dress and food are different from each other. The tribal knowledge system on plants and animals exists through words of mouth but today only a fraction is available to science. India has over 54 million tribal populations which constitute about 7.5 per cent of the total population.

Status and Utilization Pattern of Wild Edible Plants Diversity

Use of wild plants as a food source is an integral part of culture of tribal people. These plants not only provide food but also make significant contribution in fulfillment of nutritional requirement (Grivetti and

Ogle Britta, 2000; Ogle Britta *et al.*, 2001; 2003). Various tribal communities in India are repositories of rich knowledge on various uses of plant genetic resources (Khoshoo, 199). The tribal communities of this area are heavily dependent on rich floristic diversity available in forests for their livelihood and other material culture. Some of the forest produce is consumed directly, like some edible fruits (*Borassus flabellifer, Diospyros melanoxylon*, *Dillenia pentagyna, Gardenia* spp.*, Syzigium cumini, etc.*), some tubers (*Dioscorea* spp.) and tender shoots (bamboo), which make over 10 per cent of their diet. Some 88 wild edible plants used by the tribals of the region were reported by Jain (1964), categorized under vegetables, fruits, nuts, beverages, food grains, oilseeds, spices and condiments. Out of 1,200 useful plant species recognized, 180 are minor edible and wild tubers (Nanda and Shaw, 2008). Banik (2012) reported 107 wild edible plants which include 25 root/tubers, 33 leafy types, 3 nuts, 7 stems, 9 flowers from this region. Wild edible tubers including *Dioscorea* species is predominantly available in entire Bastar region besides many wild edible tubers (Jain 1964; Banik *et al.,* 2014). Yams (*Dioscorea* sp.) are used as contraceptive medicines, and birth rate of Bastar tribals inhabiting in the dense forests is automatically controlled since *Dioscorea* tubers are included in their daily diet. Women folk are the backbone of Bastar region (Malik *et al.*, 2001; Chauhan *et al.,* 2014, Heywood, 1999) as 80 per cent of the women population is involved in farm operations, collecting wild edibles from forests besides household activities.

Commodity-wise Uses of Plants in Bastar

Fruits: Depending upon the nature of different species, the inhabitants consume wild edible in the form of fruits, leaves, young shoots, flowers or flower buds, seeds or grains, nuts as well as whole plant, gathered from wild, semi-domesticated/domesticated and kitchen/community gardens (see Table 1). Some of the wild fruits commonly found in the forest of Bastar are *Aegle marmelos, Annona* spp., *Anthocephalus indicus, Antidesma acidum, Borassus flabellifer, Bridellia montana, Buchanania lanzan, Carissa carandas, Diospyros melanoxylon, Ficus* spp.*, Flacourtia indica, Gardenia* spp., *Grewia* spp.*, Leea macrophylla, Manilkara hexandra, Phoenix humilis, Schleichera oleosa, Spondias pinnata, Syzigium cumini, Ziziphus* spp. etc. During lean period (March-April), fruits of *Madhuca longifolia* var. *latifolia*, *Ziziphus jujuba*, *Ficus glomerata*, *F. religiosa*, *Emblica officinalis*, *Tamarindus indica* and *Syzygium cumini* are consumed. These indigenous fruits are either used directly or in semi-processed/cooked forms and are good source of income for the tribal women (Ramphele, 2004). The dried pulp of matured pod of *Cassia fistula* is crushed and mixed with jaggery solution and used as summer drink. Similarly, juice of *Madhuca longifolia* var. *latifolia* flowers is used for making varieties of local food items like *thukwa, laddu, lata* and *puri*, which are considered rich in nutrition and consumed during lean period.

Vegetables: The wild vegetables consumed in the form of leaves, young shoots, fruits, flowers /flower buds, etc. in different seasons and year round are *Adhatoda zeylanica, Amaranthus* spp.*, Antidesma acidum*, *Bauhinia purpurea*, *Begonia picta*, *Boerhaavia diffusa*, *Crotalaria benghalensis*, *Cassia tora*, *Celosia argentea*, *Centella asiatica*, *Chenopodium album, Chlorophytum borivilianum, Coccinia grandis, Commelina attenuata, Corchorus* spp., *Cordia myxa, Dendrocalamus strictus*, *Emilia sonchifolia, Euphorbia* spp.*, Ficus religiosa, Hibiscus subdariffa, Hymenodictyon excelsum, Ipomoea aquatica, Leucus aspera, Merremia umbellata, Polygonum* spp. and *Solanum nigrum.* Leaves and young shoots are available in plenty to consume as vegetable during rains. Some of the most preferred seasonal vegetables in the region include bamboo shoots (*kareel*, *Bambusa arundinacia*) which are cooked with a variety of spices and sometimes also mixed with local varieties of fishes to make tasty and flavoured dish. During local festival *Bhaji Jugani* in the mid rainy season, the leaves of *charoti bhajee* or *charota* (*Cassia tora*) and *dongri bhajee* (*Chlorophytum tuberosum*) are cooked as vegetable and consumed by all, which is useful to cure diarrhoea and dysentery also. Sometimes, tender green leaves of *chench bhajee* (*Corchorus capsularis*) and *koliyari bhajee* (*Bauhinia variegata, B. purpurea*) and fruits of *kachari* (*Cucumis callosus*) are dried in shade and preserved with common salt in the basket and used during rainy season. More than 90 per cent tribals use *charoti bhajee* (*Cassia tora*)*, boda kand* (*Dioscorea* sp.) and *munga/sahijan* (*Moringa oleifera*) as vegetables in their traditional foods items. In most of the cultural occasions, local liquor (*Landa*) and items prepared with *Madhuca longifolia* var. *latifolia* flowers are used and also bartered for buying cloths, oil and spices from local market. Similarly, the leaves and flowers of *Moringa oliefera* are cooked with rice *mand* (the water separated after boiling the rice) and given to anaemic patients.

Seeds/grains: Some of the species are consumed as grain, such as *kasa (Coix lacryma jobi)*. *Kotore* (*Oroxylum indicum*) seeds are pounded into flour and eaten as cereal; seeds of *karat* (*Sterculia urens*) and *banhirwa* (*Cajanus scarabaeoides*) are cooked as vegetable. Roasted seeds of *siali* (*Bauhinia vahlii*) are eaten. Seeds of *kirchi* (*Casearia graveolens*) are used as cooking oil. Seeds of *latzira (Achyranthes aspera*) are cooked as rice or along with rice and consumed in all seasons. Seeds of *hurhur* (*Cleome viscosa*) are used as condiments. Seeds of *bilariputa* (*Ipomoea pestigridis*) are eaten by the tribal children after slight roasting. Seeds of *phaphni* (*Oroxylum indicum*) are pounded into flour and eaten.

Tubers: Roots and tubers/rhizomes are considered as highly preferred food item as these are easily available in the forests of Bastar region (Nanda and Shaw 2008; Banik *et al.*, 2014; Misra and Misra 2014). The commonly available plants consumed as roots and tubers are *Amorphophallus paeoniifolius, Asparagus racemosus, Chlorophytum borivilianum, Costus speciousus, Dioscorea* spp.*, Leea macrophylla*, *Pueraria tuberosea, Takka pinnatifida*, *Urginea indica* etc. A commonly available plant, *Curcuma angustifolia* locally known as *tikhur* has high preference among the tribal communities because its rhizomes are largely used for the preparation of local recipes *viz*., beverage (*sarbat*), porridge (*halwa*) and dense milk based sweet confectionery (*barfi*). Its rhizomes are also eaten as vegetable, chutney and pickle. Though it is commonly grown in wild, but can be cultivated in kitchen gardens as well. Mostly the forest products are either used raw or cooked as vegetables; but species like *Dioscorea hispida, D. spicata* and *D. pentaphylla* require long processing techniques (24-48 h).

Wild Edible Plants as a Source of Income

Local markets (*haat*) are meeting points for socializing, especially for a tribal who lives in area difficult to reach and are away from each other. Each big village has its own *haat,* where villagers come to buy essentials, barter and exchange their produce (collected from forest areas or from their cultivated land) and meet friends and relatives, gossip, and entertain themselves. In such market, the people of the region sell large number of wild edible plants collected from the forest and locally prepared food products like *khatta bhaji* (sour vegetables from leaves of *Oxalis corniculata*), *bohar bhaji* (young leaves and fruits of *Cordia myxa*), *koliyari bhaji* (flowers, young leaves and pods of *Bauhinia purpurea*); fruits like *karmatha* (*Dillenia indica*), *chironji* (*Buchanania lanzan*), *jamun* (*Syzygium cuminii*), *tela* (*Diospyros melanoxyon*), *Takka pinnatifida* (tubers), *chind ka gud* (jaggery made of a fruit of *Phoenix humilis*); edible roots like *keukanda* (*Costus speciosus)*, *Dioscorea* spp.; *teekhur* (starch of rhizome of *Costus speciousus*), *mahua*, bamboo *chutney* and some leafy vegetables, unpolished rice, pulses, etc.

Nutritional Value of Wild Edible Plants

The tribals of the Bastar region have identified a large number of alternative sources of wild edible plants, but almost no systematic attempt has been made to develop information on their comparative utility and anti-nutritional elements to recommend them with confidence as source of food, to enable industry to take up for large-scale production. These aspects need attention from food and nutritional security point of view. Therefore, efforts are needed to undertake extensive education about their importance as a nutritionally balanced food and as a direct and indirect source of income particularly for the resource poor families (Ahmed *et al.*, 2007). Nutritional evaluation of many wild edible plant species collected from tribal/forest areas have so far been carried out in different laboratories to estimate and determine their nutritional constituents and their status at both national and international levels (Maikhuri, 1991; Freiberger *et al*, 1998; Jin *et al.*, 1999; Grivetti and Ogle, 2000; Afolayan and Jimoh, 2009; Saha *et al.*, 2014). Wild edible fruits like *Ficus roxburghii* and *Capparis zeylanica* are rich source of vitamin C (Parmar and Kaushal, 1982; Imran *et al.,* 2010; Deshmukh and Waghmode, 2011). It has been observed that tribals who still live in forest areas and consume traditional food, are found to be healthy and free from most of the diseases. This probably emphasizes sound nutritional status of WEPs, consumed by tribal as regular or supplementary food. Many WEPs in general and wild vegetables in particular are important sources of micronutrients and play important role in nutrition, especially for women. WEPs like *Cassia tora, Celosia argentea, Bauhinia variegata*, *Cordia myxa*, *Amaranthus* spp., *Costus speciosus, Ficus* spp., *Moringa oleifera* which are consumed frequently by the tribes of Bastar needs to be analyzed biochemically, which may help in selection of valuable wild species and can be improved and promoted up to varietal level (Venkatesh 2001; Jain and Tiwari 2012; Mahapatra *et al.*, 2012). Keeping this in view, several analytical studies of wild fruits which are important for commercial and dietary point of view for TSS, sugar, protein, fat, essential amino acids, vitamins, carotenoides, anthocyanin content, etc. have been undertaken in different parts of the world (Srivastava, 2001; Zatylny *et al.*, 2005; Paull and Duarte, 2011).

Future Thrust

Wild/underutilized species offer a great potential to provide better livelihoods. There is need to focus on four main themes:

1) *Climate change*: Potential of wild and less known plant species as risk buffers in times of climate change;
2) *Nutrition*: Wild edible species to improve nutrition and health;
3) *Market access*: Wild edible plant species for diversification of farm income; and
4) *Agro-biodiversity*: Wild edible and underutilized plant species for diversification of agricultural systems.

To increase the contribution of WEPs, further action and collaboration is required as follows:

- Detailed analysis of the nutritional value, contribution to the food security and livelihood
- Evaluation of commercial use and market values including potentials for its domestication and promotion
- Develop human resources for conservation of potential wild plant genetic resources and integrate them as an important unit by the concerned government bodies
- Involve communities and research scientists in conservation and crop improvement, including information gathering, knowledge sharing and dissemination
- Create and manage a database of WEP species, nutritive values, successful and unsuccessful case studies, resilience to climate change and information on genetics
- Create awareness on WEP species contribution to local nutrition, income, ecosystem health and farm productivity
- Implement and document economic and market studies of different aspects of value chains for WEPs, and pilot a number of global marketing initiatives in public-private partnership
- Inventorization of WEP at regional and national level and monitoring of their population in nature; disseminate case studies illustrating successful approaches in sustainable use of such species to improve rural health and economies
- Need based research and development on wild and edible plant species

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Biofortification in Underutilized Staple Crops for Nutrition in Asia and Africa

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ABSTRACT: Malnutrition is one of the biggest public health challenges of the century with about 2 billion people affected by it globally. Biofortification is the process of breeding micronutrients traits into staple food crops, which is bioavailable to make a positive measurable impact to the population that eats such staples on a daily basis. It is a cost-effective, sustainable strategy and complementary in nature to the existing market interventions. Iron pearl millet, iron beans, vitamin A cassava and orange sweet potato can contribute to increase household nutrition in the Asia and Africa. Over the years evidences gathered by partners in crop breeding, nutrition studies and delivery experiences will help to build the foundation for scaling out further to reach millions who need the most.

Key words: Biofortification, Iron beans, Iron pearl millet, Orange sweet potato, Vitamin A cassava

Introduction

Mineral and vitamin deficiencies are a serious public health problem in Asia and Africa. Two billion people in the world suffer from various forms of malnutrition (FAO, 2011). Malnutrition is an underlying cause of death of 2.6 million children each year - a third of child deaths globally (IFAD/FAO/WFP, 2011; Black *et al*., 2008). In general, dietary quality is poor, with high dependence on cereal and root staples for the bulk of dietary energy consumption, particularly among the poor (Food and Agriculture Organization of the United Nations (FAO, 2015). Low incomes and high prices for non-staple foods such as vegetables, fruits, pulses, and animal products are the major constraints to improved dietary quality. Non-staple foods are often dense in vitamin and minerals, and bioavailability is particularly high for animal products, yet animal products are the most expensive source of dietary energy. The poor eat large quantities of food staples to acquire dietary energy. The health consequences of poor dietary quality are well known- high morbidity and infant mortality rates, compromised cognitive development for children, stunting and low economic productivity. Eating habits of the people depends on many factors, including cultural, geographical, environmental, and seasonal factors. One of the key underlying causes leading to poor dietary quality is that current food systems do not provide minerals and vitamins in sufficient quantities at affordable prices for the poor. Poverty is a major factor that limits intake of adequate, nutritious food, which must be available, accessible, and affordable to the poor. Therefore,

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long-term agricultural investments and policies to improve the availability and affordability of more nutritious foods, such as biofortification, must be made an important part of the solution.

Biofortification is the process of breeding nutrients into staple food crops; it is a cost-effective and sustainable agricultural investment that can help to reduce mineral and vitamin deficiencies, especially in the diets of the rural poor. Research in plant breeding and human nutrition, has been largely successful and continues to generate new evidences. One of the critical task is to scale up the supply and demand of biofortified crops and communicate the benefits that are now available to farmers, particularly by impoverished and malnourished rural households, and to embed biofortification as a mainstream approach in the core plant breeding programmes.

Fortification is particularly effective for urban consumers, who purchase foods that have been commercially processed and fortified. It is less suitable for reaching rural consumers who often do not have access to or the incomes to afford commercially produced foods.

Justification for Biofortification

Biofortification provides a comparatively cost-effective, sustainable, and long-term means of delivering vitamins and micronutrients to households that might otherwise not have access to, or that cannot afford to have, a fully balanced diet. No single intervention will solve the problem of micronutrient deficiency, but biofortification complements existing interventions (discussed above) to provide micronutrients to the most vulnerable people in a comparatively inexpensive, cost-effective, and sustainable manner (Bouis, 1999; Nestel *et al*., 2006; Hotz and McClafferty, 2007; Pfeiffer and McClafferty, 2007; Qaim *et al*., 2007; Meenakshi *et al*., 2010).

Biofortification provides a feasible means of reaching malnourished populations who may have limited access to diverse diets, supplements, and commercially fortified foods. The strategy seeks to put the micronutrient-dense trait (such as for zinc, iron or vitamin A) in basic staple food crops that are being grown and consumed by people in developing countries and that have farmers' preferred agronomic traits, such as high yield. In contrast to complementary interventions, such as fortification and supplementation that begin in urban centers, biofortified crops reach consumers in rural areas first, since most rural farming households consume what they grow. As farmers produce and market surplus biofortified staple food crops, the intervention reaches urban areas. There are several advantages of growing biofortified crops:

- Unlike the continual financial outlays required for supplementation and commercial fortification programmes, a one-time investment in plant breeding can yield micronutrient rich planting materials for farmers to grow for years to come.
- Biofortified varieties bred for one country can be evaluated for performance and adaption to other countries, thereby potentially multiplying the benefits of the initial investment. As seed producers incorporate biofortified crops into their product lines, biofortification becomes more sustainable over time, if regulatory mechanisms are in place to maintain standards and related claims.
- While recurrent expenditures are required for monitoring and maintaining these traits in crops, these are low compared to the cost of the initial development of the nutritionally improved crops. Once established, the cost of maintaining biofortified traits represents a small portion of ongoing global investment in crop improvement.

Status on the Crop Development of Biofortified Staple Food Crops under HarvestPlus Programmes

There are two common approaches to biofortification, agronomic and conventional breeding. Early in the conceptual development of the HarvestPlus project, a working group of nutritionists and plant breeders established nutritional breeding targets. Based on food consumption patterns of target populations, HarvestPlus estimated nutrient losses during storage and processing, and nutrient bioavailability (Hotz and McClafferty, 2007). Breeding targets for biofortified crops designed to meet the specific dietary needs and consumption patterns of women and children. Targets were set such that for preschool children (4-6 years old) and for non-pregnant, non-lactating women of reproductive age.

Iron-biofortified beans and iron biofortified pearl millet would provide approximately 60 per cent of the Estimated Average Requirement (EAR) for iron. Provitamin A biofortified cassava and sweet potato would provide at least 50% of provitamin A.

Originally, established using limited data on consumption patterns, as well as nutrient stability and retention in the biofortified crops (Bouis *et al*., 2011), the breeding targets were refined to meet the target EARs as more data became available (Tables 1and 2).

Table 1. Information and assumptions used to set revised target levels for micronutrient contents of biofortified primary staple food crops

		Rice (Polished)	Wheat (Whole)	Pearl Millet (Whole)	Beans (Whole)	Maize (Whole)	Cassava (Fresh-weight)	Sweet Potato (Fresh-weight)
Per Capita Consumption	Adult Women (g/day)	420	260	220	200	290	940	400
	Children 4-6 yr (g/day)	160	70	85	100	170	350	200
Iron	Additional % of EAR to achieve				>30			
	Total % of EAR to achieve				>70			
	EAR, non pregnant, non lactating women (µg/day)				1460			
	EAR, children 4-6 yr (µg/day)				500			
	Micronutrient retention after processing (%)			90	90			
	Bioavailability (%)			7.5	7			
	Baseline micronutrient content (µg/g)			47	50			
	Additional content required (µg/g			+30	+44			
	Final target content (µg/g)			77	94			
Zinc	Additional % of EAR to achieve				>25			
	Total % of EAR to achieve				>60			
	EAR, non pregnant, non lactating women (µg/day)				2960			
	EAR, children 4-6 yr (µg/day)				1390			
	Micronutrient retention after processing (%)	90	95			90		
	Bioavailability (%)	25	15			20		
	Baseline micronutrient content (µg/g)	16	25			25		
	Additional content required (µg/g	+12	+12			+12		
	Final target content (µg/g)	28	37			37		
Provitamin A	Additional % of EAR to achieve				>50			
	Total % of EAR to Achieve				>50			
	EAR, non pregnant, non lactating women (µg/day)				500			
	EAR, children 4-6 yr (µg/day)				275			

		Rice (Polished)	Wheat (Whole)	Pearl Millet (Whole)	Beans (Whole)	Maize (Whole)	Cassava (Fresh-weight)	Sweet Potato (Fresh-weight)
	Micronutrient retention after processing (%)					37	35	35
	Bioavailability ratio (µg to RAE)					6:1	5:1	12:1
	Baseline micronutrient content (µg/g)					0	0	0
	Additional content required (µg/g					+15	+15	+70
	Final target content (µg/g)					15	15	70
EAR-estimated average requirement; RAE- retinol activity equivalent								

Table 2. Information and assumptions used to calculate the contribution of biofortified secondary staple food crops to estimated average requirements (EAR) for iron, zinc and provitamin A

	Consumption Levels (g/day)	Lentil (decorticated grain*)		Cowpea (whole, DW)	Sorghum (decorticated grain*)		Irish Potato (FW)**		Banana and Plantain (FW)
Micronutrient(s)		**Iron**	**Zinc**	**Iron**	**Iron**	**Zinc**	**Iron**	**Zinc**	**VitA**
EAR, non pregnant, non lactating women (µg/day		1460	2960	1460	1460	2960	1460	2960	500
EAR, children 4-6 yr (µg/day)		500	1390	500	500	1390	500	1390	275
Micronutrient retention after processing (%)		85	90	90	50	60	80	85	50
Bioavailability (%)		5	25	2.5	2	8	6	25	8
Baseline micronutrient content (µg/g)		65	46	54	30	22	4.8	4.2	10
Current additional content achieved (µg/g)		60	28	40	15	16	1.5	2.4	60
Current final content achieved (µg/g)		125	74	94	45	38	6.3	6.6	70
Max. genetic variation discovered (µg/g)		110	78	95	70	50	9.0	9.6	>100
Children 4-6 yr:	20	21	24	8					
Total % of EAR achieved, based on per capita	100				9	13	6	10	102
Consumption (g/day)	200				18	26	12	20	204
	40	15	23	6					
Adult Women:	50	18	28	7					
Total % of EAR achieved, based on per capita	300				9	18	6	14	168
Consumption (g/day)	400				12	25	8	19	224
EAR, estimated average requirement									
*assuming<16% moisture; **assuming 30% dry weight basis									

Major steps involved in the biofortification process are:

- The HarvestPlus approach to breeding first assesses whether sufficient genetic variation exists in elite or germplasm bank materials for a particular trait of interest.

- Plant breeders screen existing crop varieties and accessions in global germplasm banks, including both adapted and non-adapted material such as landraces and wild relatives.
- Initial research indicated that selection of lines with diverse vitamin and mineral profiles could be exploited for genetic improvement (Beebe *et al*., 2000; Monasterio and Graham. 2002; Pfeiffer and McClafferty, 2007; Jiang *et al*., 2008; Menkir, 2008; Menkir *et al*., 2008; Gomez-Becerra *et al*., 2010a; Talukder *et al*., 2010; Velu *et al*., 2011; Ashok Kumar *et al*., 2012; Dwivedi *et al*., 2012; Fageria *et al.,* 2012).
- When lines with these traits are identified, they are used in early-stage product development and parent building. Intermediate stage product development takes place at CGIAR centers, where breeding materials with improved nutrient content and high agronomic performance, as well as preferred consumer qualities are developed.
- Final product development takes place at both CGIAR centers and National Agricultural Research Systems (NARS). National research partners may carry out further crosses with locally adapted materials to develop final products that meet specific traits required by local producers and consumers.
- After promising high yielding, high-nutrient lines emerge, they are tested across a wide range of environments side-by-side with locally preferred varieties. Participatory variety selection (PVS) involves farmers and/or consumers who compare crop and food preparation performance to select the preferred materials. The best-performing lines are then submitted to national performance trials conducted by governmental institutions prior to release.
- The breeding process takes six to ten years to complete. As of 2017, HarvestPlus partners have released more than 158 biofortified varieties of 10 crops in 26 countries.

HarvestPlus along with the partners has used two strategies to shorten the time to market for biofortified crops: (i) Identifying adapted varieties with significant micronutrient content for release and/or dissemination as "fast-track" varieties; and (ii) while varieties with target micronutrient content are still under development, deploying multi-location regional trials across a wide range of countries and sites to accelerate release processes by increasing available performance data of elite breeding materials. Regional trials also include already released biofortified varieties and generate data on their regional performance. By substituting temporal-by-spatial environmental variation in large-scale regional genotype-by-environment (GxE) testing, testing steps can be eliminated and also time to market shortened by one to two years.

Status of Crop Development Progress to Date

Provitamin A Orange Sweet Potato is widely consumed in sub-Saharan Africa. Conventionally bred orange sweet potato (OSP) containing provitamin A was the first biofortified crop developed and released by the International Potato Center (CIP), the HarvestPlus, and its partners. Plant breeders have produced several OSP varieties with provitamin A content of 30-100 ppm, exceeding the target level of 32 ppm. The National Crops Resources Research Institute (NaCRRI), with the support of CIP, conducts breeding research in Uganda. As the provitamin A trait is mainstreamed in breeding populations, ongoing OSP breeding focuses on tolerance to biotic and abiotic stress while maintaining/enhancing provitamin A levels. In Uganda, a HarvestPlus focus country, HarvestPlus coordinates with NaCRRI and CIP to ensure a continuous flow of improved varieties. Two orange-fleshed landrace cultivars named 'Ejumula' and 'SPK004' ('Kakamega'), with the full provitamin A target, were released in 2004, and two additional varieties named 'Vita' (NASPOT 9 O) and 'Kabode' (NASPOT 10 O) were released in 2007. In 2013, two new OSP cultivars (NASPOT 12 O and NASPOT 13 O) with wide adaptation, high root yield, and high dry matter content were released. Biofortified OSP varieties have been released in more than 15 countries across sub-Saharan Africa, and are being introduced in many parts of Asia (China, Bangladesh, and India) and Latin America. At the 2016 Annual Sweet Potato Speed Breeders Meeting in Kenya, more than 30 sweet potato breeders working in 14 African countries signed a commitment to mainstreaming beta-carotene into national breeding efforts, striving to ensure that at least 50 per cent of the clones submitted for release are biofortified, orange-fleshed types.

Provitamin A yellow cassava is a dietary staple in much of tropical Africa, and grows well in poor soils with limited labour requirements. Screening of cassava accessions from the International Center for Tropical Agriculture (CIAT) germplasm collection found a range of 0-19 ppm of provitamin A in existing cassava varieties, exceeding the breeding target of 15 ppm (Chavez *et al*., 2005; Ceballos *et al*., 2012). Studies on GxE interaction for carotenoid content did not find significant changes in the relative ranking of genotypes, and found high (>0.6) heritability of carotenoid content in cassava roots (Ssemakula and Dixon, 2007; Ssemakula *et al*., 2007; Morillo *et al.*, 2012; Njoku *et al*., 2015). Rapid-cycling recurrent selection was used to shorten the normal breeding cycle from eight years to two to three years for high carotenoid content (Ceballos *et al.,* 2013). Breeding programmes for provitamin A cassava are based at CIAT and the International Institute of Tropical Agriculture (IITA). CIAT generates high-provitamin A sources via rapid cycling in pre-breeding and provides *in vitro* clones and seed populations to IITA and the national research programmes in two target countries, Nigeria and the Democratic Republic of Congo (DRC), for local adaptive breeding. These national research programmes are the Nigerian National Root Crops Research Institute (NRCRI) and the Institute National pour l'Etude et la Recherche Agronomiques (INERA) in the DRC. Cassava varieties that best meet farmer-preferred traits include high yield, early maturity, tolerance to pests and diseases, dry matter content, poundability, mealiness, sweetness, ease of peeling, marketability, and in-ground storage durability (Njoku *et al*., 2015). Genotype-by-environment (GxE) testing is used to verify that varieties proposed for release are widely adapted and stable across different environments (Maroya *et al*., 2012). Investments in marker-assisted selection have identified phytoene synthase 2 (PSY2) as one of the major alleles for provitamin A accumulation in cassava roots, and markers are beginning to be tested as a breeding tool, in addition to the ongoing phenotypic selection (Welsch *et al*., 2010; Ferguson *et al*., 2011; Rabbi *et al*., 2014).

Iron bean (common bean) is the most common food legume in Latin America and eastern and southern Africa. Bush beans are cultivated in low to mid-altitudes and climbing beans in mid- to high-altitude areas. Initial screening found ranges of 30-110 ppm iron (and 25-60 ppm zinc) in cultivated and wild beans from the germplasm collection at CIAT, exceeding the target level of 94 ppm for iron. The highest levels were found in wild and weedy germplasm (Guzman-Maldonado *et al*., 2000). High-iron genotypes were used to initiate crosses to combine the high-mineral trait with acceptable grain types and agronomic characteristics. Grain mineral content is influenced by environmental factors such as soil organic matter and precipitation (Beebe, 2012; Rai *et al*., 2014a). Genotype-by-environment (GxE) testing is, therefore, used to identify materials with stable mineral accumulation across sites and generations (Blair *et al*., 2010). Biofortified lines are developed by the breeding programme at CIAT and are being evaluated for local adaptation by national programmes in several East and Southern African countries as well as in South and Central America. The lines are at varying stages in the breeding pipelines in each of these countries. Breeding programmes in African target countries Rwanda (Rwanda Agriculture Board-RAB) and the DRC (L'Institut National pour l'Etude et la Recherche Agronomique-INERA) have developed crosses locally and are assuming a greater portion of the selection work. A full breeding pipeline consists of both locally developed germplasm and CIAT introductions.

In Rwanda, four first-wave, fast-track varieties (two bush, two climber) were released in 2010 and five second-wave climbing bean varieties in 2012. In the DRC, five first-waves, fast-track varieties (three bush, two climber) were identified for release and dissemination in 2011 and five second-wave varieties (three bush, two climber) in 2013. Five varieties (two climbers, three bush) were released in Uganda in 2016. Released bean varieties contain about 60 per cent of the iron target level (+44 ppm more iron) in the first wave, 80 per cent in the second wave, and 100 per cent in the third wave. In addition, they are resistant to major pests and diseases have good yield and farmer preferred end-use quality, and different grain colors and sizes that cover a range of major market classes. New climber and bush bean lines with 90-100 per cent target increment for iron are in advanced line validation trials to identify agronomically competitive third-wave varieties. Current breeding efforts focus on developing climate-smart iron beans that are high iron, higher yielding, and tolerant to drought and heat. Additional crop improvement research is underway to combine a low physic acid (LPA) mutation with the iron trait, which increases the bioavailability of iron when beans are consumed.

Iron Pearl Millet (pearl millet) breeding programme is based at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. Initial screening of germplasm accessions found ranges of 30-76 ppm iron (and 25-65 ppm zinc) in pearl millet, nearly reaching the full breeding target of 77 ppm (that is, an increment of +30 ppm additional grain iron compared to 47 ppm on average in non-biofortified germplasm). High-iron genotypes were selected to initiate crosses (Velu *et al*., 2007; Gupta *et al*., 2009). High correlation between iron and zinc content indicated good prospects for simultaneous selection for the two micronutrients (Velu *et al*., 2008 a; b; Rai *et al*., 2013). Both micronutrients are largely under additive genetic control, implying that iron hybrids will require both parental lines to have high iron density (Govindaraj and Rai, 2016; Govindaraj *et al*., 2016; Velu *et al*., 2011). Genotype-by-environment (GxE) testing was used to evaluate the most promising local germplasm and potential parents and verify that mineral accumulation was stable across sites and generations (Rai *et al*., 2012).

The breeding pipeline at ICRISAT initially included open-pollinated variety (OPV) development. However, since approximately 70 per cent of the pearl millet area in India is planted to hybrids, emphasis is now placed on hybrids and hybrid-parent development. The major focus of the breeding programme is to develop higher yielding, high-iron hybrids with stable yield and iron performance for the major pearl millet growing areas in India. Major traits include drought tolerance, resistance to downy mildew, and end-use quality traits. Pearl millet biofortification research at ICRISAT is carried out in alliance with HarvestPlus, the ICAR-All India Coordinated Pearl Millet Improvement Project, six State Agricultural Universities, more than 15 seed companies, and two state seed corporations. To ensure long-term sustainability, HarvestPlus engages seed companies in GxE testing of hybrids and inbred lines developed at ICRISAT, and encourage them to develop their own high iron hybrids for commercialization.

In 2014, Dhanashakti, an OPV was developed by ICRISAT in collaboration with Mahatma Phule Krishi Vidyapeeth, Rahuri under ICAR- All India Coordinated Research Project on Pearl millet. The first wave of high-iron and high-yielding hybrid, ICMH-1201, was developed by ICRISAT under HarvestPlus Biofortification Programme, widely tested over 48 field trials during three consecutive years. This hybrid contains +28 ppm additional iron (more than 90% of the target increment) and has 38 per cent higher grain yield than ICTP 8203. Second wave of biofortified iron hybrids HHB 229 (contains 73.0 ppm and zinc 41.0 ppm), AHB1200 (contains 73.0 ppm and zinc 40.00 ppm) developed by ICRISAT in partnership with CCS-Haryana Agricultural University, Hisar and Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani respectively in collaboration with under the ICAR-All India Coordinated Research Project on Pearl Millet.

The success of pearl millet biofortification in India suggests that similar achievements could be realized for Western and Central Africa (WCA). The WCA region has the largest area under millets in Africa, of which more than 90 per cent is pearl millet. Studies of pearl millet landraces and other locally adapted materials from Niger and Sudan showed promising ranges of mineral density (Bashir *et al*., 2014 a, b; Pucher *et al*., 2014). The most promising iron pearl millet OPVs are currently being tested on-farm at more than 30 locations across five countries in WCA. Two OPV varieties (GB8735 and ICTP8203) have been selected as candidates for fast tracking in Niger, Ghana and Senegal.

Delivery Strategies and Results to Date

Vitamin A Cassava in Nigeria

Delivery may be conceptualized and discussed as three broad sets of activities, which to some extent are interdependent and must be implemented simultaneously: (i) cassava stem multiplication and extension to farmers, (ii) creating and building consumer demand, and (iii) connecting supply and demand through markets. The foundation of the successful introduction of yellow cassava in the Nigerian food system and its ultimate sustainability is consumer demand. However, a certain investment and momentum in the supply chain must be established initially before investing heavily in building consumer demand. Scaling up the supply of cassava tubers stem multiplication HarvestPlus employs two major channels (public and commercial) in the multiplication of vitamin A cassava in Nigeria. Generally, public multiplication programmes funded by the government, development agencies, farmer and community-based associations have social responsibilities aimed at alleviating poverty and food security gaps. Commercial multiplication programmes, funded by private investors, aim at making profit. The former channel ensures horizontal access, where every farmer can access a small quantity of stems for planting. While the latter is vertical and demand-driven, it ensures sufficient seed-stem supply for larger-scale production. Starting with the distribution of small free stem packs allows farmers to test the new biofortified varieties with minimal risk, and they can later link to commercial seed farms to purchase stems in larger quantities.

In 2011, the biofortification crop delivery programme started with stem multiplication in ten local government areas (LGA) in each of the following four states; Oyo in the West, Imo in the East, Akwa Ibom in the South and Benue in the North. In 2012, the programme expanded to six villages in each LGA making a total of 60 villages per state and 240 villages in the four targeted states. The programme rolled out to 18 more states between 2013 and 2015, thus covering over 60 per cent of all the states in the country and over 80 per cent of the major cassava producing states even though the level of coverage differs from one state to the other.

Marketing activities along the value chain are necessary to ensure that effective demand can pull the supplies of yellow cassava from rural production to rural and urban markets. Available data from vitamin A cassava investors suggest that '*gari*' is the most traded vitamin A cassava product, accounting for 58 per cent of total sales in 2015. '*Fufu*' accounted for 30 per cent of the total sales, followed by flour (12%), resulting from the high demand for vitamin A cassava-based snacks and confectioneries like queen cake, combo-bits, and combo-strips.

Creating demand consumer marketing using print, television, and radio media were used extensively to communicate the importance of vitamin A cassava to consumers to create demand, and to investors to increase product supply. Radio and television reach jingles were developed and translated into five local languages for creating awareness on radio and television prior to stem distribution. Nutritious Food Fair (NFF) creates awareness and builds linkages among farmers, processors, marketers and consumers. In 2016, four million people were growing and consuming vitamin A cassava.

Iron Beans in Rwanda

In Rwanda, the crop delivery work began in 2011, following the first biofortified bean varietal releases in 2010. According to monitoring data, HarvestPlus and its partners had delivered close to 3,000 metric tons of iron bean seed to over 800,000 farming households by the end of 2015. Delivery may be conceptualized and discussed as three broad sets of interdependent activities: (i) bean seed multiplication and delivery to farmers; (ii) creating and building consumer demand; and (iii) connecting supply and demand through markets. The foundation for successful introduction of iron beans in the Rwanda food system and, ultimately for its sustainability, is consumer demand. However, investment in strengthening the supply chain must be established prior to heavy investment in generating consumer demand. This section presents the delivery activities in Rwanda, followed by additional experiences from DRC.

To facilitate the production of iron bean seed, HarvestPlus worked closely with RAB, contracting individual commercial farmers, farmer-based cooperatives, and small seed companies to multiply biofortified varieties. To increase available seed for the 2015 planting season and beyond, HarvestPlus collaborated with established local and regional seed companies for seed multiplication, with RAB certifying the biofortified seed. These partners include SeedCo, Kenya Seed Company, Rwanda Improved Seed Company (RISCO), and WinWin Agritec. In Rwanda, the biofortification crop delivery programme started in 2011 in four districts, Nyagatare, Kirehe, Ngoma and Musanze. In 2012, the programme rolled out to 13 additional districts and now operates throughout the country. Delivery of iron beans in Rwanda initially occurred through various platforms and mechanisms, including agro-dealers, farmer-based cooperatives, direct marketing in local markets, and a payback system. In direct marketing, marketing agents sold iron bean seed at local markets, reaching a large number of farmers with relatively small quantities of seed. This allowed farmers to try the varieties before committing to greater production.

Agro-dealers sold iron bean seeds directly to farmers and had the advantage of being close to farmers throughout the year.

As biofortified beans gained traction in the market, seed companies and agro-dealers became increasingly interested in iron beans in their product lines. From 2015 on, HarvestPlus has been working closely with the private sector to scale up production and delivery of iron bean seeds.

There is a secondary effort to brand biofortified beans through the value chain, which requires educating farmers and consumers about the specific characteristics- including shape, color, and size – that allow for the identification of biofortified varieties. Radio talk shows increase awareness among farmers and general consumers about iron bean production, seed availability, and nutritional benefits. A media-based awareness campaign uses entertainment to reach the public and consumers of iron beans with nutritional messages. This campaign has been conducted in partnership with locally renowned musicians and journalists and included a music video and outreach tour touting the benefits of growing and consuming iron beans in Rwanda. In 2016, two million people were growing and consuming iron beans.

Orange Sweet Potato in Uganda

Research conducted in Mozambique and Uganda that provided solid evidence (collected from 2002-2009) that an integrated agriculture-nutrition-marketing intervention using Orange sweet potato (OSP) as a key entry point could significantly and positively impact on young child vitamin A intakes. The three pillars of the integration are: (i) agriculture-with OSP providing a low cost, easy to grow bioavailable source of vitamin A; (ii) nutrition-both producers and consumers need to be informed of the nutritional value of OSP (demand creation campaigns) and change agents need to work with caregivers to ensure they have core, basic knowledge of good dietary and feeding practices and how to incorporate OSP effectively into the young child diet as well as their own; and (iii) marketing-opportunities to commercialize OSP surplus stimulates OSP uptake and rates of permanent adoption. Managing the "seed system" based on vines that are easily shared among growers and hence, typically of limited interest to private sector seed companies, is critical to success. The five cases described below vary depending on whether the major outcomes are nutrition improvement (four of the cases) or cash generation (the Rwanda case study).

Integrated agriculture-nutrition-marketing: case study of Uganda (2011 to date). In Uganda, the going-to-scale dissemination strategy led by HarvestPlus has a three pronged approach integrating agriculture, nutrition and marketing. Principal target groups are children under five years of age and women of child-bearing age. This approach has involved establishing a self-sustaining seed system with trained vine multipliers, ensuring availability of vines to both smallholder farmers and other partners. Local laboratories propagate disease-free or "clean" pre-basic cuttings (planting material) and train multipliers receiving the cuttings on agronomy, post-harvest handling, pest and disease control, and vine conservation.

Promotional activities, including community dramas, field days, and radio campaigns, have been conducted to increase the level of awareness of nutritional benefits of the crops, and thus increase demand and uptake by both government and non-governmental organizations (NGOs). An increasing number of NGOs (for example, World Vision, Save the Children, and Finnish Refugee Council) are purchasing the cuttings. In addition, farmers with surplus production are trained in post-harvest handling and value addition and linked to traders and markets. Commercial farmers are engaged to increase production of OSP and the volumes marketed. HarvestPlus also supports offseason production where possible to enable a reliable and robust supply to markets and institutions (such as schools and prisons). In 2016, a total of 550,000 people were consuming OSP in Uganda

Iron Pearl Millet in India

An iron version of one of the most popular OPVs, ICTP 8203, was developed by ICRISAT, commercialized in 2012 with in partnership with Nirmal Seeds for Maharashtra, India. Due to its high iron content (exceeding

80% of the iron target increment) and wide adaptation, ICTP 8203-Fe was released and notified under the name "Dhanashakti" in 2014 for cultivation in all pearl millet-growing states of India (Rai *et al*., 2014a; b). Dhanashakti was also included in the Nutri-Farm Pilot Project, initiated by the Government of India, for addressing iron deficiency (Purushottam Singh and Uddeen, 2016). Nirmal Seeds Company initiated commercial production of Dhanashakti in 2012 and at the end of 2017, the variety has been marketed to more than 90,000 farmers, mostly in Maharashtra. From 2016 two public sector companies, Mahabeej and KSSC initiated sales and distribution of Dhanashakti in Maharashtra and Karnataka, respectively. The first high-iron and high-yielding hybrid, ICMH-1201, was developed by ICRISAT. Shakti Vardhak Seeds commercialized under its brand name Shakti-1201 since 2014 (Purushottam Singh and Uddeen 2016). Promotional activities were engaged with HarvestPlus partners like product demonstrations, mobile campaign, marketing collaterals with nutrition messaging, farmers meetings. In collaboration with external marketing agency, market research study was conducted to understand the consumer insights towards biofortified crops. At the end of 2017, 465,000 people were consuming iron pearl millet in India.

Conclusions

Agricultural investments and policies in Biofortification will not only improve the availability and affordability of more nutritious food, but also will help in placing the solution in the hands of farmers and the communities (Bouis, 2000). In the long-term, increasing the production of micronutrient-rich foods and improving dietary diversity will substantially reduce micronutrient deficiencies (Bouis *et al*., 2011). Biofortification provides a feasible means of reaching malnourished populations in relatively remote rural areas, delivering biofortified foods to people with limited access to commercially marketed fortified foods, which are more readily available in urban areas. Biofortification and commercial fortification, therefore, are highly complementary. The biofortification strategy seeks to take advantage of the consistent daily consumption of large amounts of food staples by households, including women and children, who are most vulnerable for micronutrient malnutrition. Biofortification in pearl millet can help in securing household nutrition security of the population, especially millions in the arid and semi-arid regions of the country that consume pearl millet in their daily diet. Favorable policies for linking it to the existing public food and nutrition programmes, price incentive for primary grain producers can help to trigger demand. Public private partnership (PPP) of value chain players will help to build foundation for scaling out biofortified crops to create long-term sustainable market. Biofortification is a cost-effective agriculture-based strategy for a sustainable solution for public health and nutrition.

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Knowledge Management Resources in CABI for Underutilized Crops

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ABSTRACT: The key Knowledge Management (KM) resources available in the Center for Agriculture and Biosciences International (CABI) that are useful to support the underutilized crops (UUCs) initiative are highlighted. These resources include: (i) Books, e-books and multimedia tools, (ii) the Global Open Data for Agriculture and Nutrition Action (GODAN) and (iii) Mobile advisory services such as m-Kisan and m-Nutrition. CABI also provides knowledge management services that include managing research information, mobile agri-services and systematic reviews; drives globally the CABI-led Plantwise programme and continually updates comprehensive databases such as the Invasive Species Compendium. It is anticipated that CABI's various knowledge management resources will largely complement and enhance the existing knowledge repositories on UUCs in the public domain. These resources can also be effectively used while developing road maps for each country's food and nutritional security especially towards identifying and prioritizing the UUCs for interventions. Despite the possibilities, there are major challenges for gearing and mainstreaming UUCs. These range from the availability, accessibility and deliverability of accurate and verifiable information that helps with identifying crucial gaps in Research and Development (R&D) which could become a game changer for the UUCs agenda. The various resources available within CABI could also provide impetus to developing new knowledge sharing platforms.

Key words: CAB International, food security, knowledge management, resources, underutilized crops

Introduction

Knowledge Management (KM) and Underutilized Crops: CABI's Perspective

CABI is known globally as a knowledge-based organization. It believes that a crucial way to solve problems in agriculture and the environment is by managing, curating and disseminating information. Our experience in scientific research, publishing, knowledge management and communications allows us to put know-how into the hands of the people who need it the most. CABI's Knowledge Management (KM) theme also supports the Sustainable Development Goals such as SDG2 (Zero hunger), SDG4 (Quality education), SDG5 (Gender equality), SDG15 (Life on land) and SDG17 (Partnerships for the goals). Further, it underpins CABI's international development work to:

- Provide scientific information and evidence to a wide variety of users;
- Promote data-driven development, engaging in data-focused research partnerships, adding value to data, and engaging with stakeholders to build data literacy;
- Support data collection and two-way communication.

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Despite having diverse KM resources, CABI is yet to undertake a specific KM dedicated programme on underutilized crops (UUCs). Regardless, CABI has in its KM portfolio several documentation and specific studies that embrace UUCs as targets. CABI's KM platform, which has recently migrated from traditional print platforms to online subscription models/platforms and multimedia tools, also helps to support project work that it undertakes across countries. Some KM resources available for UUCs are illustrated below.

KM Products for Underutilized Crops

Books, E-books and Multimedia tools

CABI is a leading global publisher producing key scientific publications, including the world renowned CAB Abstracts (the world-leading database covering agriculture and environment). In addition, Global Health, the definitive bibliographic database for public health information, as well as compendia, books (e.g Crop Wild Relative Conservation and Use; chapter 44 on Minor crops and underutilized species: lessons and prospects), eBooks, and the full text electronic resources invariably include information on the various aspects of UUCs. There is also CABI Direct (CABI's online development platform), providing a single point of access to all CABI's database subscriptions.

Open Data for Agriculture and Nutrition Action (GODAN)

This initiative advocates for open data and open access policies by default, in both public and private sectors, whilst respecting and working to balance openness with legitimate concerns in relation to privacy, security, community rights and commercial interests (Fig. 1). GODAN also advocates for the release and re-usability of data in support of innovation and economic growth, improved service delivery and effective governance, and improved environmental and social outcomes. It is a programme launched by the UK's Department of International Development (DFID). It brings together agriculture and nutrition specialists and open data experts, this project is led by Wageningen UR and its partners are Technical Centre for Agriculture and Rural Cooperation (CTA), Open Data Institute (ODI), AgroKnow, Land Portal Foundation, Food and Agriculture Organization of the United Nations (FAO), Institute of Development Studies and AidData. At an appropriate time, some of the outputs of impact evaluation methodologies, materials from capacity building, and lessons learned from a proposed course - which are important building blocks of any open data and research data management framework - will be shared with all interested parties.

Fig. 1. *GODAN framework*

The e-learning modules and capacity building activities help strengthen the capacity of data producers and data consumers to manage and use open data in agriculture and nutrition. The modules focus on how to deal with different types of data formats and uses, and on the importance of reliability, accessibility, interoperability and transparency of data.

Mobile Advisory Services

CABI works with farmers, mobile operators content providers, extension services and industry bodies to provide mobile services across the whole agricultural supply chain. The growth of mobile in developing countries, and rural regions in particular, presents an opportunity to deliver critical, information-based agricultural services directly to rural smallholder farmers. Access to the right information, absorbed and applied correctly, can increase productivity and improve livelihoods in many of these farming households. Through our work we are providing farmers with targeted information via text and voice message. Farmers are also able to contact agricultural experts via mobile helplines to get the information they need.

Not only can mobile services be used to provide information directly to farmers, they can also be used to gather information from the field. CABI has developed a data collection application that is being used by extension field workers equipped with smartphones or tablets to gather and process information from remote sites both quickly and efficiently.

The highlights of our work to date include:

- delivery of agro-advisory services to around 4 million fee-paying smallholder farmers
- creation of a core information product; a database of actionable agricultural extension information (factsheets)
- development of mobile data collection application and systems to enable extension workers to gather and analyse field data
- development of web-based analytics and inference tools

CABI's expertise in indexing and managing vast amounts of complex data, combined with our experience in agricultural best practice, soil health, and plant pests and diseases have allowed us to harness mobile solutions to improve livelihoods of smallholders worldwide (CABI, 2017)

Examples of Mobile Advisory Services to Help Farmers

mKisan: The mobile advisory services that CABI provides together with partners have been embraced by thousands of smallholder farmers. Farmers view mobile delivery of agricultural information as beneficial, enabling them to access up-to-the-minute data in order to improve their food security and livelihoods. From CABI's point of view, we have found our growing programme of mobile advisory services has allowed us to be much more ambitious in the reach, frequency and impact of the knowledge we provide, creating synergies across our expertise and services.

This is best illustrated by the experience of farmers in one of the beneficiary districts-Gwalior in the northern Indian state of Madhya Pradesh. In this arid area, farmers are highly dependent on irrigation where available, but rain-fed agriculture is more common, and suffers from poor productivity. Many farmers only harvest one crop per year. Land holdings are small and scattered and soils generally lack micronutrients and have low to medium levels of nitrogen and phosphorus.

In terms of agricultural information, there are many suppliers in Gwalior, including the state, civil society and private sector. However, the reach of these suppliers is uneven and access is frequently limited to peri-urban areas or to wealthier farmers, leaving out the section of the population most in need of information – smallholder farmers surviving on low incomes.

The mKisan information service, launched in January 2013 by CABI and its partners, is intended to fill this information gap and serve farmers who have been overlooked by existing providers and services (Banerjee *et al.*, 2014). Drawing on CABI's expertise in processing large quantities of complex data and knowledge of agricultural best practice and sustainability, the service provides practical farming advice to subscribers in six Indian states: Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra and Uttar Pradesh. At the time of launch, it estimated a target market of 13.8 million rural customers.

CABI is the principal knowledge partner, providing content and quality assurance through our 'Direct2Farm' information database (Fig. 2). This includes information and advice on crop agronomy, animal health, weather forecasts and market prices for major crops, which are delivered to subscribers through SMS and an interactive voice response (IVR) service. mKisan is operated by the mobile service

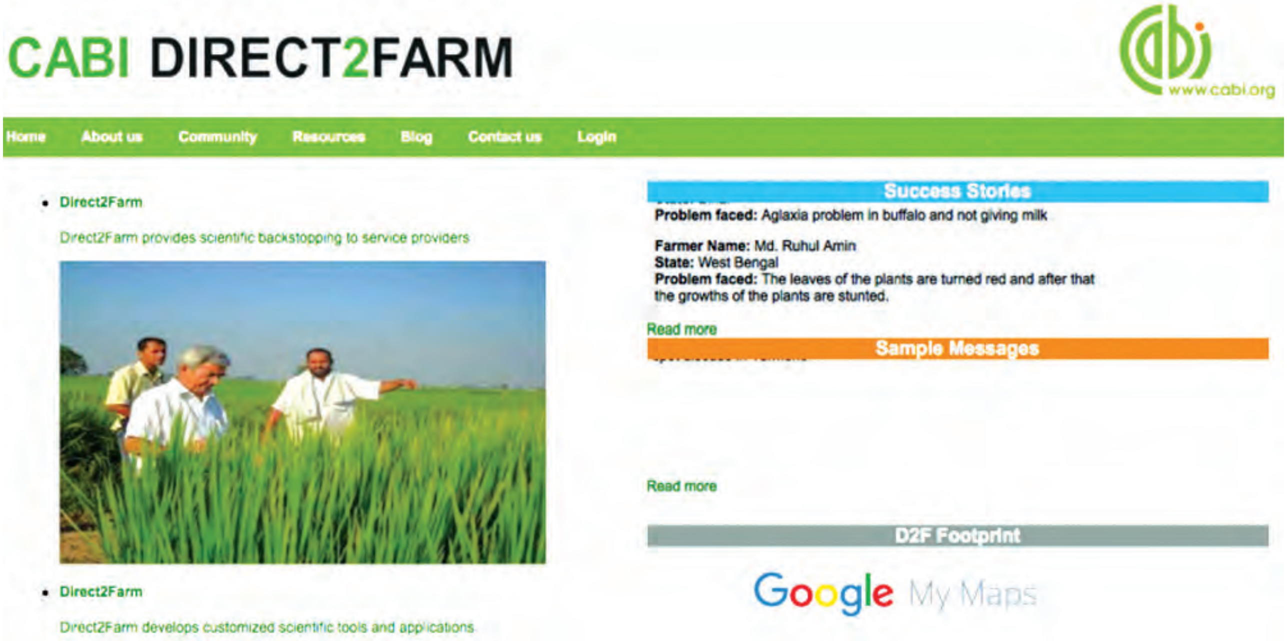


Fig. 2. *Direct2Farm initiative*

provider Handygo, with further support from the International Livestock Research Institute (ILRI) and the communication company DigitalGreen.

mNutrition: The open-access Nutrition Knowledge Bank (Fig. 3) has been created as part of a GSMA mNutrition initiative to help tackle malnutrition in Africa and Asia. This collection of content on good nutritional practices includes factsheets and mobile messages for anyone to download and use. Funded by the UK Department for International Development (DFID), the mNutrition project aims to deliver nutrition information to 3 million people in 12 developing countries. Adequate nutrition is critical

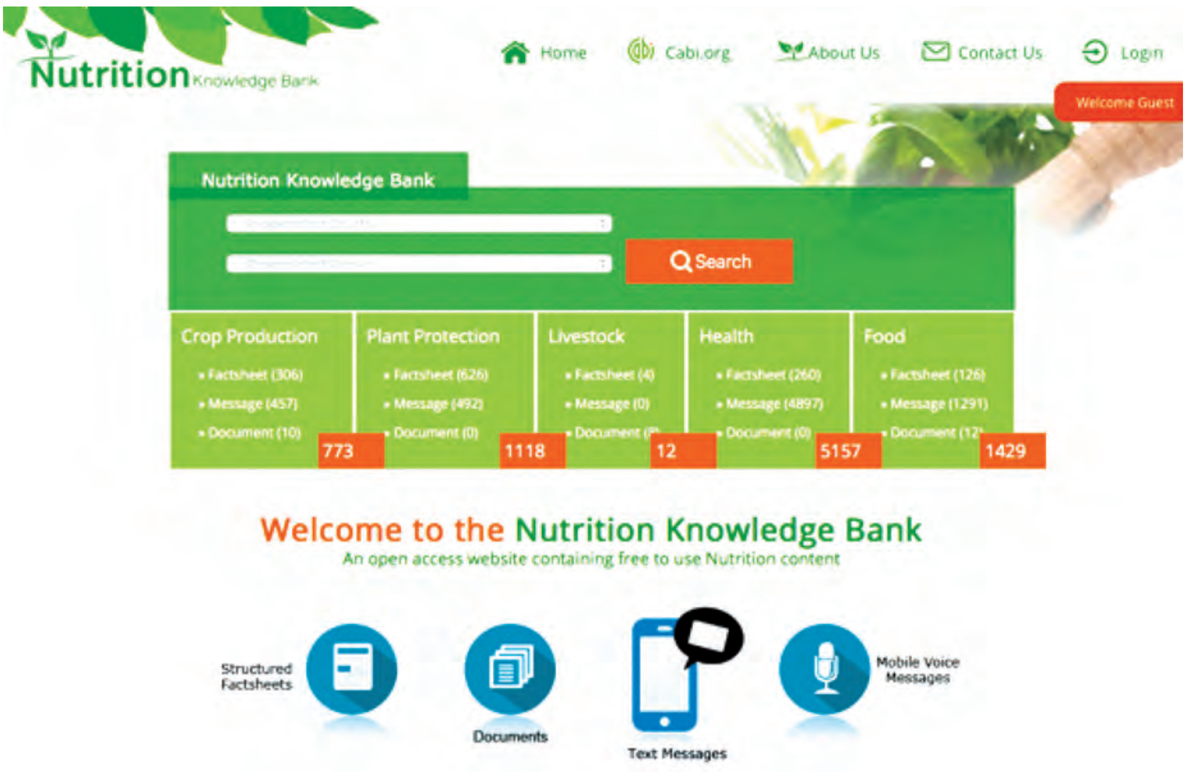


Fig. 3. *Nutrition Knowledge Bank*

to the physical and mental development of children and to long-term human health, but one out of three people in developing countries suffers from micronutrient deficiency. Experts consider poor access to agricultural and health information a major barrier to the uptake of improved nutritional practises, particularly by women and vulnerable groups in marginalized areas.

mNutrition delivers content to people at risk of malnutrition in Bangladesh, Ghana, Kenya, Malawi, Mozambique, Myanmar, Nigeria, Pakistan, Sri Lanka, Tanzania, Uganda and Zambia. An expert consortium on nutritional matters- BMJ, CABI, the Global Alliance for Improved Nutrition (GAIN), the International Livestock Research Institute (ILRI) and Oxfam International- is partnering with local organizations in these countries to produce useful and reliable nutritional, agricultural and health information, which is then distributed through mobile phone networks in each country. The Nutrition Knowledge Bank is searchable by country and subject. The messages and factsheets are available in several local languages and take into account the differing cultural contexts. The topics covered include breastfeeding advice for new mothers, practical tips for rearing dairy cows and growing healthier crops, including a number of underutilized vegetable crops, for human consumption. The groups who can make most use of the Nutrition Knowledge Bank include mobile network operators, agriculture and health ministries, agricultural support workers, community organizations and development practitioners. More content will be uploaded over time, providing continuous improvement of this new practical resource for directly helping people make informed choices that improve their nutrition wellbeing.

In Myanmar where mNutrition operated to deliver nutrition sensitive information under the mAgri theme, underutilized crops such as green gram and pigeon peas were worked on to produce information under various knowledge domain categories related to crop production and plant protection. These factsheets contain information on land preparation, nutrient management, crop requirement, harvest and post-harvest, inter-culture and weed control, seed and seeding and water management. Plant protection included information on pest management and description. Ooredoo Myanmar, the local telco operator and project partner in the country, delivered the information using its mobile application, 'Site Pyo' to end users. The application was pre-loaded onto basic smartphones with ready data packages at an affordable price targeting its user demographics. By including underutilized crops as part of the service, farmers are able to obtain information to enable them to grow the crops better. Plant protection and Department of Agriculture staff contribute to the service by providing their expertise and knowledge on underutilized crops.

Knowledge Management Services

Managing knowledge is a core activity for CABI's team of content development editors and researchers. We make agricultural and environmental science information flow, giving users access to accurate, timely and relevant knowledge and exploit the latest web technologies and search algorithms, giving us a global reach. We work closely with user groups to optimise reach and impact and identify both their knowledge management needs and appropriate communication channels. The CABI knowledge management user groups include policy makers, institutions, researchers, extension workers; farmers and land managers.

Organisational Knowledge Management

Development and research organizations' primary focus is on delivering programmes that improve lives or discover new research findings. Keeping track of the outputs of the work can be difficult for large and often geographically spread organizations even within the organization but making this information available to the wider world in a coherent form is even more of a challenge.

Managing Research Information

The benefits of sharing research findings and knowledge are widely understood, but the task of putting this into practice for investment portfolios worth hundreds of millions of dollars by gathering together reports, images, data and publications, which are in multiple formats and locations, can be beyond the capacity and expertise of many organizations. CABI has exactly this type of expertise, gained over many years of collecting, abstracting, indexing and publishing scientific and development information for a wide audience, as has been done with our database CAB Abstracts. More recently we have put this expertise to use helping organizations to catalogue and manage their institutional knowledge to best effect through the web, as we have done with DFID's Research for Development site, DANIDA's research portal in Denmark and through archiving agricultural knowledge on behalf of developing countries.

Mobile Agri-advisory Services

CABI is working with technology partners to create a platform to communicate directly with farmers and their farm calendars. This channel of communication is piloting and scaling agro-advisory services to improve livelihoods, trade and household nutrition including Direct2Farm which has over 4 million subscribers in India. Direct2Farm, a mobile-enabled agriculture infomediary service aimed at making high quality information readily accessible to farmers, thus empowering them to solve their everyday farming problems. CABI's expertise in indexing and managing vast amounts of complex data, combined with its experience in agricultural best practice, soil health, plant pests and diseases will provide the basis for developing a powerful core of farming information. The Direct2Farm service synthesizes this data into short SMS and voice messages, which can be delivered via mobile phones (Banerjee *et al*., 2014). This information transmitted on agricultural issues will help smallholder farmers to improve profitability and consequently their livelihoods. The model being developed enables factsheets to be turned into small packages of information in the local language and delivered directly to farmers via SMS and voice messaging. Farmers will be also able to consult a virtual helpline – the cloud contact centre.

CABI created the core information product, a database of factsheets known as the agro-extension information repository, which includes administrative functionality such as allowing input and updating, accepting weather and agricultural market data, and outputting in a range of formats, which will be delivered to end-users by external organisations. CABI will work in partnership with mobile service providers as well as extension services, NGOs and agribusiness support.

Systematic Reviews – Understanding Research Evidence

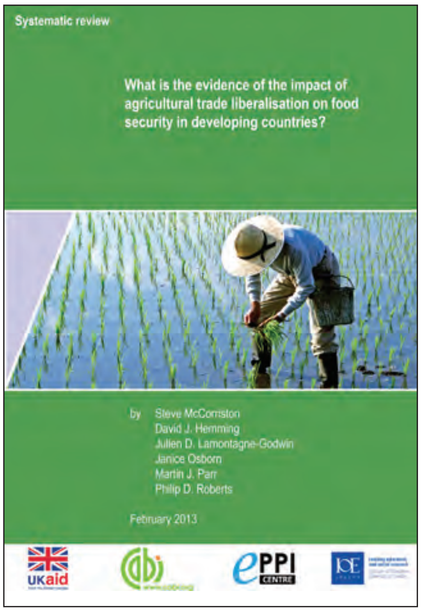
CABI applies systematic review methodologies, a technique developed in clinical medicine context, to review research questions and deliver better understanding of the research question and whether new research needs are identified. Systematic Review is a tool used to summarize, evaluate and communicate the results and implications of a large quantity of research and information. Fig. 4 shows examples of such reviews done by CABI.

Plantwise – Disseminating Plant Health Knowledge

CABI's Plantwise knowledge portal delivers user-friendly information to combat plant health issues. The portal provides pest identification and diagnostic tools and data and factsheets of actionable information, and information from our global network of field-based plant clinics. Created originally as a global resource for anyone interested in plant health, the Plantwise Knowledge Bank has become an essential tool for many professionals working each day to protect farmers against pests on almost 'all crops and all pests and diseases', including underutilized crops such as yams, sweet potato etc. This is an online and offline gateway to actionable plant health information and services – from pest diagnostic search tools to maps of pest locations and customized alerts on pest news about your area. It combines global and local open access data from leading experts working around the world in a dyanmic and easily searchable way, so answers can become actions.

There are more than 10,000 factsheets produced by top global institutions and Plantwise partners available on the Knowledge Bank, free of charge. Factsheets are short, practical guides which can

Systematic review-
trade and food security



Systematic review- the impact of invasive species on endangered species

Protocol for a systematic review on agricultural input subsidies

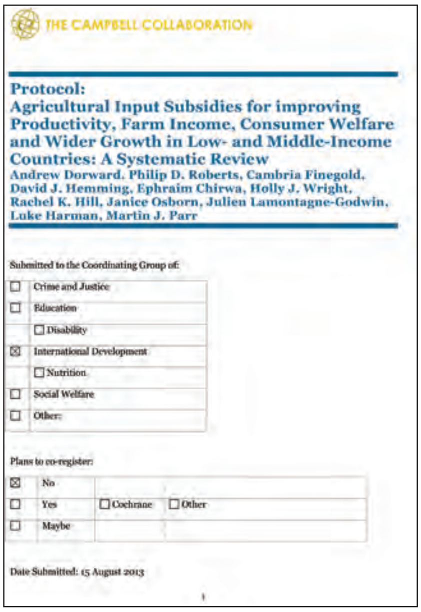


Fig. 4. *Systematic reviews*

be taken offline into the field to identify a plant pest on-the-spot and find a safe and effective solution. Factsheets include Pest Management Decision Guides, which describe safe options for fighting pests and reduce harmful risks of pesticides. Users can search for these resources by crop, pest, country or region – and even by climate zone – to find the answer to a plant health problem.

Data recorded from plant clinics are stored online in plant clinic online data management system (POMS). This secure national resource provides vital information collected at plant clinics, which policy-makers can use to better respond to emerging and re-emerging crop problems. Behind the scenes, each record from each farmer's visit is analysed and reviewed to reveal a broad picture of the real challenges facing farmers in a country or region, and the quality of the recommendations given by plant doctors. Plantwise portal delivers user-friendly information to combat plant health issues. The portal provides pest identification and diagnostic tools, data and factsheets of actionable information, including information from our global network of field-based plant clinics. Fig. 5 illustrates the Plantwise Knowledge Bank.

Agricultural and Biodiversity Research - Access and Use

CABI facilitates policy, research and support practical decision-making in the field by identifying and addressing gaps in access to digital agriculture and biodiversity research. We use a multi-stakeholder approach and collate existing research to identify gaps for a range of government departments, development agencies, academic institutions, and private sector organizations. The Invasive Species Compendium (Fig. 6) is a key programme that illustrates this work. CABI's Invasive Species Compendium is a unique resource, providing free access to up-to-date datasheets, records and information about invasive species. This database is a comprehensive resource for those working in the field of invasive species management from identification, economic assessment and management of invasive species around the world. Here, CABI has worked with governments to identify such gaps to improve better informed policies for invasive species management. This helps with facilitating policy, research and support practical decision-making in the field by identifying and addressing gaps in access to digital agriculture and biodiversity research. Such endeavors use a multi-stakeholder approach, collating existing research to identify gaps for government departments, development agencies, academic institutions and private sector organizations.

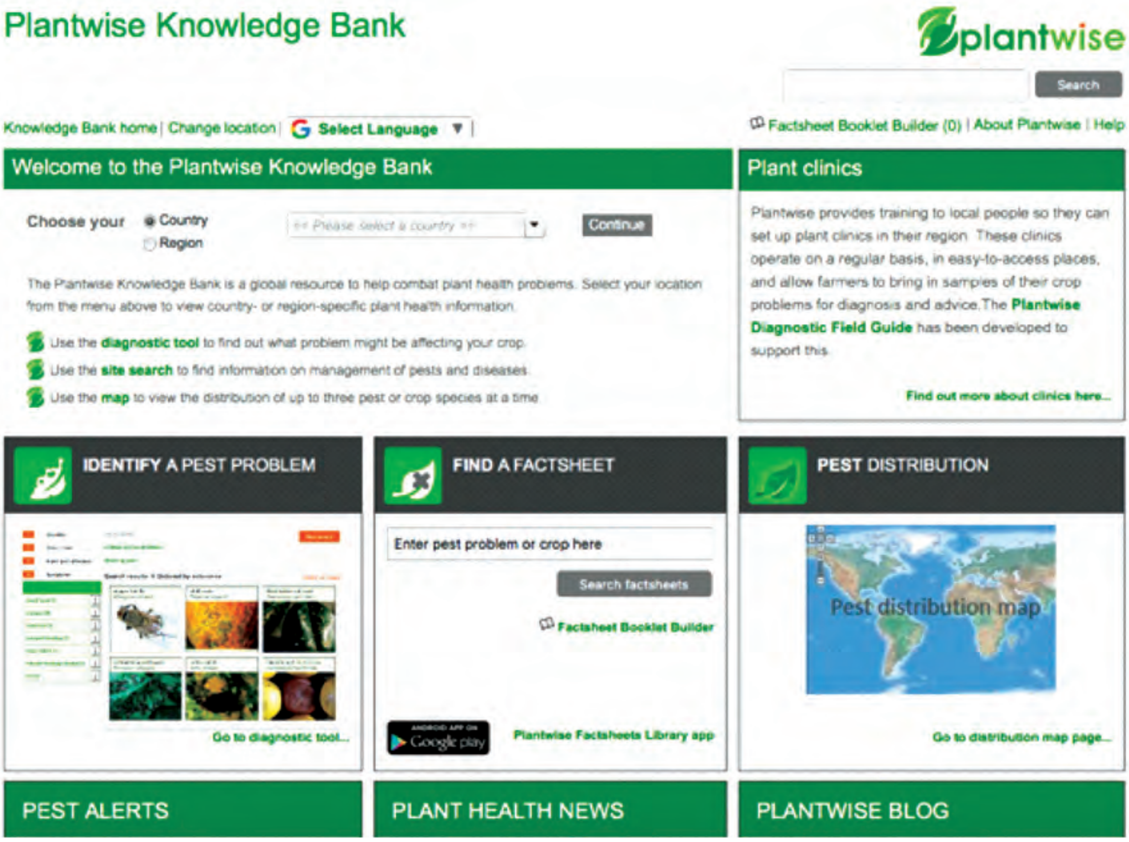


Fig. 5. *Plant-wise Knowledge Bank*

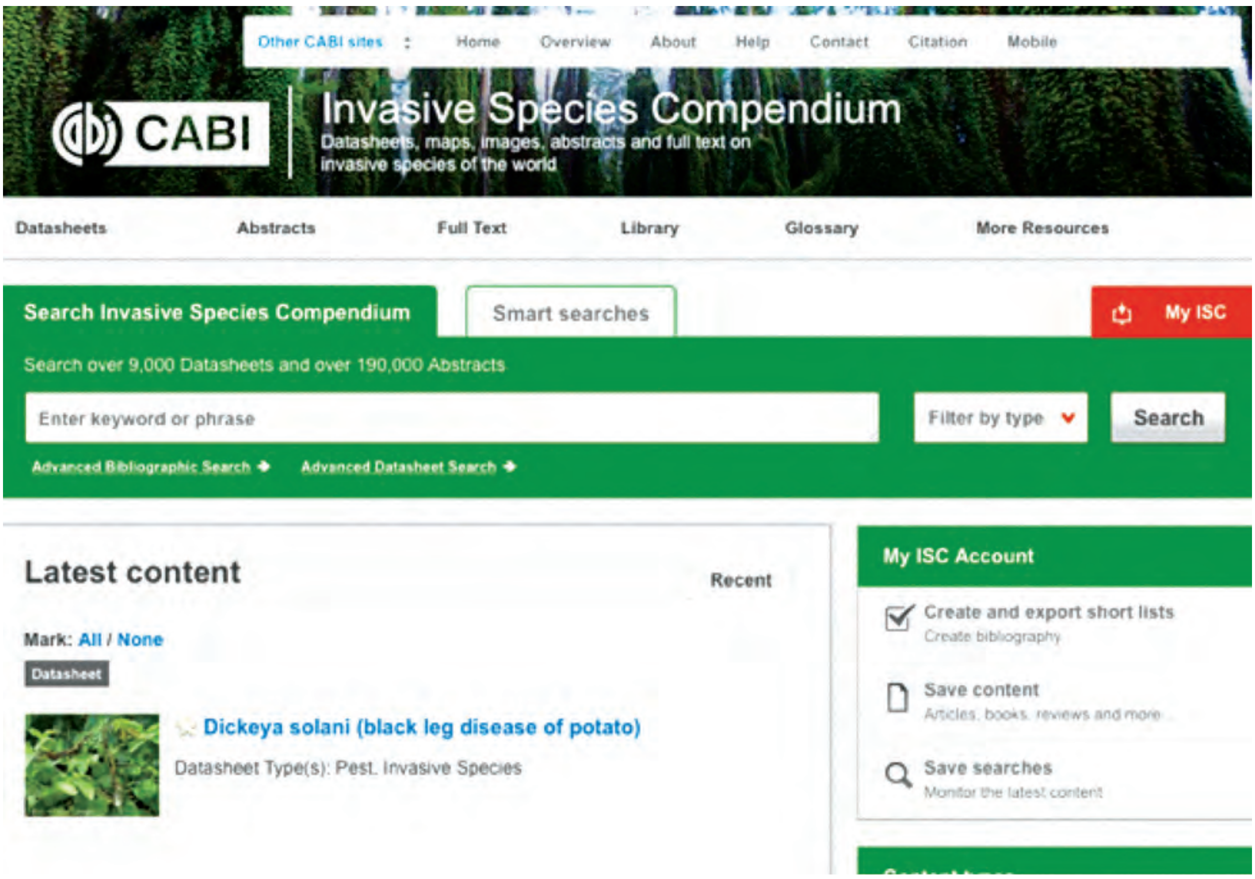


Fig. 6. *Invasive species compendium*

Examples of information provided on underutilized species (listed by FAO-UN) are as follows:

- Datasheet on *Chenopodium quinoa* (quinoa) has the following information: (i) Index with pictures, (ii) Identity, (iii) Taxonomic Tree, (iv) List of pests, and (v) Uses List.
- Drumstick (*Moringa oleifera*) has the following information: (i) Pictures, (ii) Identity, (iii) Taxonomic Tree, (iv) Notes on Taxonomy and Nomenclature, (v) Description, (vi) Distribution, (vii) Distribution Table, (viii) Biology and Ecology, (ix) Latitude/altitude ranges, (x) Air Temperature, (xi) Rainfall, (xii) Rainfall Regime, (xiv) Soil Tolerances, (xv) Uses, (xvi) Uses List, (xvii) Wood Products, (xviii) References, and (xix) Distribution Maps.

Conclusions

Securing food and nutritional security is now at the top of the agenda for most developing economies. But, there are major challenges and uncertainties to be confronted. This scenario requires a paradigm shift from current lock-in situations, *i.e.* focus on the four major crops such as maize, wheat, rice and soybean (the BIG 4) for our food and nutritional needs, to positions that transcend over-dependence on these crops. It is imperative, and perhaps incumbent on national governments, to utilize the existing spectrum of underutilized crops to diversify the food system towards a more sustainable food production system that meets current challenges in ecological and climatic vicissitudes. Outstanding R&D efforts over the years by various CGIAR Centers and National Agricultural Research Centers underpin the popularity and competitiveness of the BIG 4. Similar R&D efforts are also needed to mainstream the selected UUCs. However, there are critical data gaps on these UUCs. In that context, CABI's various knowledge management resources (e.g. e-books; compendias, factsheets and the GODAN Initiative), will largely leverage the existing knowledge repositories on UUCs in the public domain. These resources could also be effectively used to develop road maps for each country for food and nutritional security especially towards identifying and prioritizing the 'winners' amongst UUCs.

It is noted that there are major challenges that come with the opportunities pertaining to knowledge resources for UUCs. Specifically, this pertains to the availability, accessibility and deliverability of accurate and verifiable information that helps with identifying crucial gaps or bottlenecks in R&D. There are also still a number of fundamental data gaps (e.g. which species out of a suite of crops, their potential and realized crop yields; agronomic performances under various environmental vagaries). Therefore, a focused global effort is needed by all stakeholders to take the UUCs agenda forward. In that context, CABI has the expertise, gained over years, to provide the necessary resources to catalyse the R&D agenda for UUCs worldwide. This could fast-track and create new knowledge sharing platforms. There is also potential for big data analytics to be applied towards better informed decisions on various aspects of UUCs in future.

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The authors are thankful to APAARI's invitation to participate in this watershed Regional Expert Consultation on Underutilized Crops for Food and Nutritional Security in Asia and the Pacific. In particular, we thank Dr Ravi Khetarpal, the Executive Director, APAARI, and Dr Rishi Kumar Tyagi, Coordinator, Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB). We are also grateful to the contributions of Ms Andrea Powell, Chief Information Officer, CABI; Ms Cambria Finegold, Global Director, Knowledge Management, CABI and Dr Ulrich Kuhlmann, Executive Director, Global Operations, CABI.

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Forecast Application for Risk Management in Agriculture: Case Study from Tamil Nadu, India

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ABSTRACT: Agricultural production is largely dependent on static cultivation cycles make agriculture highly prone to the effects of climate. Climate risks to food security mainly arise from two sources – current climate variability including extremes and the threats posed by future climate change. Climate change may pose a serious threat to agriculture production in future if current agriculture practices are not adapted with changing climate. Underutilized plant species that can take advantage of the gaps in traditional crop cycles based on stationary seasonal cycles of past climate to mitigate climate change impacts should be identified and promoted. Weather and climate forecasts are very important for farmers to prepare immediate remedies to address unexpected change in weather in a short term and/or adjust their seasonal crop plan in the long-term. Capacity building of farmer's for utilization of forecast information and providing a user friendly platform to access state of the art location specific forecasts brings significant changes in the way farming practices are approached. The traditional crops have much more tolerance to the severe weather conditions and thus could be a better alternative for adaptation to climate change. Regional Integrated Multi Hazard Early Warning Systems (RIMES) took the initiative to build the capacity of farmer's through FARM School process and also develop an integrated platform "Specialized Expert system for Agro-Meteorological Early warning for climate resilient agriculture (SESAME) which enables broadcasting of weather information timely and integrates the domain knowledge of a farmer into the system to support him making his own decisions at critical stages of the crop lifecycle.

Key words: Climate knowledge, FARM School, SESAME, weather advisory

Introduction

Agriculture in a location or region has evolved over centuries as a combination of human needs and the physical environment controlled by soil, climate and ecology of the place. As technology and industries developed at a rapid rate since the beginning of the 20^{th} century, human needs started dictating agricultural development, pushing the role of physical environment into background as technology enabled unsustainable exploitation of earth's natural resources. Growing realization of the need to put such unsustainable development into an "environment friendly path" is now beginning to drive a change in agricultural systems. Climate knowledge is an important and primary driver that is likely to lead this change. Communities in various parts of the world have displayed complex adaptation strategies to deal with climatic variability by building water harvesting structures, water-regulating structures, and by resorting to agricultural strategies such as crop diversification (Shanmugasundaram *et al.,* 2017).

Climate change is expected to result in warmer temperatures, increased rainfall variability and extreme weather that may pose substantial additional risk to food security. Climate change is also

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accompanied by increased weather uncertainty (Lobo *et al.,* 2017). This may possess a serious threat to agriculture production in future if current agriculture practices are not adapted with changing climate. Nelson *et al.* (2009) reported that in South Asia rice production is set to fall by 14 per cent, wheat production by up to 49 per cent and maize production by up to 19 per cent by 2050. High water consumption cropping systems such as the paddy systems cannot be sustained on a large scale due to increasing climate stress. Life-style changes and enhanced health consciousness is opening up markets for coarse and climate resilient cereals. Such opportunities should be leveraged to usher shifts to climate-supported crops such as millets and oats that can sustain in harsher conditions of future.

Over time increasing productivity for a growing population was the main goal of agricultural systems. Optimizing food wastage and life-style changes towards optimized food consumption are also emerging factors that could force us to question quantity oriented agricultural production targets. This could again provide us opportunities to naturalize agricultural systems to native ecological conditions and leveraging climate information towards this end. Crop suitability is largely a climate-governed process where water plays a key role particularly in tropical and sub-tropical conditions.

In Tamil Nadu 40 per cent population depends on agriculture sector for livelihoods and thus growth of agriculture sector is key for inclusive development. Growth of agriculture sector since 1990s has been far below its potential. Stagnant agriculture sector when exposed to recurrent climate extremes becomes a serious development concern (UNDP, 2013). Traditional adaptive strategies of rural communities of Tamil Nadu, evolved to manage climate risk, are on decline. These strategies were built around conserving and utilizing moisture judiciously, relying on less water demanding coarse grains, adoption of mixed farming system (fodder-based livestock system), and collective sustenance with social adjustments (Shanmugasundaram *et al.,* 2017). All these adaptive strategies have been weakened over the last few decades due to over reliance on chemical fertilizers, hybrid seeds, pesticide intensive agriculture, neglect of traditional water harvesting structures, and reliance on high water consuming crops such as sugarcane, paddy over millets and coarse grains. Stagnant agriculture with weakening adaptive strategies of farmers render them more vulnerable to periodic climate shocks such as droughts, floods and storms. Consecutive multi-season drought events of 2002-2003 and 2016-2017 highlighted the need to have climate compatible agriculture development.

Despite the availability of state-of-the-art forecasts and outlooks at different lead-times, ranging from 3-days up to a season in advance, using such information to take decisions is still a challenge for the farmers. Under-utilization of forecast information is due to - information not reaching at a time when required most; information not clearly understood; and trust in the information to make critical decisions that involve financial consequences. For example, it is difficult for a small-hold farmer to change his usual cropping practice, unless he has confidence in the information he receives. Thus, it is required to build the capacity of farmers for utilization of the available weather and climate information products and apply the wealth of traditional knowledge to overcome the challenges bought by climate variability and change. To build the confidence of farmers', there is a need to capacitate them to better manage resources and risks through the utilization of climate information of different timescales. Forecast Application in Risk Management (FARM) School in agriculture process has been introduced by Regional Integrated Multi Hazard Early Warning Systems (RIMES) in Tamil Nadu with major goal and objective as follows:

Goal : Increased capacity of farmers to understand the weather forecast and make use of it in their regular farming operations.

Objective : To employs methodologies to make scientific processes related to weather and climate understandable to farmers and to enhance its utilization in regular farming activities.

This study presents, the process of FARM school training, the weather based advisory services developed for Tamil Nadu and, the feedback received from the trained farmers'. Weather based Agro Advisory Expert System is the efficient system that could minimize the potential impacts of weather/climate events through informed decision making. A case of how Agro Advisory could benefit farmers in Tamil Nadu is presented in the study.

Site Details

Tamil Nadu is the southern-most State (province) of India (Fig. 1), with a long coastline of over 1,000 km along the Bay of Bengal and the Indian Ocean forming the eastern and southern boundaries, exposing the State to tropical depressions, storms and cyclones. Water, however poses a larger problem. Deficient rainfall (921 mm compared to national average of 1,200 mm) leading to over-reliance on irrigation for agriculture, and increasing abstraction of ground water reserves (estimates show over 60 per cent of reserves are already exhausted) pose a big issue for the future. Tamil Nadu being a lower riparian State has to depend to a large extent on water from neighboring states, which are under greater pressure to increase exploitation of the rivers for their own irrigation purposes.

In Tamil Nadu, 37 million out of the 72 million population belong to rural areas and 90 per cent of the rural population is engaged in agriculture sector. Agriculture in Tamil Nadu enjoyed three decades of growth rate based on rapid technological changes. While agriculture growth rate in Tamil Nadu is the highest among the other States in India during 1980s and early 1990s, deceleration of growth since mid 1990s is a big concern for policy makers. Rice is the dominant crop in Tamil Nadu. Groundnut, sugarcane and cotton are important commercial crops. Sorghum (*jowar*), pearl millet (*bajra*) and pulses are some important food grains. The traditional growth in agriculture sector faces major constraints of water scarcity, increasing land degradation, declining farm sizes and rising cost of labour. Given these constraints diversification into high value, less water-intensive crops and products such as fruits, water, spices and livestock may be one of the promising sources of agriculture growth.

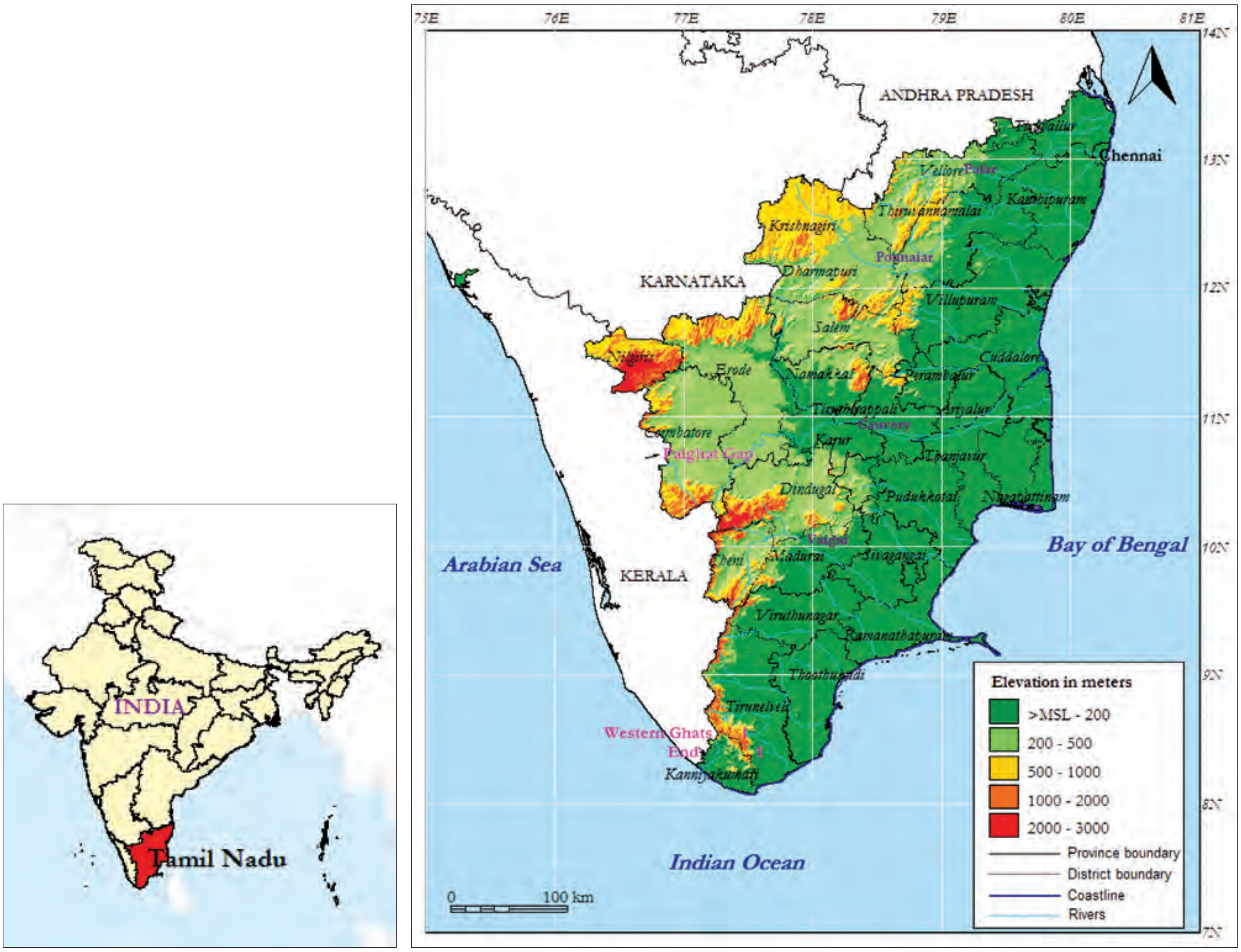

Fig. 1. Location map of Tamil Nadu

Climate related hazards affecting agricultural sector directly impact the production as well as livelihood of this huge population involved in agricultural sector. Around 65% of food grains crops such as paddy, millets and pulses are sensitive to rainfall fluctuations. During consecutive drought years most of the irrigation systems are dysfunctional and food grain production level goes down by almost 50 per cent. These climate shocks thus endanger food, income and nutritional security of these populations periodically. There needs to be a shift from water-intensive crops to coarse cereals with value-additions to meet emerging demands for coarse cereals and to reduce climate sensitivity.

Process Formulation

To build the confidence of farmers' for better managing resources and risks through the utilization of climate information of different timescales, Forecast Application in Risk Management (FARM) School in agriculture process has been introduced by RIMES and customized for the context of farmers in Delta districts of Tamil Nadu with help of local partners including Indian Meteorological Department (IMD), Department of Agriculture (DoA) and NGO partner Centre for Ecology and Research (CER). The customized curriculum was delivered to a selected group of Agriculture Officers who further deliver it to progressive farmers in the region. Thus a multi-tier learning process was followed. A web base platform "Specialized Expert system for Agro-Meteorological Early warning for climate resilient agriculture (SESAME)" was developed for the selected districts which enabled the registered users to access the location specific weather and climate forecast. The process of FARM School and salient features of SESAME are further explained in this section.

Forecast Application in Risk Management (FARM) School

The FARM School is a bottom-up processes designed to bridge the gap in relaying the information generated to the farmers and to make sure that the information is clearly understood in their specific farm context. Designed as a season-long series of interfacing sessions among forecasters, Agriculture officers, and farmers, the FARM School is a multi-tier learning-by-doing capacity building programme customized for farmers in specific areas. The main objective of the FARM school is to:

- Provide a mechanism for identification of farmers' information requirements for customizing/tailoring information products and services for the agriculture sector
- Facilitate regular and better access to enhanced information products and services by building on available channels of information communication/ dissemination, and harnessing extension workers-farmers network
- Enhance understanding, by farmers, of climate information of various timescales and build their capacity for seamless integration of the same into plans and decisions
- Establish a robust mechanism for regularly obtaining farmers' feedback concerning information products and services amidst evolving capacities and gaps, technologies, risks and other relevant concerns relating to agriculture

The FARM School process consist of a training that captures and describe the changes in weather and its effects to crop water demand, water supply availability, crop growth and yield, and incidence of pest and diseases. The training is fully field-oriented, participatory and discovery learning based with the field as primary learning material. A multi-cycle training approach is adopted which starts from the training of trainers (TOT) with experts from concerned agencies [e.g. Indian Meteorological Department (IMD)] and local experts identified by RIMES as trainers and agricultural officers at block level as trainees. It is followed by the training of first batch of farmers with the trained agricultural officers as trainers this time. Emerging "champion farmers" during the training are than utilized as resource speakers to support the agricultural technicians. A "champion farmer" is a trainee who is articulate, smart, and showed authority and leadership during the training session. In the process, the trained agricultural technicians could organize several sessions simultaneously in their respective area. In every session, the learning process outlined in Fig. 2 is utilized.

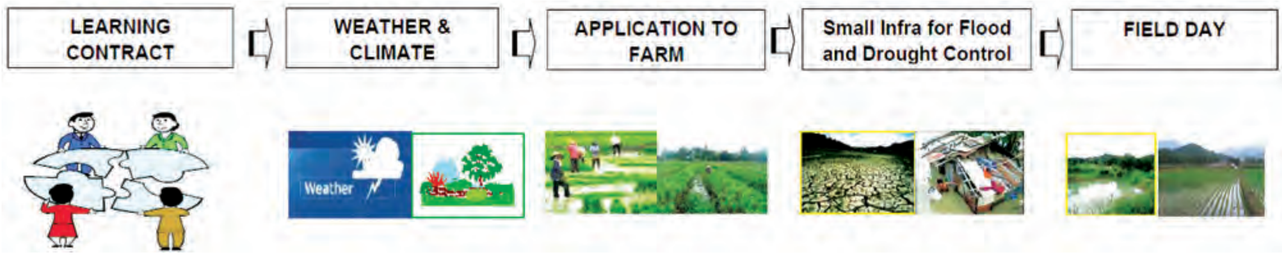

***Fig. 2.** The learning process flowchart*

For establishing the FARM School in Tamil Nadu, the training curriculum was customized for the context of Cauvery Delta region including Thanjavur, Thiruvarur and Nagapattinam districts. The training included four parts which consists of 12 modules as described below:

Part I: Human dimension of the learning process

- Module 1: Learning contract

Part II: Weather and climate and forecast products

- Module 2: Knowing weather and climate elements
- Module 3: Understanding weather and seasonal climate forecasts
- Module 4: Process of rain formation
- Module 5: Introduction to weather and climate measuring instruments and simple instrument fabrication and calibration
- Module 6: Field visit to a weather observation station

Part III: Application of climate information to farming operations

- Module 7: Field observation on weather, plant pests and diseases and growth conditions of plants
- Module 8: How to use climate information for setting up planting strategies
- Module 9: Leaning the field water balance concept and its use to assess irrigation requirements and flood risks

Part IV: Assessing economic value of climate information

- Module 10: Assessing economic value of climate information
- Module 11: Flood and drought control programme using low cost and location-specific technologies to address extreme climate events
- Module 12: Preparation for CFS field day

Training curriculum is designed to involve farmers in the process and make them learn from themselves. The process makes them to think about:

- the major challenges they face in farming
- the probable solutions for the problems
- who can really solve the problem (farmer himself, village community, Agriculture department or Government)

Farmer's get knowledge as well as identify the solutions for water management, pest management, relationship with crops and soil, and also learn to apply weather forecasts in routine farming activities as well formulate the advisories for their own field. Training material used for teaching the modules include power point lectures, hands outs for practice, exercise materials, pictures of various aspects of farming, weather and climate, instruments and tools. A proper balance of classroom teaching and field practice for practical knowledge was used during the training.

Specialized Expert System for Agro-Meteorological Early Warning for Climate Resilient Agriculture (SESAME)

SESAME is a web portal, developed for providing simplified Agro-meteorological bulletins to farmers for faster and effective decision-making. The tool can generate crop advisory with weather forecast information at four different time scales: a) seasonal (three months) outlook, b) Monthly outlooks, c) 10-day weather forecast (separated into two Pentads) and d) 3-day high resolution weather forecast. The system works with the idea of mapping the sensitivity of a specific crop to certain weather condition and comprehend how the weather in general, influencing the growth of a crop during the entire growth cycle. The tool is designed to be farmer-centric and requires very basic inputs to list out the all the scheduled activities for a selected crop for a season. The system gathers this knowledge, progressively and uses it to device the advisories for that crop for different weather conditions. The system thus is not limited to any specific crop rather scalable to include any number of crops with some historical knowledge about its characteristics. To meet this requirement the system combines a dynamic crop-weather calendar with sufficient information on the growth stages and sensitivity of the crop to different weather conditions.

SESAME has been customized and operationalized for selected districts of Tamil Nadu (Fig. 3). It serves as a platform to access forecasts on daily basis and apply the learning from the FARM School training to make information-based decisions for regular farming activities. The primary source of the forecast products shall be from the IMD, however, for the initial system integration and pilot testing, forecast products available at RIMES and European Center for Medium range weather forecast (ECMWF1) products are used for the Decadal, monthly and seasonal outlooks.

The advisories generated by SESAME includes:

- The weather information for the past season, month and decade and most recent observation data from the area to understand the current and recent history of weather condition.

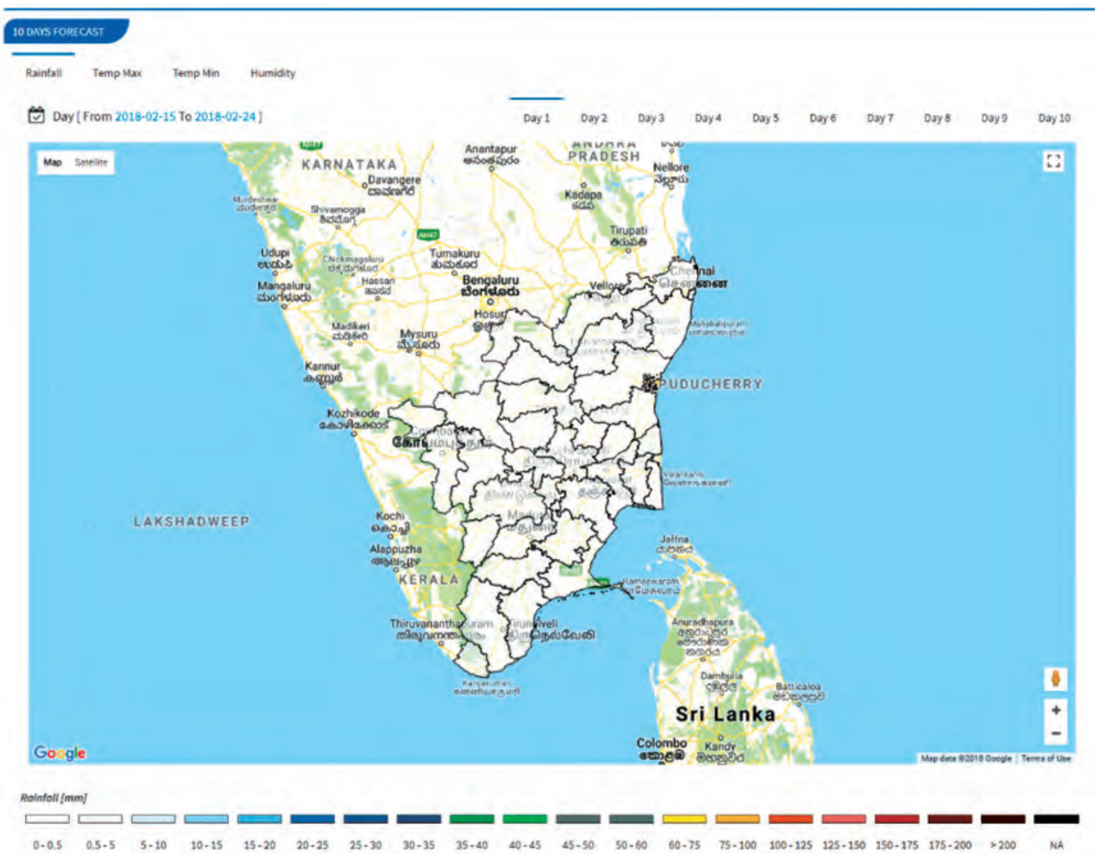

Fig. 3. *Tamil Nadu Agro Advisory System*

- Followed by outlook for the upcoming season, and with daily updates on the Pentads (five-day spells) and daily weather forecasts.
- The bulletin also includes information on the normal for the season, month, decadal, pentads.

Development of the contingency table requires involvement of all the user sectors, to quantify the sensitivity of the weather conditions to different cropping patterns, and crops. The farmers could share the information based on experience, while Agro-met officers can validate the information. The crop advisories are formulated then, following the contingency table.

Major Outcomes

Starting from the year 2012 various FARM Schools were organized in Tamil Nadu. To analyze the impact of FARM School training, and change it brings in the behavior of trained farmers, RIMES and CER teams had discussions with FARM School participants in their respective blocks and villages. The discussion was held with three groups of farmers' who attended the training in years 2012, 2014 and 2016. The outcomes of the discussion is presented below:

General Feedback

- FARM School process force participants to think and analyse what challenges they are facing and how these could be resolved.
- Farmers are now aware that so much information is available for free which could help them to take decisions for daily farming activities.
- Training imparted them with skills to use the weather forecasts and take decisions based on the forecast. This bought a holistic change in approach towards farming because of new level of understanding of forecasts.
- They are able to relate the agronomic practices to weather which was very nicely packaged in the training.
- Farmers are able to generate the advisories relevant to their own field based on forecast.
- Use of pesticides is significantly reduced as they are applying locally available organic materials to control pest and rodents.

Changes the Training Brought in Approach for Farming

Water Management

- After training irrigation is only need based. Now farmers do not panic as they know actually how much water their crop needs. Also they are aware whenever there is chance of rain. So they wait for the right time and irrigate only when it is required and also irrigate the right amount rather than just flooding the field.
- They regularly measure the rainfall in their fields. This approach saved several unnecessary hours of pumping in their block and bring efficient utilization of power and water.

Pest Management

- Most of the farmers significantly reduced the spraying of pesticides due to knowledge on IPM provided during FARM School.

Other Changes

- Farmers now have an attitude of a researcher and developed a strong bonding with their crops and field.

- They take care of their fields in a much better way.
- Attitude towards farming has completely changed and they feel much more confident than before. The income of all farmers has increased.

Weather and climate forecasts are very important for farmers to prepare immediate remedies to address unexpected change in weather in a short term and/or adjust their seasonal crop plan in the long term. The weather and climate forecast information include short-range, medium-range, long-range and seasonal weather forecasts. Twenty-four hour weather forecasts (e.g. "Rain or thundershower is likely to occur at a few places over Tamil Nadu Puducherry", IMD-Chennai) help farmers to plan their daily farming activities. On the other hand, climate seasonal forecasts in the form of probabilities of rainfall falling in any of the following three categories: above-normal, near–normal and below-normal help farmers to develop their cropping pattern and calendar in a given cropping season. It is important that farmers appreciate the usefulness of weather and climate forecasts in their farming operations and in crop planning and water budgeting.

After knowing weather and climate elements and information that could be utilized in farming operations, equally important forecasts of different timescales are provided. SESAME enable farmers to receive the location specific forecasts of different timescale from various sources at different resolution.

How Trained Farmers Managed the 2016 Drought Season?

The year 2016 was a drought year in Tamil Nadu and delta districts were among the most affected areas. Here are some examples on how the farmers managed during the drought.

- Seasonal forecast in October 2016 clearly indicated that north east monsoon will be below normal. Farmers discussed the matter with the CER team to seek advice whether to go with normal sowing of paddy as there was no clear advice from agriculture department. Instead of regular sowing of paddy farmers sow short duration pulses in this area. So when in other area farmers are suffering due to loss of their investment this area farmers got benefitted by taking right action at right time.
- Another interesting case happened in January 2017; there was a forecast for heavy rain when their pulse crops were ready for harvest. Farmers who follow the forecast harvested their crop early and saved the crop compared to farmers who did not harvest it before rain. The time required in wet field to harvest is much more than in dry field and so farmers who harvested after rain also paid much higher cost for harvesting machines.

Continuous Support

The process does not end with the training but it continues in form of weekly advisories, guidance, and regular support for farmers. It continues until farmers get the full confidence of transforming their traditional farming to climate/weather informed and need based farming. Within the villages farmers now take collective decisions for farming operations and thus support each other during critical periods. It removes the stress from farmer's to decide for farming activity with so much uncertainty around. Now they can better plan each activity well in advance and also have the capacity to adjust for any weather surprises. In case of any difficulty or doubt they know where to look for.

Conclusions

Capacity building of farmers' for utilization of forecast information and providing a user friendly platform to access state of the art location specific forecasts brings significant changes in the way farming practices are approached. This process could bring back the traditional crops, which are underutilized now, back to the fields as seen in Tamil Nadu during 2016. The traditional crops also have much more tolerance to the severe weather conditions and thus could be a better alternative for adaptation to climate change. The trained farmers are:

- able to identify climate-related issues and constraints with respect to their area;
- familiarize themselves on various climate elements and other climate-related terminologies;
- understand the importance of climate information and forecasts in annual farming operations;
- understand the concept, make simple analysis and interpretation of historical climate information;
- develop location-specific and cost-effective strategies to mitigate the impacts of extreme climate events;
- assess the economic value of climate information and forecasts; and disseminate new knowledge and learning to facilitate broader adoption.

The major challenges and opportunities lies ahead are:

- Understanding interaction of development patterns and climate variability over a long term could enable us to manage risks as well as resources efficiently. Climate forecasts on a seasonal, monthly and daily scale could be useful to anticipate and manage climate/ weather associated risks. Climate variability associated knowledge could guide long term development process holistically in a given micro-climate and socio-economic setting through decentralized climate variability management approach.
- Decentralized climate variability management approach, by building up resources during the period of normal or above normal seasons and draw them during sub-normal or low rainfall years is the basic principle behind traditional livelihood practices to cope with climate risks. Farmers of Tamil Nadu used to build up food / fodder / water reserves during normal/excess rainfall years in order to draw reserves anticipating subsequent 2-3 drought years. The assured State interventions particularly during drought emergencies, relies on the transfer of resources-food, water, fodder etc., from distant places to drought affected zones in the last four decades and its continuance even during normal years rendered traditional climate friendly resource management practices redundant. A centralized resource transfer based drought management approach needs to be complimented or replaced by decentralized *in situ* resource regeneration based decentralized climate variability management practices.
- It is not possible to revert back to traditional practices, as the current socio-economic political context has changed from the past. However recent experiences of stakeholder led community based institutions' resource management practices could provide opportunities to revitalize traditional practices.
- There are discernible positive trends in recent years to revitalize climate compatible traditional cropping systems e.g. millets particularly in rain fed zones. High nutritional content and adaptability to adverse soil and climatic conditions with positive marker signals led the promotion of millets to a significant scale in recent years. The millets provide multiple securities as food, fodder, health, nutritional and livelihood.

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Strategic Papers

Strategies on Underutilized Crops for Food and Nutritional Security: Pseudocereals

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ABSTRACT: Presently, ICAR-NBPGR, New Delhi is coordinating the All India Coordinated Research Network on Potential Crops (AICRN-PC) and conducting research on 17 crops of food, fodder and industrial value through 14 main, nine cooperating and 15 voluntary centers located in diverse agro-climatic zones of India. Over a period of more than three decades, a germplasm holding of 6,472 accessions of pseudocereals *viz*., amaranth (5317 accessions), buckwheat (938) and chenopods (217) have been collected and introduced, characterized and conserved in the National Gene Bank at ICAR, NBPGR, New Delhi, and Medium Term Facility, ICAR-NBPGR, Shimla. In buckwheat, *Fagopyrum tataricum*-'Himgiri' and 'Himpriya' have been developed. Unique germplasm in buckwheat (easy de-hulling) and chenopodium (brown seed) have been registered. Research and development thrust are needed in grain amaranth (lodging, seed size, seed shattering, insect resistance), buckwheat (lodging, de-hull, asynchronous maturity, self-incompatibility, seed size, colour, shattering, bitterness, phenols) and in chenopods (seed size, colour, shattering, lodging and saponin).

Key words: Food and nutritional security, Under-utilized crops.

Introduction

The growing world population and the challenges posed by climate change demand increase in the food production. It is estimated that 1.2 billion people in the world do not have enough food to meet their daily requirements and a further 2 billion people are deficient in one or more micro-nutrients. In addition, loss of agro-biodiversity and farmers' dependence on a few highly selective crops resulting in narrow food baskets, have also caused food and nutritional insecurity. The under-utilized crop (UUC) species are neglected and unused crops that are domesticated plant species and have been used for centuries for their food, fibre, fodder, oil or medicinal properties, but have been neglected over time due to constraints in their production, supply and use. These crops are being displaced because of pressure from imported species, demography and household structural changes. However, they have the potential to contribute to the mix of food sources and improvement of food security. The provide a basis for more productive and resilient production systems that are able to cope with various climatic changes and biotic and abiotic stresses. Globally more than 100 species have been grouped as UUC. These comprise cereals and pseudocereals (13 species), fruit and nut (33 species); vegetable and pulse crops (33 species), root and tuber crops (17 species), and oilseed crops (16 species).

In view of the dangerously narrow food base, which could imperil the existence of human kind during a time of crisis, a global concern was raised with emphasis on crop diversification through exploitation of underutilized, neglected and lesser known life support species and new crop resources.

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Some of these crops are rich sources of protein, amino acids, minerals and vitamins. Thus, the role of underutilized crop species in enlarging the basis of food and nutritional security is a global issue and "promoting development and commercialization of UUC and species" was adopted as one of the six activities of the Global Plan of Action by the IV International Technical Conference on Plant Genetic Resource held at Leipzig, Germany in 1996. It is now well realized at national, regional and global levels that agricultural production can be sustained/enhanced through the use of underutilized and underexploited plant species. Consequently, throughout the globe, there has been emphasis on introduction, evaluation and utilization of under-exploited crops that can adapt themselves to different environmental and degraded soil conditions and ensure food and nutritional security. In the developing countries which are diversity rich and have enormous indigenous knowledge, the research and development in under-utilized species is increasing due to their robustness and adaptability to local agro-ecosystems, farming systems, and degraded and marginal lands.

In India, Indian Council of Agricultural Research (ICAR), with a view to exploit the potential of UUC/ lesser-known plants initiated the organized work in 1982 with the establishment of the All India Coordinated Project on Under-utilized Crops (AICRP-UUC) with emphasis on crops such as amaranth, buckwheat, chenopods, cluster bean, winged bean etc. at Indian Agricultural Research Institute (IARI), New Delhi and later on at National Bureau of Plant Genetic Resources (NBPGR), New Delhi. The network is now rechristened as All India Coordinated Research Network on Potential Crops (AICRN-PC). The main objective is to generate improved technologies in selected crops of the minor economic importance for food, fodder and industrial use. Presently, ICAR-NBPGR, New Delhi is coordinating the network as a coordinating unit and conducting research on 17 crops of food, fodder and industrial value through 14 funded, nine cooperating and 15 voluntary centers located in diverse agro-climatic zones of India.

The project envisages: (i) to identify new plant resources for food, fodder and industrial use, (ii) to collect, introduce, characterize, evaluate and conserve plant genetic resources, (iii) to develop high yielding varieties for different farming systems, and (iv) popularization of such UUC in newer areas, besides taking up transfer of technology related activities to promote their cultivation. Since the inception of the project, the major thrust of research has been to address the local needs of region specific UUC. Considering the native diversity available in these species in India and the potential of introducing diverse genetic resources from different countries, efforts were made to identify species which could fit well in different areas as new crops, and their acceptability by the farming communities. In addition, significant efforts were also made for introducing and acclimatizing new UUC. The following crop species have been prioritized under the project:

Crop group	Crop	Botanical name
Pseudocereals	Grain Amaranth	*Amaranthus* spp.
	Buckwheat	*Fagopyrum esculentum* Moench; *F. tataricum* Gaertn.
	Grain Chenopods	*Chenopodium album* L. for plains; *C. quinoa* Willd. for hills
Minor cereals	Job's Tear	*Coix lacryma-jobi* L.
Food Legumes	Rice Bean	*Vigna umbellata* (Thunb.) Ohwi & Ohashi
	Faba Bean	*Vicia faba* L.
	Adzuki Bean	*Vigna angularis* (Wild.) Ohwi & Ohashi
	Winged Bean	*Psophocarpus tetragonolobus* (L.) DC.
Vegetables	Spiny Gourd (*kankoda*)	*Momordica dioica* (Roxb.) ex. Wild
	Wild watermelon (*kalingada*)	*Citrullus lanatus* (Thunb.) Matsum. & Nakai
Oilseeds	Perilla	*Perilla frutescens* L.
	Simarouba	*Simarouba glauca* DC
	Colocynth (*tumba*)	*Citrullus colocynthis* (L.) Schrad
	Jatropha	*Jatropha curcas* L.
	Jojoba	*Simmondsia chinensis* (Link.) Schneid

Potential of Pseudocereals

The important traits associated with pseudocereals include their wide adaptability, higher nutritional value, medicinal value, resilient in nature and tolerance to biotic and abiotic stresses. The nutritional status (protein, carbohydrate, lipid, crude fibre, mineral matter, calcium, potassium and iron content) of pseudocereals and the comparative values for wheat and rice are given in Table 1. The essential amino acid composition of amaranth and buckwheat versus wheat, rice and milk is presented in Table 2.

Table 1. Nutritional status of pseudocereals (per 100g) in comparison to staple cereals

	Protein (g)	Carbohydrates (g)	Lipid (g)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Pseudocereals								
Amaranth	16.0	62.0	8.0	2.43	3.0	490	600	17.5
Buckwheat	13.0	72.9	7.4	10.5	2.1	120	280	15.5
Chenopodium	14.0	65.0	7.0	-	3.0	-	-	-
Staple cereals								
Wheat	12.0	69.0	1.7	1.2	2.7	41	306	5.3
Rice	6.7	68.0	0.3	0.2	0.3	45	160	3.5

Table 2. Essential amino acid composition (g/ 100g protein) in amaranth and buckwheat in comparison to wheat, rice and milk

	Lysine	Methionine	Cystine	Isoleucine	Leucine
Pseudocereals					
Amaranth	5.0	4.0	4.0	3.0	4.7
Buckwheat	6.2	1.6	1.6	3.7	6.2
Wheat	2.8	1.5	2.2	3.3	6.7
Rice	3.8	2.3	1.4	3.8	3.2
Milk	5.8	3.7	2.1	5.0	7.3

ICAR-NBPGR is the nodal organization for management of plant genetic resources in India. Over a period of more than three decades, a germplasm holding of 6,472 accessions of pseudocereals *viz*., amaranth (5,317 accessions), buckwheat (938) and chenopods (217) have been collected/ introduced, characterized and conserved in the National Gene Bank at ICAR-NBPGR, New Delhi, India. Crop-wise status of germplasm holdings is given in Table 3. Pseudocereals germplasm are being maintained in the Medium Term Storage (MTS) facility at ICAR-NBPGR Regional Station, Shimla (Table 4).

Table 3. Status of germplasm of pseudocereals in the National Genebank, ICAR-NBPGR, New Delhi

Crop	Accessions (no.)	Species
Amaranthus spp. (Amaranth)	5,317	*Amaranthus amora* (6), *A. blitum* L. (23), *A. caudatus* (181), *A. cruentus* (196), *A. dubius* (59), *A. edulis* (1), *A. fimbriatus* (2), *A. flavus* (1), *A. gangeticus* (26), *A. hybridus* (85), *A. hypocondriacus* (3,027), *A. leucocorpus* (2), *A. palmeri* (3), *A. paniculatus* (17), *A. polygonoides* (4), *A. retroflexus* (5), *Amaranthus* sp. (1,269), *A. spinosus* (31), *A. tricolor* (325), *A. viridis* (54)
Fagopyrum spp. (Buckwheat)	938	*Fagopyrum esculentum* (528), *F. emarginatum* (1), *F. himalianum* (8), *Fagopyrum* sp. (5), *F. tataricum* (396)
Chenopodium spp. (Chenopods)	217	*Chenopodium album* (124), *C. botrys* (8), *C. giganteum* (2), *C. hybridum* (4), *C. quinoa* (18), *Chenopodium* spp. (61)

Table 4. Status of pseudocerealsin MTS Facility, ICAR-NBPGR, Shimla

Crop	Accessions (No.)	Species (accessions)
Amaranthus spp. (Amaranth)	2825	*Amaranthus hypochondriacus* (2,700), *A. caudatus* (12), *A. cruentus* (51), *A. dubius* (8), *A. edulis* (10), *A. hybridus* (19), *A. lividus* (4) *A. spinosus* (4) *A. tricolor* (12), *A. viridis (5)*
*Fagopyrum*spp. (Buckwheat)	849	*Fagopyrum esculentum* (239), *F. tataricum* (597), *F. cymosum* (3), *F. emarginatum* (1), *F. gigantium* (2), *F. himalianum* (7)
Chenopodium spp. (Chenopods)	204	*Chenopodium album* (191), *C. quinoa* (13)

Grain Amaranth

The use of grain amaranth especially as food has caused major expansion of cultivation in the USA and Canada. It is a major cash crop in the high-altitude Himalayan region, where the farmers barter its grains for twice to thrice the amount of wheat or rice grains. The grains are used for making bread, biscuits, flakes, cake, pastry, ice cream and lysine rich baby foods. It is an excellent source of iron and β-carotene and being rich in folic acid increases the blood hemoglobin. The lysine content in seed proteins is as much as in milk (5%) but is higher than in cereals. Amaranth oil containing squalene has been suggested as an alternative to marine animals as a natural source of squalene. It is used in cosmetics as a skin penetrant and also used as lubricant for computer discs. It is also useful in the treatment of diseases viz., measles, snake bite, foot and mouth disease of animals, kidney stone, chest congestion, piles etc. *AMA-1* gene for high quality protein has been isolated and introduced in rice and potato. Its high grain yield, superior nutritional composition, diversified use, wider adaptability and suitability to low input conditions makes it indispensable for future sustainable agriculture.

Evaluation of germplasm accessions/breeding lines of amaranth revealed great diversity with respect to inflorescence color, inflorescence length, plant height and leaf length etc. Some of the promising accessions to different agro-morphological traits are given in Table 5.

Table 5. Range of variation for agro-morphological traits in grain amaranth germplasm at ICAR-NBPGR, Shimla

Trait	Range	Mean ± SE	Promising accessions
Days to flowering	58-116	90.76 ± 0.59	IC382253, IC382748, IC381185
Plant height (cm)	100.5-330.5	248.18 ± 1.72	IC363742, IC415220, IC415236
Infl. length (cm)	29.3-197.4	75.58 ± 0.73	IC398233, IC415222, IC415224
Days to maturity	124-175	156.52 ± 0.36	IC328903, EC519556, IC260313
1000-seed wt. (g)	0.30-0.95	0.69 ± 0.01	IC321282, IC363767, IC363768
Seed yield/plant (g)	10.00-186.39	49.24 ± 1.09	IC362199, IC313250, IC313270

Two accessions namely IC20306 and IC07920 with long Inflorescence have been identified (Fig. 1). Also, grain amaranth accessions IC333211, IC341505, IC321281, IC329550 have been identified superior for multiple traits *viz.*, plant height, inflorescence length and seed yield/plant.

Varieties developed/released in grain amaranth: Multilocation evaluation of germplasm/breeding lines has led to identification and release of 12 varieties and standardization of their cultivation practices for different regions of the country. These varieties have been released for grain purpose (Fig. 2). They comprise six varieties for hills (Annapurna, Durga, VL Chua 44, PRA-1, PRA-2, PRA-3) and six varieties for plains (GA-1, Suvarna, GA-2, BGA-2, GA-3, RMA-4).

Cropping systems developed: Different cropping systems have been developed for different regions of the country. These include:

Fig. 1. *Amaranth accessions IC20306 and IC07920 with long inflorescence*

Fig. 2. *Varieties released in grain amaranth*

- The crop can be grown as a pure crop as well as inter crop.
- In hills, the crop can be suitably grown as a mixed crop with either maize, small millets, French bean or other beans. The best economic yields can be obtained when amaranth and French bean are grown in the ratio of 1: 2.
- In Western India, as a pure crop, the benefit:cost ratio has been recorded to be higher than wheat, potato and chickpea at farmers' fields.
- In Tamil Nadu, and Odisha, inter-cropping with pigeon pea has been found to be most profitable.
- Some of the cropping systems of tribals include mixed cropping of local grain amaranth variety in millets; grain amaranth, HYV in millets; and grain amaranth and maize.

Some of the value added products which can be prepared from grain amaranth include popped grain *laddus, chapathi, chikkies*, biscuits, snacks etc. Efforts are on for the popularisation of amaranth in non-conventional areas in Tamil Nadu.

In view of the great potential of grain amaranth, the following points need to be considered

- Awareness programmes for the public about the nutritional benefits of grain amaranth.
- Extension activities to popularize the growing and use of the grain.
- Explore the market potential for value added products of grain amaranth.
- Make the crop more profitable compared to other existing crops.

Buckwheat (also known as *Ogla, Phaphra, Bharesha*)

The plant has a medicinal value and due to presence of a glucoside called 'rutin' which strengthens blood vessels and is also used in the treatment of several other diseases. It is an excellent source of lysine. Evaluation of germplasm accessions/breeding lines of buckwheat revealed diversity with respect to inflorescence color, inflorescence length, plant height and leaf length etc. Some of the promising accessions of buckwheat to different agro-morphological traits are given in Table 6.

Table 6. Range of variation for agro-morphological traits in buckwheat germplasm maintained at ICAR-NBPGR, Shimla

Character	Range	Mean ± SE	Promising accessions
Plant height (cm)	36 - 195	95.73 ± 1.65	RSR/SKS-41, EC286379, EC18225
No. of inflorescence/plant	4 - 36	13.52 ± 0.29	IC321798, IC294344, IC026596
Days to maturity	74 - 149	127.97 ± 0.76	JCR-2134, IC321798, IC013531
No. of seeds/ inflorescence	2 - 9	4.21 ± 0.07	EC321798, IC013140, IC204020
Seed yield/plant (g)	0.2 - 3.3	1.15 ± 0.04	EC018225, EC321798, EC286379

Also, the buckwheat accessions EC286379, EC329178 and IC026596 are superior for multiple traits including number of inflorescence per plant, days to maturity, seed yield per plant and plant height. Two varieties of *Fagopyrum tataricum,* namely Himgiri and Himpriya have been developed under AICRN-Potential Crops. The mean grain yield of these varieties in North-Western hills is 10.67 and 9.89 q/ha respectively.

Although buckwheat holds great promise, deserving exploitation both as a food grain crop and for medicinal purposes, its potential has not been harnessed even partially through judicious introduction and intensive breeding programmes. Utilization of buckwheat crop for extraction of rutin and its grain for developing various value added products will definitely encourage buckwheat production on a large scale and will be economically remunerative to the resource poor hill farmers who cannot afford costly inputs required for raising other commercial crops. In view of the recent emphasis on the promotion of organic farming in the Himalayan states, buckwheat could become a major component of sustainable agriculture due to its low nutrient demand that can largely be met from organic sources.

Chenopods

The grain chenopod is more nutritive than staple cereals and is equivalent to whole dried milk. Chenopodium contains etherel oil, a substance resembling cholesterol, ammonia and amines in both free and combined forms. Chenopods contain exceptionally high lysine comparable with animal food sources and have higher amount of methionine and cystine. A great diversity exists in *Chenopodium quinoa* (Fig. 3). Some of the promising accessions of chenopods with agro-morphological traits in the germplasm maintained at ICAR-NBPGR, Shimla are given in Table 7.

Table 7. Range of variation for agro-morphological traits in chenopods germplasm maintained at ICAR-NBPGR, Shimla

Character	Range	Mean ± SE	Promising accessions
Infl. length (cm)	29.05-62.66	45.35 ± 0.86	IC108819, IC109731, EC359449,
Leaf length (cm)	4.10-17.20	13.08 ± 0.31	EC359449, IC258332, EC349447
Leaf width (cm)	2.20-18.10	11.05 ± 0.50	EC359449, EC349447, EC359448
Days to 80% maturity	101-155	128.11 ± 2.21	IC415477, IC381078, NIC22488
1000-seed weight (g)	0.40-1.30	0.69 ± 0.03	IC415477, IC415402, IC415494
Seed yield/plant (g)	2.58-100.12	22.95 ± 2.58	IC415477, NIC-15022, NIC-22492

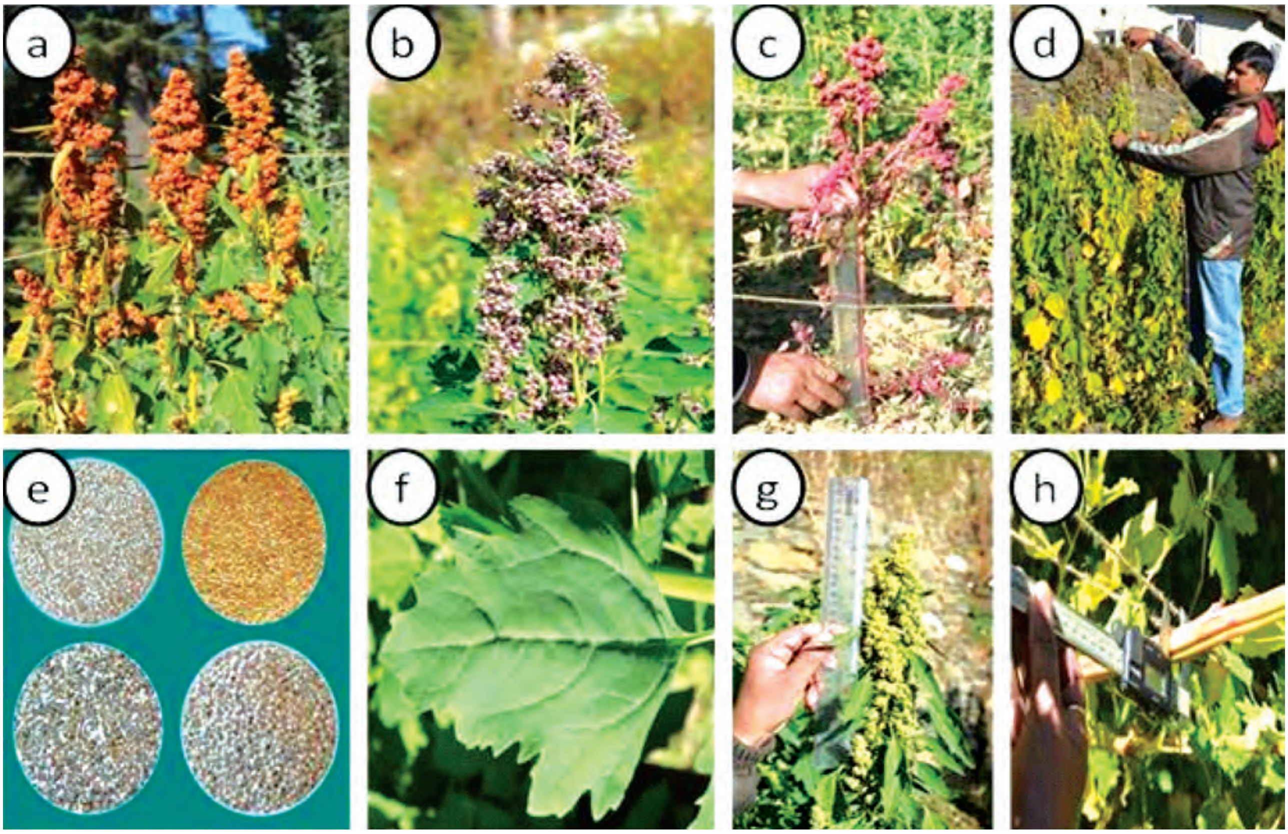

Fig. 3. *Diversity in Chenopodium quinoa; distinct morphological traits - a, b, c different inflorescence colors, d - plant height; e - seed colors, f - leaf length and width, g - inflorescence length and h - stem diameter*

Chenopod accessions IC108817, IC108819, IC415477 and IC341703 have been identified superior for multiple traits viz., days to 80 per cent maturity, seed yield/plant, seed weight and plant height. The high nutritional quality of chenopods, their wider adaptability, multifarious utility coupled with low nutrition demand make them one of the important candidates for future sustainable agriculture.

Registration of unique germplasm: Two accessions from ICAR-NBPGR Regional Station, Shimla; one in buckwheat for easy de-hulling and another in chenopodium for brown seed colour have been registered.

Buckwheat: Easy dehulling type (INGR No. 04034): Tartary buckwheat has a tightly adhering hull that makes it difficult to dehull and contains a bitter component that affects its palatability. IC 258233, a unique accession, easy dehulling type has been registered. In this the hull can be removed to get white kernel just by rubbing the seeds with hand, thus a useful breeding material to diversify the uses of tartary buckwheat.

Chenopod: Brown seeded (INGR 04093): An accession IC258253 registered had been collected from Pangi (Himachal Pradesh) and found to have brown to whitish seed colour. Its high seed yield is at par with other high yielding varieties of black seeded chenopods. Also, the lower plant height and early maturity are the added advantages of this genetic stock.

Perspectives

- Need to diversify the present day cropping system with alternative crops of future potential that are well-endowed with specific traits for producing reasonable yield and also their conservation and management.
- Introduction of lesser known exotic plants which have potential value. Need for concerted efforts on evaluation, utilization, maintenance, conservation and documentation of available

diversity in under-utilized species of pseudocereals by strengthening the coordinating institutes and industries.

- Researchable issues: Over all, yield increase is the primary objective for all these crops. Traits which need to be improved in pseudocereals include:

  (i) Grain amaranth: lodging, seed size, seed shattering, insect resistance (*Spoladeare curvalis* – amaranth caterpillar)

  (ii) Buckwheat: lodging, difficult to de hull, asynchronous maturity, self-incompatibility, seed size, colour, shattering, bitterness, phenols.

  (iii) Chenopods: seed size, colour, shattering, lodging and saponin content

- Need to promote research and development in UUC through regional networks, to include at least species of inter-regional interest such as amaranth, buckwheat, rice bean, adzuki bean, faba bean several minor fruits, vegetables and others in the South, South-East and East Asia.

Underutilized Climate-Smart Nutrient Rich Small Millets for Food and Nutritional Security

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ABSTRACT: Small millets such as finger millet, foxtail millet, proso millet, kodo millet, little millet and barnyard millet are considered as climate-smart and nutrient rich crops. They have diverse adaptation and play an important role in food and nutritional security in rural households in areas where these crops are grown globally. However, their presence in the food basket has been declining over the years, mainly because of the increased availability of rice and wheat, lack of crop improvement efforts in developing high yielding cultivars, and lack of modern technologies for processing and utilization. Over the last few years, there is an increasing recognition of their nutrient composition and benefits as healthy food. Considering their diverse adaption and agronomic and health benefits, small millets could be an alternate/supplement crop to widen food basket to ensure food, feed and nutritional security. More research effort in germplasm collecting, conserving, evaluating and utilizing, and developing high yielding cultivars, processing and utilization technologies, and policy innervations are required to promote small millets cultivation, and for food and nutritional security of vulnerable population under climate change scenario for sustainable agriculture.

Key words: Climate change, climate-smart crop, germplasm resources, small millets

Introduction

Small millets, also called as minor millets, include the group of small seeded millets such as finger millet, foxtail millet, proso millet, kodo millet, little millet and barnyard millet (Table 1, Fig. 1). These crops were grown globally in a limited acreage, and are used as food, feed and fodder purposes. Small millets have several agronomic advantages, including diverse adaptation, less affected by biotic and abiotic stresses, short-duration, high water use efficiency, drought tolerance, etc. and play an important role in supporting marginal agriculture. Small millets are the source of important food grain in their areas of cultivation, while their straw is highly valued as fodder. Many kinds of traditional foods and beverages are made from these crops and play an important role in the local food culture. Nutritionally, small millets are characterized by high micronutrient content, particularly rich in calcium and iron, and high dietary fibre. The nutraceutical value of small millets' grains, because of their high dietary fibre and low glycemic index, is receiving increasing attention.

Small millets are under-utilized and under-researched crops and continued to be neglected in terms of support for production, promotion, research and development. Their presence in the food basket has been declining over the years. One of the main reasons for this decline is the increased availability of other staple and commercial crops such as rice, wheat, maize, etc. The lack of crop

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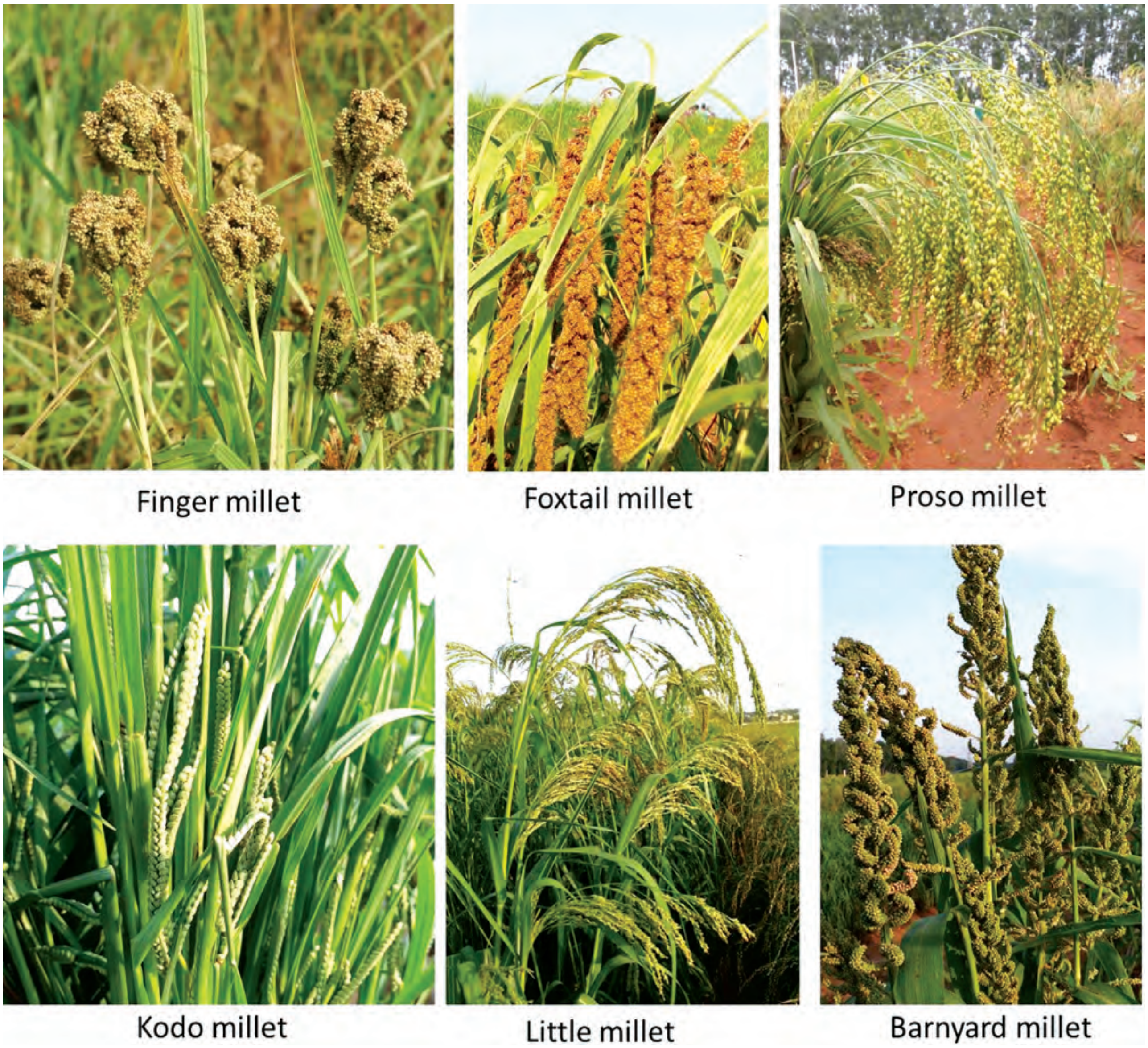

Fig. 1. *Small millets: (top row; L to R) Finger millet, foxtail millet, proso millet; (bottom row; L to R) prodo millet, little millet and barnyard millet.*

improvement efforts in developing high yielding cultivars and lack of modern technologies for seed processing and utilization are also the main reasons for their declining importance. Over the last few years, there is an increasing recognition of their nutrient composition and benefits as healthy food. Thus, apart from their continued strategic role as staple for the poor in marginal agricultural regions, they are also assuming a new role as a health food for the urban high-income people. More research efforts in developing high yielding cultivars, processing and utilization technologies, and policy innervations are required to promote cultivation and consumption of these underutilized grains for sustainable agriculture and healthy lives.

Origin and Domestication

Finger millet [*Eleusine coracana* (L.) Gaertn.] is an allotetraploid evolved from its wild progenitor, *E. africana*. Domestication of cultivated finger millet started around 5,000 years ago in Western Uganda and Ethiopian highlands and the crop has extended to Western Ghats of India around 3,000 BC (Hilu *et al.,* 1979; Hilu and de Wet, 1976). Foxtail millet [*Setaria italica* (L.) P. Beauv.] is a member of the subfamily Panicoideae and the tribe Paniceae. The green foxtail (*S. viridis*) is a wild ancestor of cultivated foxtail millet. Foxtail millet is grown since >10,500 years ago in China (Yang *et al.,* 2012). Several hypotheses regarding the origin and domestication have been proposed and a multiple domestication hypothesis (China, Europe and Afghanistan-Lebanon) has been widely accepted (Li *et al*., 1995). Proso millet (*Panicum miliaceum* L.) is an annual herbaceous plant in the genus *Panicum.* Vavilov (1926) suggested China as the centre of diversity for proso millet, while Harlan (1975) suggested that proso millet probably was domesticated in China and Europe. The earliest records come from the Yellow River valley site of Cishan, China dated between 10300 and 8700 cal BP (Lu *et al.,* 2009). Evidence of proso millet also occurs at the number of pre-7000 cal BP sites in Eastern Europe, in the form of charred grains and grain impressions in pottery (Hunt *et al.,* 2008). These two centres of earlier records suggest independent domestication of proso millet in eastern Europe or Central Asia or may have also originated from a domestication within China and then spread westward across the Eurasian steppe (Hunt *et al.,* 2011; Jones, 2004). Hunt *et al.* (2014) suggested the allotetraploid origin of proso millet with the maternal ancestor being *P. capillare* (or a close relative) and the other genome being shared with *P. repens*, however, further studies of *Panicum* species, particularly from the Old World are required. Little millet (*Panicum sumatrense* Roth. ex. Roem. & Schult.) was domesticated in India particularly important in the Eastern Ghats of India, where it forms an important part of tribal agriculture (de Wet *et al.,* 1983a). In barnyard millet, two species namely *Echinochloa crus-galli* and *E. colona* are cultivated as cereals. *E. crus-galli* is native to temperate Eurasia and was domesticated in Japan some 4000 years ago, while *E. colona* is widely distributed in the tropics and subtropics of the Old world, and was domesticated in India (de Wet *et al.,* 1983b). Kodo millet belongs to the genus *Paspalum,* a diverse genus comprising about 400 species, most of which are native to the tropical and subtropical regions of the Americas, and the main center of origin and diversity of the genus is considered to be South American tropics and subtropics (Chase, 1929). Kodo millet was domesticated in India some 3000 years ago and cultivated by tribal people in small areas throughout India, from Kerala and Tamil Nadu in the south, to Rajasthan, Uttar Pradesh and West Bengal in the North. It occurs in moist or shady places across the tropics and subtropics of the Old World (de Wet *et al.,* 1983c).

Racial Diversity

Small millets have considerable within specific diversity and are further subdivided into races and subraces based on comparative morphology of accessions. The species *E. coracana* consists of two subspecies, *africana* (wild) and *coracana* (cultivated). The subsp. *africana* has two wild races, *africana* and *spontanea*, while subsp. *coracana* has four cultivated races; *elongata*, *plana*, *compacta*, and *vulgaris*. These cultivated races are further divided into subraces; *laxa*, *reclusa*, and *sparsa* in race *elongata*; *seriata*, *confundere*, and *grandigluma* in race *plana*; and *liliacea*, *stellata*, *incurvata*, and *digitata* in race *vulgaris*. The race *compacta* has no subraces (de Wet *et al.,* 1984; Prasada Rao and de Wet, 1997). Prasada Rao *et al.* (1987) suggested three races of foxtail millet based on the comparative morphology of the foxtail millet accessions: (i) *moharia* (ii) *maxima* and (iii) *indica*. These races can be further divided into ten subraces (*aristata*, *fusiformis*, and *glabra* in *moharia*; *compacta*, *spongiosa*, and *assamense* in *maxima*; and *erecta*, *glabra*, *nana* and *profusa* in *indica*). Proso millet can be divided into five races; *miliaceum, patentissimum, contractum, compactum* and *ovatum* (de Wet, 1986*).* Little millet has two races; *nana* and *robusta*, and two subraces each; *laxa* and *erecta* in *nana,* and *laxa* and *compacta* in *robusta* (de Wet *et al.,* 1983a). The species *E. crus-galli* is classified into two subspecies; *crus-galli* and *utilis,* four races; *crus-galli* and *macrocarpa* in subsp. *crus-galli*, and *utilis* and *intermedia* in subsp. *utilis*. Similarity, *E. colona* has two subspecies, *colona* and *frumentacea*. The subsp. *colona* has no races and subsp. *frumentacea* is divided into four races: *stolonifera, intermedia, robusta* and *laxa* (de Wet *et al.,* 1983b). Kodo millet has three races namely *regularis*, *irregularis* and *variabilis* (de Wet *et al.,* 1983c).

Small Millets Cultivation and Production Status

Small millets contribute considerably to the total global millets production; however, area and production of small millets are usually merged with pearl millet and called together as 'millets'. Foxtail and finger millets rank second and third after pearl millet, respectively in total world production of millets (http://www.cgiar.org/our-research/crop-factsheets/millets/). Finger millet is grown in more than 25 countries in eastern and southern Africa, and across Asia from the Near East to the Far East. The major finger millet producing countries are Uganda, India, Nepal and China. In India, finger millet was grown in about 1.13 m ha with a production of 1.88 million tons during 2014. In Nepal, finger millet is the fourth major cereal crop, cultivated in 0.27 million ha with an annual production of 0.31 million tons. Foxtail millet is widely cultivated in Asia, Europe, North America, Australia and North Africa for grains or forage, and an essential food for human consumption in China, India, Korea and Japan (Austin, 2006). China ranks top in foxtail millet production with 1.81 million tons from 0.72 m ha during 2014. Though considerable yield improvement has been made in China, area under foxtail millet cultivation has been reduced from 9.2 m ha in 1949 to 0.72 m ha in 2014, with corresponding decrease in grain yield from 7.79 m tons to 1.81 million tons, respectively because of low grain yielding potential and other marketing factors (Diao, 2017). In India, foxtail millet is cultivated mostly in Telangana, Andhra Pradesh, Karnataka, Rajasthan, Madhya Pradesh, Tamil Nadu and Chhattisgarh. Proso millet is grown in Asia, Australia, North America, Europe and Africa, and used for feeding birds and as livestock feed in the developed countries and for food in some parts of Asia (Rajput *et al.,* 2014). The total cultivated area of proso millet in the United States is approximately 0.20 million ha, and most of the proso millet crop is utilized for birdfeed and in cattle-fattening rations. The United States is among the top producers and exports 15–20 per cent of its annual millet production to over 70 countries, primarily as feed (Habiyaremye *et al.,* 2017). Barnyard millet is mainly grown in India, China, Japan and Korea for human consumption as well as fodder (Upadhyaya *et al.,* 2014). Kodo and little millets are largely cultivated throughout India by tribal people in small areas.

Table 1. Small millets and the region of cultivation

Crop	Botanical name	Chromosome number	Region of cultivation
Finger millet	*Eleusine coracana* (L.) Gaertn.	2n=4x=36	India, Uganda, Nepal, China, Myanmar, Sri Lanka, Kenya, Eritrea, Sudan, Zimbabwe Zambia, Malawi, Madagascar, Rwanda, Burundi
Foxtail millet	*Setaria italica* (L.) P. Beauv.	2n=2x=18	Asia, Europe, North America, Australia and North Africa
Proso millet	*Panicum miliaceum L.*	2n=4x=36	Asia, Australia, North America, Europe, Africa
Little millet	*Panicum sumatrense* Roth. ex. Roem. & Schult.	2n=4x=36	India, Sri Lanka, Pakistan, Myanmar
Kodo millet	*Paspalum scrobiculatum* L.	2n=4x=40	India
Barnyard millet	*Echinochloa crus-galli* and *E. colona*	2n=6x=54	India, Japan, Korea, China, Nepal

Potential Uses

Small millets are good sources for micro- and macro-nutrients with high nutraceutical and antioxidant properties. These crops are rich in protein, fat, crude fiber, iron and other minerals and vitamins. Finger millet contains over >10 fold higher calcium (350 mg per 100g); proso, foxtail and barnyard millets are rich in protein (11 to 12.5%); foxtail and little millets are rich in fat (4.0 to 5.2%); barnyard, little and foxtail millet are rich in crude fiber (6.7 to 13.6%), little and barnyard millets are rich in iron (9.3 to 18.6 mg per 100g) compared to other major cereals such as rice, wheat and sorghum (Saleh *et al.,* 2013). Small millets are used as an ingredient in multigrain and gluten-free cereal products and serves as a major food component for various traditional foods and beverages, such as bread, porridges, and snack foods, and while grains are feed to animals, including pigs, fowls, and cage birds. All these crops have superior nutritional properties including high micronutrients, dietary fibre content and low glycemic index (GI) with potential health prospective (Chandel *et al.,* 2014; Dwivedi *et al.,* 2012; Saleh *et al.,* 2013).

Germplasm Resources: Global Status

Large numbers of small millets germplasm accessions are available to scientific community. Over 46,000 foxtail millet, >37,000 finger millet, >29000 accessions of proso millet, >8000 accessions each of barnyard and kodo millet, >3000 accessions of little millet germplasm accessions have been conserved *ex situ* in genebanks globally (Upadhyaya *et al.,* 2015; Vetriventhan *et al.,* 2015). The major collections of foxtail millet germplasm accessions are housed in genebanks at China, India, France, and Japan, while India and African countries (mainly Kenya, Ethiopia, Uganda and Zambia) conserve major finger millets collections. The major collection of proso millet germplasm accessions are assembled in Russian Federation, China, Ukraine and India; barnyard millet in Japan and India; kodo millet in India and USA; and little millet in India (Upadhyaya *et al.,* 2015; Vetriventhan *et al.,* 2015).

Germplasm Diversity Representative Subsets

Germplasm resources provide pool of genes for breeding high-yielding, biotic and abiotic resistant cultivars. Systematic breeding efforts and utilization of genetic resources are limited in small millets. Use of germplasm accessions in breeding programme can be enhanced if small subsets of a few hundred germplasm lines, which represent the entire diversity of is available. Such germplasm representative subsets are available in small millets collection from ICRISAT (Table 2). These diversity sets such as core and mini-core collections could be effectively evaluated to identify germplasm trait-specific sources for their enhanced utilization in breeding high yielding cultivars with diverse adaptation.

Table 2. Germplasm diversity representative sets of small millets developed at ICRISAT, India

Crop	Germplasm subsets	Accessions used (no.)	Traits/ SSRs (no.)	Accessions in subset (no.)	Reference
Finger millet	Core collection	5940	14	622	Upadhyaya *et al.* (2006a)
	Mini-core collection	622	20	80	Upadhyaya *et al.* (2010)
	Composite collection	-	-	1000	Upadhyaya *et al.* (2005)
	Reference set	1000	19 SSRs	300	Upadhyaya (2008a)
Foxtail millet	Core collection	1474	23	155	Upadhyaya *et al.* (2008)
	Mini-core collection	155	21	35	Upadhyaya *et al.* (2011b)
	Composite collection	-	-	500	Upadhyaya *et al.* (2006b)
	Reference set	500	20 SSRs	200	Upadhyaya (2008b)
Proso millet	Core collection	833	20	106	Upadhyaya *et al.* (2011c)
Barnyard millet	Core collection	736	21	89	Upadhyaya *et al.* (2014)
Little millet	Core collection	460	20	56	Upadhyaya *et al.* (2014)
Kodo millet	Core collection	656	20	75	Upadhyaya *et al.* (2014)

Core and Mini-core Collection as Source of Trait-specific Germplasm Sources

Small millets germplasm collection conserved globally has large variation for morpho-agronomic traits. Researchers at ICRISAT and elsewhere have assessed germplasm collections and identified sources for various biotic and abiotic stresses tolerance and for grain quality traits (see Upadhyaya *et al.,* 2015; Vetriventhan *et al.,* 2015). Core and mini core collections of small millets developed at ICRISAT (Table 2) have been extensively evaluated and identified sources for important traits. At ICRISAT, Upadhyaya *et al.* (2011b) have identified 21 diverse accessions having agronomically (earliness and high grain yield) and nutritionally (protein, 15.6 to 18.5%; Ca, 171.2 to 288.7 mg kg^{-1}; Fe, 58.2 to 68.0 mg kg^{-1}; and Zn, 54.5 to 74.2 mg kg^{-1}) superior traits from core collection of foxtail millet. Similarly, in finger millet core collection, 15 accessions each for grain, Fe (37.66 to 65.23 mg kg^{-1}), Zn (22.46 to 25.33 mg kg^{-1}), Ca (3.86 to 4.89 g kg^{-1}) and protein (8.66 to 11.09%) contents were identified, and 24 of them were identified based on their superiority over control cultivars for two or more grain nutrients (Upadhyaya *et al.,* 2011a). In little millet, Vetriventhan and Upadhyaya (2016) have identified high grain and biomass yielding accessions. Proso millet, kodo millet and little millets germplasm (200 accessions each, including core collections) were assessed for grain yield and grain nutrient contents and sources for high grain yielding and nutrients dense accessions were identified (ICRISAT, Unpublished).

Small millets are less affected by biotic and abiotic stresses however, a large variation exist among germplasm for stress tolerance. Identification and utilization of such trait specific sources in breeding programme will enhances yield and adaption. Blast in both finger and foxtail millets, grain smut and sheath blight in little millet, head smut and blight in kodo millet, smut and leaf spot in barnyard millet, and head smut, sheath blight and bacterial spot in proso millet are important diseases. In finger millet mini-core collection, 66 accessions with combined resistance to leaf, neck and finger blast have been identified, of which nine accessions also had desirable agronomic traits such as early flowering, medium plant height, semi-compact to compact inflorescence (Babu *et al.,* 2013). Similarity in foxtail millet, Sharma *et al.,* (2014) have evaluated the core collection accessions for blast resistance and identified 21 accessions resistant to neck and head blast under field evaluation and 11 accessions had seedling leaf blast resistance in the greenhouse. Further evaluation against four isolates of blast pathogen resulted in identification of 16 accessions which were resistance to leaf, sheath, neck and head blast to at least one isolate, and two accessions (ISe 1181 and ISe 1547) were free from head blast infection and were resistance to leaf, neck and sheath blast against four isolates (Sharma *et al.,* 2014). Foxtail and finger millets are the potential crops for salt-affected soils (Krishnamurthy *et al.,* 2014a, b).

At ICRISAT, Krishnamurthy *et al.* (2014b) assessed the finger millet mini-core collection for response to salinity in terms of total shoot or grain biomass at maturity and grouped the accessions into tolerant (22accessions), moderately tolerant (20), sensitive (21) and the sensitive and late ones (5) based on yield under saline condition. Similarly, Krishnamurthy *et al.,* (2014a) screened the foxtail millet core collection under saline condition in pot culture which revealed a large variation for salinity tolerance and identified salinity tolerant accessions. For drought tolerance, Krishnamurthy *et al.* (2016a, b) evaluated finger millet mini-core collection and foxtail millet core collection and identified 16 foxtail millet and 11 finger millet drought tolerant accessions. Ramakrishnan *et al.,* (2017) have identified finger millet mini-core accessions tolerant to low Phosphorus stress, and five (IE5201, IE2871, IE7320, IE2034, IE3391) of which had high root and shoot length, root hair density and root hair length. Limited number of resistant sources for major diseases and to some extent for pests in proso millet, barnyard millet, little and kodo millet have been reported (Upadhyaya *et al.,* 2015; Vetriventhan *et al.,* 2015). Barnyard millet reported to be tolerant to both drought and waterlogging (Zegada-Lizarazu and Iijima, 2005), while proso millet is susceptible to drought (Seghatoleslami *et al.,* 2008). Lodging is a constraint in many crops including finger millet, foxtail millet, proso millet, little millet, barnyard millet and kodo millet causing substantial losses in grain yield and quality. Use of lodging resistant cultivars along with good crop husbandry is the most effective way to minimize losses due to lodging.

Genomics Resources

Genomic resources such as DNA markers, linkage maps, and genome sequence are essential for gene tagging, QTL (quantitative trait loci) mapping, marker-assistant selection for rapid crop improvement. In foxtail millet large numbers of molecular markers have been developed like SSR (simple sequence repeat), EST-SSR (expressed sequence tag- simple sequence repeat), ILP (Intron length polymorphic) TE (Transposable element), and microRNA (miRNA) based markers during pregenome sequence era. The major breakthrough in the area of Setaria genomics is the release of two reference genome sequences (Brutnell *et al.,* 2012; Wang *et al.,* 2012). Recently, Hittalmani *et al.* (2017) have reported genome and transcriptome sequence of finger millet. In proso millet, Rajput *et al.,* (2016) constructed a genetic linkage map and mapped 18 QTLs for eight morpho-agronomic traits. Foremost challenge for the molecular characterization of barnyard, little and kodo millets is the availability of very limited genomic resources like DNA markers, lack of genetic/linkage maps and genome sequences. However, genomic resources of closely related species like foxtail millet where two reference genome sequences can be utilized towards enriching genomic resources in these underutilized crops. DNA markers such as SSR, EST-SSR, ILP and microRNA based molecular markers developed using foxtail millet genome sequence information showed >85 per cent of cross-genera transferability among other millets including proso, barnyard, little and kodo millets, as well as non-millet species (Kumari *et al.,* 2013; Muthamilarasan *et al.,* 2014; Pandey *et al.,* 2013; Yadav *et al.,* 2014).

Developments in sequencing technologies have made it possible to analyze large amounts of germplasm against low production cost. It enables to screen genebank collections more efficiently for DNA sequence variation which will be useful for mining sequence variation associated with economically important traits through genome wide association studies (GWAS). In barnyard millet, Wallace *et al*. (2015) genotyped the barnyard millet core collection (Upadhyaya *et al.,* 2014) using genotyping-by-sequencing (GBS) approach and identified several thousand SNPs, and investigated the patterns of population structure and phylogenetic relationships among the accessions. The procedure used to identify SNPs following GBS approach in barnyard millet can also be applied easily and rapidly to characterize germplasm collections of other crops as well (Wallace *et al.,* 2015). The GBS approach can play a major role in the crop species like proso millet, barnyard millet, little and kodo millet for which genome sequence is not available. Research is in progress at ICRISAT to characterize proso millet, kodo millet and little millets using GBS approach.

Small Millets Improvement

Globally, small millets have received very limited research attention in terms of crop improvement for enhanced yields and adaptation to biotic and abiotic stresses. Majority of cultivars released globally were through pure line selection from landraces.

In India, the All India Coordinated Research Project on Small Millets (AICRP-Small Millet) was launched in 1986. The research project under AICRP-Small Millet is carried out through network of 13 centres located in State Agricultural Universities, ICAR institutes and 21 cooperating centres. The AICRP-Small Millet has the responsibility to plan, coordinate and execute the research programmes to augment the production and productivity of six small millets. The research in the project focuses state/regional needs from the point of developing appropriate agro production technology for maximizing production/productivity. The crop improvement through AICRP-Small Millet led to the development of high yielding varieties with resistance to blast disease, quality fodder, early and medium maturity and white seed in finger millet, resistance to head smut in kodo millet and resistance to shoot fly in both proso and little millets. So far, a total of 245 varieties in 6 small millets have been released in India (http://www.aicrpsm.res.in/). Majority of released cultivars were following pure line selection. Two ICRISAT germplasm accessions, one each in barnyard millet (IEc 542 originated from Japan was released as PRJ 1 in India during 2003) and proso millet (IPm 2769 originated from Ukraine was released as DHPM 2769 in India during 2015) were directly released in India. Currently recombination breeding has been the approach especially in finger millet resulting in developing diverse and high grain yielding cultivars. Recombination breeding also been used in foxtail millet, proso millet and barnyard millet. The modern finger millet varieties yield up to 5 to 6 tons/ha, and cultivars other small millets yields up to 2.5 to 3 tons/ha under optimum management conditions.

In Africa, finger millet is an important food crop in small scale cereal-based farming systems, particularly the upland areas of Eastern Africa (Uganda, Ethiopia, Tanzania and Kenya). Systematic breeding efforts are very limited in Africa; majority of cultivars grown were either landraces or direct introduction. The ICRISAT-HOPE project in collaboration with Department of Research and Development (DRD), Tanzania, released cultivars such as P224 and U 15 in Tanzania, and the same cultivars were also released in Kenya and Uganda because of their high yielding, blast resistance and drought tolerance than the existing cultivars (http://hope.icrisat.org/new-varieties-promise-an-increase-in-tanzanias-finger-millet-production/). Three finger millet germplasm accessions of were directly released in Zambia (IE2929 as Lima and IE2947 as FMV287 during 1987) and Kenya (IE4115 as ICRISAT' KAK-WIMBI 2 during 2016).

In China, foxtail millet is one of the important crops. Breeding of foxtail millet began with simple grain yield comparisons among landraces in the 1950s and 1960s, while hybridization-based pedigree selection become popular in the 1970s and remains the main breeding method in China. About 870 cultivars were released since 1950. Research using heterosis began in the 1960s with the development of male sterile lines by various approaches. Various male-sterile lines have been identified having dominant, recessive genes and photo/thermosensitive nuclear system, gene interaction male-sterile lines, cytoplasmic male sterility, and cytoplasmic- nuclear male-sterile type. These lines are potential sources for heterosis breeding and have been used in developing hybrid cultivars in China. For example, Zhangzagu 5, a high yielding hybrid cultivar, was released from Zhangjiakou Academy of Agricultural Sciences, Hebei Province, China, and yielded 12159 kg/ha versus conventional cultivars ranging from 4500 to 6000 kg/ha in 2007 (Liu *et al.,* 2014). The development of herbicide resistant foxtail millet cultivars has made the use of foxtail millet heterosis a reality by us of herbicide resistant varieties as the restorer line (Diao, 2017).

Among the millet species produced worldwide, proso millet is the most important species traded in the world market. In the United States of America (USA) the focused breeding programme for proso millet productivity improvement was started in the year 1972 under the alternative crops breeding programme at Panhandle Research and Extension Centre (PHREC), and released several cultivars such as Sunup, Dawn, Cerise, Rise, Early bird, Hutsman, Sunrise and Horizon. In the United States of America (USA) there are 15 cultivars of proso millet available to growers, and nine of these were selections from adapted landraces, and six were developed through hybridization (Habiyaremye *et al.,* 2017).

Opportunities of Networking for Research and Development

Research and development activities on small millets are meager as compared to major cereals such as maize, wheat and rice. Limited efforts have been made in India (all six small millets), Africa (finger millet), China (foxtail millet) and USA (proso millet) on cultivar development and towards enhancing millets cultivation and marketing. Recently, there is a considerable interest in millets consumption due to their better nutritional quality and health benefits besides their ability to withstand changing climatic conditions. Integrated approaches and networking among key players on research and promotion of small millets are crucial for wider impact. Research on processing and utilization technologies and developing value added products such as easy-to-cook and ready-to-eat will add value in commercialization of small millets as healthy foods.

Conclusions

Small millets have the potential to improve food security, health, income, livestock production, diversifying agriculture, supporting traditional farming systems and overall development of smallholders living in marginal lands. Small millets are environmentally friendly crops and are much more tolerant to biotic and abiotic stresses compared to major crops such as maize, wheat, and rice. Despite of many advantages, these crops have received very little attention in terms of research and development to enhance their cultivation and utilization. Currently small millets are recognized as healthy foods and there is a rapidly growing global market for diverse and healthy foods. Globally there are significant numbers of germplasm accessions have been conserved in genebanks and reported to have substantial variation for economic important traits. The germplasm diversity representative subsets such as core and mini-core collections are available in small millets and trait specific sources for important traits such as resistance/tolerance to biotic and abiotic stresses and high yield and grain nutrients content were identified. Except finger millet and foxtail millet, other small millets have received very poor research attention in terms of genetic and genomic resources development and breeding for yield enhancement. Considerable breeding efforts were made in finger and foxtail millets, in India and China, respectively. Both finger millet and foxtail millet genomes have been decoded, while other small millets yet to come. Research is in progress at ICRISAT to characterize proso millet, kodo millet and little millets using genotyping-by-sequencing approach. Considering diverse adaption and agronomic and health benefits small millet crops offer, these crops could be an alternate/supplement crop to widen food basket to ensure food, feed and nutritional security. More research effort in developing high yielding varieties and processing and utilization technologies and policy innervations are required to promote small millets cultivation, and to diversify food habits for healthy lives and to face the global threats of malnutrition and climate change.

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Underutilized Grain Legumes: Rice Bean, Moth Bean, Adzuki Bean, Faba Bean and Horse Gram

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ABSTRACT: Through history, mankind has met its food needs with only 5,000 plant species, representing 1 per cent of the world flora, and big nuclei of human population depends essentially on three cereals (wheat, rice and maize) and one tuber crop (potato) for subsistence. Because of population pressure and increasing urbanization, highly productive agricultural land is increasingly being used for urban development, placing extreme pressure on the remaining agricultural land and increasing the risks of degradation or erosion. Under the situation, the role of underutilized species in general and grain legumes (rice bean, fababean, moth bean, adzukibean and horsegram) in particular has evolved over time; it adds to the quality of life besides meeting needs of the rural poor. Grain legumes are known for their nutritional richness especially protein and amino acids, which are largely lacking in human diets leading to malnutrition. Worldwide ~50,000 germplasm accession of these grain legumes are being conserved the genebanks. Although efforts have been made to harness the potential of these crops but still they are not receiving the adequate attention in the national research programmes. An integrated gene resource management strategy to combat malnutrition, identify gene resources for their improvement and enhance their value as traditional food and medicine is needed.

Key words: Genetic resources, grain legumes, nutrition, underutilized species, utilization

Introduction

Food and nutrition security *vis-a-vis* economic growth are going to face a stiff challenge due to population outburst especially in the developing and third world countries. By 2030 the humanity has to face challenge of feeding 9 billion people as against 5.7 billion at present. It is estimated that nearly 1.2 billion people in the world do not have enough food to meet their daily requirement and a further 2 billion people are deficient in one or more micro-nutrients (Azan-Ali and Battcock, 2002). Further, it is assumed that the population growth will continue, agricultural land will be increasingly converted to non-agricultural purposes, thus increasing competition for the remaining land area and disorders due to malnutrition continue to kill tens out of thousands of productive people. Under the circumstance, we certainly urge to exploit the alternate source of energy (food) and livelihood generation. Ethno-botanical surveys confirm that hundreds of such crops are still found in many countries representing an enormous wealth of agro-biodiversity which can play a vital role to improve income, food security and nutrition. Agricultural development and food security depends in part on our ability to broaden the range of agricultural species in an effective and sustainable way. Ways to protect and enhance the locally important species so that they can be deployed more widely

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in agriculture and environment management, to explore the use of local crops in order to tap the hidden potential contained in them need to be explored. The benefits of underutilized crops (UC) such as local importance in consumption and production system, adaptability to specialized agroecological niche and marginal areas, fragile environment, nutrient richness, and associated indigenous knowledge-based cultivation and utilization make them most potential candidate species for broadening the food basket. In the subsequent text we have discussed few underutilized legumes *viz.* rice bean, moth bean, adzuki bean and faba bean and horse gram.

Rice Bean [*Vigna umbellata* (Thunb.) Ohwi & Ohashi]

Rice bean is an annual food legume, belonging to the subgenus *Ceratotropis* in the genus *Vigna,* rice bean also known as red bean, climbing mountain bean and oriental bean, is considered to have originated in South and South-East Asia where it is a multipurpose crop. Its wild form (*V. umbellata* var. *gracilis*) is found in the Himalayas and central China to Malaysia. The cultivated forms seem to have originated from the wild populations occurring in the Indian subcontinent (Chandel *et al*, 1982). It is cultivated in India, China, Korea, Japan, Myanmar, Malaysia, Indonesia, Philippines, Indonesia, Mauritius, Fiji, Bangladesh, Sri Lanka and Nepal (Rachie and Roberts, 1974). Rice bean is a short-day plant in India, and it is grown predominantly in North-eastern region particularly in Assam, Meghalaya, Manipur, and to a limited scale in peninsular tract, and in sub-temperate hilly region. It is a profusely branching, erect or trailing annual herb. Stem erect/sub-erect or flexuose, tending to be viny usually clothed with fine deciduous deflexed hairs; stipules lanceolate; leaflets entire or lobed; inflorescence a raceme; bracteoles linear; flowers medium sized; hair of the stem, short, but spreading, not ferruginous, stipules much smaller and narrower, leaflets membranous, subglabrous, 5-10 cm long, the terminal one broad-ovate, cuneate; flowers 10-20, the lower pedicels as long as the calyx and the raceme 5-10 cm long, calyx teeth short, deltoid; corolla yellow; pod glabrous, 6-8 cm; cylindrical, 8-12 seeded; glabrous from the beginning, considerably recurved at the end and sometime straight. Pod attaches to the peduncle downward; seed slender oblong with a raised, white hilum; colour vary from pale to deep yellow, green, brown, maroon, black and mottled.

Nutritional Significance

Rice bean seeds possess remarkable storage quality without much being infested by bruchids. Immature pods and bean sprouts are excellent as vegetable. Sprouting also removes the anti-nutritional factors (Kaur *et al.,* 2013; Singh *et al.,* 2012). It is an excellent forage crop with substantially nutritionally rich green biomass production. The nutritive value of rice bean is exceptionally high especially protein and amino acids (Table 1). The seed protein ranges from 14.0-25.0 per cent. The

Table 1. Nutritional composition of rice bean

Constituents	Range	Constituents (mg/100g)	Range
Moisture (%)	11.0 - 13.8	Niacin	2.2-2.4
Total carbohydrate (%)	60.7 - 65.5	Tryptophan	0.79-1.10
Crude protein (%)	17.8 – 25.1	Methionine	0.45-1.18
Fat (%)	0.6 - 1.2	Isoleucine	2.10-5.78
Crude fibre (%)	4.0 - 5.8	Leucine	6.17-9.50
Ash, (%)	3.81 – 4.06	Lysine	5.60-7.73
Crude Fiber, (%)	3.30 – 4.80	Phenylalanine	4.71-7.68
Calcium (mg/100 g)	315.00 - 450.00	Tyrosine	2.54-4.71
Phosphorus (mg/100 g)	301.0 - 480.0	Threonine	3.12-4.57
Iron (mg/100 g)	7.2 - 10.9	Valine	3.27-5.23
Total phenols	0.09 – 0.14	Thiamine	0.39-0.57
Free reducing sugars (%)	3.71 –5.37	Vitamin A	30 IU

amino acid especially the methionine and trytophan are considerably high as compared to other *Vigna* species. It contains high quality of vitamins, thiamine, niacin and riboflavin. Minerals such as calcium and iron contents are also appreciably high. It was also argued that the presence of low amounts of total free amino acids in rice bean is of advantage because of the fact that lesser loss of amino acids is likely to occur on cooking and if so, this enhances the food value. Rice bean apart from rich quantity of protein also possesses fair amount of starch, digestible carbohydrate and in this respect it may have an edge over other common pulses.

Rice bean is a nutritious pulse with good cooking quality. Seeds are utilized, similar to mung bean for the production of bean sprouts. The green immature seeds, pods and the young leaves are boiled and eaten as a vegetable. The seeds are also eaten in soups. The dried seeds, like other pulses are usually boiled and eaten with rice as *daal*. In eastern parts of India, the plant is grown both as a pulse and as a forage crop. It is particularly valuable because it provides forage at a time when other sources are scarce. The foliage, green pods, immature seeds and flowers are readily eaten by animals. In Indonesia, it is often grown as a backyard crop and provides handy supply of leaves, pods and seeds for the family meals. In China and to some extent in Japan and Korea, the beans are generally ground into flour or meal. The beans are often boiled or pressure cooked also with onion and carrot and eaten as a side dish or as soup almost the same way, as adzuki bean is eaten in Japan. It is sometimes cultivated as a green manure and/or cover crop for soil improvement and conservation. It is a very good deterrent against soil erosion if used as a cover crop. It is also grown as living fence and biological barrier against pest attack. In Russia, adzuki bean and rice bean both are used together for green manure and for farming in sub-tropical acidic soils.

Genetic Resources Management and Utilization

Rice bean being an indigenous to the Indian subcontinent possesses rich genetic diversity. In India, germplasm has been collected from predominantly tribal inhabited tracts of Assam, Meghalaya, Manipur, Mizoram, Tripura, Arunachal Pradesh, Sikkim and North Bengal, Santhal pargana in Bihar and North western parts of Odisha particularly Kalahandi, Koraput and Mayurbhunj districts and parts of Uttarakhand and bordering areas in Himachal Pradesh. India has also introduced substantial germplasm accessions from many countries over the years. Some accessions of rice bean procured from Taiwan had high yield, wide adaptability and drought resistance. Distinct seed coat colour groups germplasm had considerable variation in epicotyl colour, shape and size of leaves, plant height, flowering time, flower colour, seed weight and protein content among the groups (Sastrapradja and Sutarno, 1977). However, there was not much variation in characters occurring within each group of seed coat colour. Variability has been recorded for growth habit, time of maturity and seed colour. Early maturing cultivars are strictly bushy and mostly erect while late maturing types are highly viny and branched, some are decumbent. At present, 5567 accessions of rice bean are conserved at various genebanks globally (Table 2).

Table 2. Rice bean germplasm conserved at various genebanks

Genebank	Accessions	Genebank	Accessions
NBPGR, India	2,067	IPB-UPLB, Philippines	150
ICGR-CAAS, China	1,615	PGRC, Vietnam	117
NIAS, Japan	476	LBN, Indonesia	100
AVRDC, Taiwan	266	Others (18)	364
CPBBD, Nepal	467		
		Total	5,567

Germplasm comprising of both indigenous and exotic collections have been characterized and evaluated. Genetic variability was mainly observed for leaf and seed characters viz. leaf shape, length, width, pubescence, seed length, breadth, colour, 100-grain weight and also for other characters such as maturity, pod length and pod number (Table 3). Cultivated forms of rice bean differ considerably in their plant habit; short stemmed erect plants to twining ones that may grow up to 3 m long. Intermediate types (semi-bushy forms) occur in Assam, Meghalaya and Manipur. The tendril forms are also reported in some areas. Generally, tall (1.5-3.0m), robust morphotypes with prolific fruiting tendency and long and thick pods have been identified. Some accessions possessed only 2-3 branches while majority of the landraces possessed up to 12 fruiting branches. Flowering range was from 60 to 110 days. Pods per cluster showed variation from accession to accession and some landraces possessed as high as 20 pods/cluster.

Ecotypic variation was also noticed in the germplasm. The taller genotypes were observed from Odisha, profusely branched types from Mizoram and Manipur, types with more number of seeds per pod from Meghalaya and Mizoram, and collections with higher number of pods per peduncle, bold seeds and high grain yield from Manipur. A high degree of polymorphism was noticed in seed colour. Several landraces had black, red, cream, violet, purple, maroon, brown, chocolate or mottled grains with greenish, brownish or ash grey background. A rare uniform light green colour occurred in a few accessions from Mao hills bordering Manipur and Nagaland (Sarma *et al.*, 1995; Negi *et al.*, 1998).

Table 3. Comparative performance of mean and range for quantitative traits of some underutilized legumes

Character	Moth bean	Rice bean	Adzuki bean
Days to 50% flowering	63.73 (32.00-84.00)	89.26 (62.00-123.00)	61.46 (50-.00-94.00)
Day to 80% maturity	82.84 (57.00-105.00)	148.05 (95.00-180.00)	105.24 (93.00-127.00)
Plant height (cm)	26.45 (11.68-49.30)	147.46 (62.40-372.50)	68.99 (32.80-120.33)
Primary branches	6.09 (1.58-12.00)	5.15 (3.00-13.00)	3.96 (2.00-7.00)
Clusters/ plant (no.)	20.98 (9.00-73.67)	36.37 (9.00-124.00)	12.76 (4.54-26.50)
Pods/ cluster (no.)	2.89 (1.49-7.67)	3.80 (2.00-7.00)	3.16 (2.00-6.00)
Pod plant (no.)	49.52 (24.83-128.33)	113.07 (38.00-296.00)	36.26 (9.75-65.58)
Pod length (cm)	3.95 (2.20-5.30)	10.11 (7.60-12.80)	6.34 (3.20-9.56)
Seeds/ pod (no.)	6.75 (2.00-10.00)	9.11 (7.00-12.00)	7.77 (5.5-10.55)
100-seed weight (g)	2.90 (1.50-4.60)	8.35 (4.70-21.40)	10.68 (4.05-18.23)
Yield/ plant (g)	6.17 (1.55-19.08)	22.35 (2.70-73.00)	30.24 (4.68-71.46)

Molecular characterization has also revealed wide range of genetic diversity. Tian *et al.* (2013) studied genetic diversity in 472 rice bean accessions (388 cultivated and 84 wild) from 16 Asian countries by using 13 simple sequence repeat (SSR) markers. In total, 168 alleles were detected, and the numbers of alleles in cultivated and wild accessions were 129 and 132, respectively. The gene diversity in cultivated populations (0.565) was about 83% of that for wild (0.678) populations. Cultivated populations from Vietnam, Myanmar, Nepal, and India had the highest gene diversity (>0.5). Tremendous possibilities exist for developing better cultivars through inter-specific hybridization such as *V. umbellata* × *V. angularis*, using embryo culture (Ahn and Hartman, 1978) and *V. radiata* × *V. umbellata* (Rushid *et al.,* 1987). Wide hybridization has been attempted among *Vigna* spp., aiming to incorporate certain characters, for example, productivity and other desirable traits from *V. umbellata* to *V. mungo* (Singh *et al.*, 2013), transferring urdbean anthracnose from *V. umbellata* to *V. mungo*, mung bean YMV resistance from *V. umbellata* to *V. mungo* (Sehrawat *et al.,* 2016), and yellow mosaic disease resistance from *V. umbellata* to *V*. species (Pandiyan *et al.,* 2010).

Many high yielding varieties *viz*. RBL-1, PRR-1 (PRR 8801), PRR-2 (PRR 8901), RBL-6, RBL-35, RBL-50, VRB-3 (Him Shakti), Palam Rajmung, BRS 1, BRS 2, RCRB 1-6, Bidhan 1, Bidhan 2, Bidhan 3, KRB-1, MNPL 1 and MNPL 2 have been identified and released for different agro-ecological regions of India. *Angoubi, arangbi, arangbimacha, tanakla, temusingla, teremla, thengbon, thengbouso,* *mathia*, *naini, megha rumbaiza* and *chaukhamba* are popularly grown land races across part of India. Farmers also have identified different rice bean landraces for different purposes in Nepal. For example, *Seto thulo* (white large) and *khairo thulo* (brown large), *rato jhilunge* (red rice bean), *bhadaure* (early and small grained) *kalosano, chhirkemirkesano, chhirkemirkethulo, kalothulo, rato, setosano, thulopinyalo* are some of the popular landraces used for food and high biomass as fodder. Biochemical evaluation of rice bean shows that that rice bean is not inferior in any way to other pulses, in fact rice bean compares very well with other pulses in its crude protein, ash, ether soluble extract, crude fibre and phosphorus contents. Rice bean apart from rich quantity of protein also possesses fair amount of starch-digestible carbohydrate and in this respect, it may have an edge over other common pulses.

Moth Bean [*Vigna aconitifolia* (Jacq.) Marechal]

Moth bean [*Vigna acounitifolia*(Jacq.) Marechal] is a minor legume of family Fabaceae having 2n=22 and is thought to have been domesticated in South Asia (Arora and Nayar, 1984). Moth bean is also known as *math, khari, kumkuma, matbean, matki*, Turkish gram in different places of the world. It evolved in dry and hot regions of western Indian subcontinent with inherent mechanism to adapt restrictive water and environment (Jain and Mehra, 1980). Moth bean showed the highest heat tolerance among 15 *Vigna* species, surviving conditions of 36°C for 12 days followed by 40°C for 11 days while all other *Vigna* species tested died at 40°C (Tomooka *et al.,* 2001). States like Rajasthan, Gujarat and Maharashtra occupying about 16.2 lakh hectares area and with production of 7.9 lakh tonnes with an average yield of 486 kg/ ha. Rajasthan alone contributes over 95 per cent both in area (13.6 lakh hectares) and production (3.7 lakh tonnes). The distribution of this crop is confined to plains or very low elevation between 30°N and 30°S. It can be grown in a variety of soils but grows best in light soils. Bulk of the moth bean cultivation is confined to the dry land of arid zone where seasonal rainfall ranges from 250 to 500. Moth bean plants generally grow 15-40 cm tall, having short internodes. Primary branches being as large as 1.5 m, trail horizontally on the ground giving mating type look. Deep lobed leaflets can easily distinguish this species from other common species of *Vigna* group. Flowers are papilionaceous. Flowers are 2-6 cm long, pods are yellow brown, bearing 4-10 seeds each. The distinguishing features of moth bean are deeply lobed leaflets (3-5 in number), pods appear to be nearly glabrous and stipules are small.

Moth bean with deep and fast penetrating root system, can survive up to 30-40 days in open fields, experiencing fast depletion of soil moisture, in concomitant with high atmospheric temperature. These adaptive features embodied in moth bean against harsher and unhospitable growing situations for unspecified intervals. Not only adaptive features but broad canopy, winy and semi-trailing growth habits also prove useful in keeping the soil intact and lowering the soil temperature besides, help reducing the soil erosion. These multi-adaptive and adjusting features have scaled moth bean as the only alternative annual crop of the sand dunes, requiring no inputs and negligible agronomic aftercare. The crop is an essential component or sub-segment of cropping systems, prevalent and common, in arid zone like, agri-horticulture, silvi-pastoral, agro-forestry, mix-cropping, intercropping, sale cropping, etc. This crop is therefore, a part of all systems of texturally common poor lands representing the holding of common men, characterized with limited physical and financial resources.

Nutritional Significance

Moth bean is a source of food, fodder, feed, green manuring and used as pasture hence, serves as a multi-purpose crop. Green pods are delicious source of vegetables. It is a cheap source of vegetable protein for balancing the nutritional deficiency, most commonly occurring on less productive soils, on which financially less equipped, great chunk of people have been depending for their livelihoods. Studies have indicated that moth bean is a good source of amino acids, particularly of lysine, leucine and certain vitamins, like carotene. Among the protein fractions, albumins are important, which are found maximum with the fraction of 6.7 to 7.4 per cent of total proteins. Composition of moth bean seed and herbage have revealed that it is a good source of protein and carbohydrates, along with substantial amounts of fibre, minerals but sulphur containing amino acids (cysteine and methionine) are found in lesser quantity. Gupta *et al.* (2016) reported significant variation in the contents phytochemical viz. protease inhibitors, phytic acid, radical scavenging activity, and tannins. The studies of theses phytochemicals. Presence of photochemical composition was correlated with seed storage proteins like albumin and globulin.

Certain anti-nutritional factors like, trypsin inhibitors, saponins, phytic acids, etc., are also found in moth-bean. Studies carried out have indicated that by sprouting/ cooking the seeds, these factors could be removed considerably. For instance, the trypsin inhibitors activity was reduced upto 98 per cent by cooking of sprouted seeds or pressure cooking of seeds. Similarly, saponin activity could be reduced by about 77 per cent on cooking of sprouted seeds. Protein digestibility is generally known to be increased by about 20-50 per cent on cooking of seeds. It offers a variety of edible products-vegetable, fodder for animals, whole seed, *papad, nuggets, bhujia* etc., hence, quality consideration of its grains and products is desired. Food based industries are coming-up in a big way, exporting such commercial edible products and generating employment for agro-based industries

Genetic Resources Management and Utilization

In India, germplasm have been collected largely from the states of Rajasthan, Gujarat, Maharashtra, Karnataka, western Uttar Pradesh, Punjab, Haryana and Madhya Pradesh and around 2000 accessions have been assembled by NBPGR. Moth bean collections possess variation in growth habit, leaf location, and pod and seed colour. The collections made from Rajasthan and Gujarat seems to be more promising. The exploration and collection efforts were undertaken in several countries in South and South-East Asia and sizeable germplasm collection have been assembled particularly in Philippines, Indonesia and China and parts of Japan, Nepal and Sri Lanka. Germplasm have been characterized and evaluated and wide range of variations (Table 3) was observed for yield and other growth characters in moth bean (Kohakade*et al.,* 2017; Yogeesh*et al.,* 2016). The varieties showed a wide variation in nodulation and nitrogenase activity (Rao *et al.*, 1984). Omvir and Singh (2015) reported high degree of genetic variability during both seasons for seed yield per plant (g), plant height (cm), pod length (cm), peduncle length (cm), number of branches per plant (cm), number of clusters per plant, number of cluster per branch and cluster length (cm). The accession IC39786 exhibited absolute genetic resistance to crinkle virus disease in the field conditions. The accessions IC36245, IC36555, IC36667, IC36577 and IC 36604 exhibited yield advantage over best check during summer whereas accessions IC39675, IC36607, IC251908, IC36245 and IC36563 performed better for seed yield during *kharif* season.

Varietal differences exist for resistance to insect pests and diseases (Dabi and Gour, 1988). Several promising accessions and few to mention PLMO39, identified amongst germplasm evaluated at NBPGR, Regional Station, Jodhpur India. A wide range of variation for different agro-morphological attributes, biochemical constituents, and disease and pest reaction was reported among 690 accessions of moth bean studied for 36 descriptors (Singh *et al.*, 1974; Chandel *et al.*, 1978; Arora *et al.*, 1980; Chandel *et al.*, 1982; Arora, 1986; Negi *et al*, 1998). Many varieties *viz*. Maru moth 1, Jadia, Jwala, Moth-880, RMO-40, CAZRI Moth 3, CAZRI Moth 2, CAZRI Moth 1 have been released by the Central Variety Release Committee while RMO 257, RMO 423, RMO 435, RMO 225, FMM 96, GMO 2 are related by the state of Rajasthan.

Most of the moth bean varieties evolved and released for cultivation are selections from the landraces which are adapted to conditions of intercropping under low fertility and poor management. Bhargava (1991) has listed the some of the desirable traits that are present in moth bean such as photo and thermos sensitivity, determinate growth habit, synchronous maturity, non-shattering of pods, compact/ semi-erect growth, resistance to insects-pest and diseases, induction of new genes for earliness and resistance to various biotic and abiotic stresses. Diseases are mainly being responsible for reduction and uncertainty in yield. Yellow mosaic virus, transmitted through white fly (*Bemisia tabaci*) a vector of this virus, Cercospora leaf spot caused by *Cercospora dolichi* Ellis & Everlast, leaf crinkle virus, dry root rot, incited by *Rhizoctonia bataticola* (Taub.) Butler and, *Macrophomina phaseolina* (TassilGoid), bacterial leaf spot caused by *Xanthomonas campestris*, powdery mildew (*Erysiphe polygoni* DC) and root-knot nematode infestation by *Meloidogyne incognita* are some of the prominent diseases of moth bean. Black weevil Black weevil adults (*Cyrtozemia dispar*) attack plant leaves in advanced stage and grubs attack the roots in initial stage. Hence the breeding efforts should be made considering the above factors, which may help stabilize yields and increase adaptation of new genotypes to different environments.

Adzuki Bean [*Vigna angularis* (Willd.) Ohwi and Ohashi]

Adzuki bean also known as small red bean is a food legume utilized in many ways. The origin of adzuki bean is not clear but it probably originated in Asia. Its wild types (*V. angularis* var. *nipponensis*) have been found from northern Honshu in Japan to Nepal. In the southern latitudes, *V. angularis* var. *nipponensis* occurs in mountain areas. in China, India, Korea, Myanmar and Taiwan. It is cultivated in China, Korea, Japan Taiwan and Far East of Russia for human food. Adzuki bean It was introduced into the USA, Angola, India, Kenya, New Zealand, Zaire, Belgium and Argentina. Adzuki bean is reported to be short-day plant and performs best under warm and dry conditions.

The adzuki bean is an annual vine widely grown throughout eastern Asia and the Himalaya for its small beans which are variously coloured. It was cultivated in China and Korea before 1,000 BC and subsequently taken to Japan, where it is now the second most popular legume after the soybean. The grain resembles mung beans but has a maroon seed coat and is usually slightly larger. Major consumers include Japan, China and South Korea. It is a new crop to the Indian mountains. It germinates by epicotyl growth, leaving the cotyledons below the soil surface. The plant is erect, 30-60 cm high, with indeterminate, growing habit. The yellow flowers are followed by a cluster of several smooth, short and small, cylindrical pods. Leaves resemble those of Southern peas, while the pods are much like that of the mung bean. The seeds are smaller than common beans but are two to three times larger than mung beans. The predominant seed colour is uniform red, but white, black, gray and varied mottled types also occur. The round seeds have a hilum (seed scar) with a protruding ridge on the side.

Nutritional Significance

Adzuki beans are most useful as a dry bean. The ripe seeds are rich source of protein, highly nutritious and easy to digest. It can be grown both for grains and green pods. Young tender pods can be harvested as snap beans. The pod is eaten like snow peas or cooked like common green beans. Since it is new crops to South East Asian region, hence not very common among the people. The seeds are used primarily as a dry bean, sprouts, whole, or ground into bean meal, but many cooks use them green. Since they have a sweeter taste than most beans, they are sometimes used in desserts. Sprouts from adzuki beans are particularly nutty and tasty. The seed is used in many different ways in these Asian countries, but the most common is highly sweetened bean paste with a range of different flavours and textures (it is often boiled with sugar). Bean paste is made into a large range of cakes, buns, confectionery, ice blocks and drinks. Many Chinese food such as: *tangyuan, zongzi, mooncakes, baozi* are prepared from the red paste. It is also used as a filling for Japanese sweets such as *anmitsu, taiyaki*, and *daifuku*. At least 50 other beans are also used to make these pastes, but the adzuki bean is the most prized, in large part due to its desirable red color, but also due to a delicate flavour and to the characteristic grainy texture of the pastes made from it.

Genetic Resources Management and Utilization

Limited exploration and germplasm collection efforts were made in adzuki bean. Systematic collections need to be undertaken to assemble the entire diversity available in the region particularly from Korea, China and Japan. In India, the areas surveyed are parts of Himachal Pradesh and Uttar Pradesh. Few accessions were introduced which possessed long pods and high grain yield. An emphasis was also given on the introduction of wild and related species of *Vigna* from France, Germany, Italy, Japan Nigeria and the USA (Gautam *et al.*, 2000). Various international and national genebanks maintaining wide diversity of underutilized legumes are: International Centre for Agriculture Research in the Dry Areas (ICARDA), Aleppo, Syria; Asian Vegetable Research and Development Centre (AVRDC), Shanhua, Taiwan; International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria; Bogor Research Institute for Food Crops (BORIF), Bogor, Indonesia; Commonwealth Scientific and Industrial Organization (CSIRO), Canberra, Australia; Malang Research institute for Food Crops (MARIF), Malang, Indonesia; National Plant Genetic Research Institute (NPGRI), University of Philippines, Los Banos, Philippines, and United States Department of Agriculture (USDA), Southern Regional Plant Introduction Station, USA, and ICAR-National Bureau of Plant Genetic Research (ICAR-NBPGR), New Delhi, India.

Evaluation of entire set at ICAR-NBPGR, Regional Station, Shimla revealed a wide range of variation (Table 3). As a result of evaluation promising donor identified for different traits were HPAB-13, HPU-29, EC30270, EC108080, EC340258 for plat height; EC89959, HPAB-9, EC 249, HPAB-13, EC340252 for branches/plant; EC340245, HPAB-13, EC390280, EC30270 HPAB-36, HPAB-7, EC340277, HPU-51 for leaf area; EC108080, HPAB-13, EC249, HPAB-6, HPU-51 for pods/plant; HPAB-51, A-1, EC340258, EC15648, EC390282 for pod length and EC340280, EC340283, HPAB-7, IC108856, EC340282 for seed yield/plant (Dobhal and Rana, 1994c, 1997). Efforts are being made to introduce more germplasm especially having traits like good yield, erect plant type, bold seed, deep red colours and resistant to foliar diseases. Genetic variability for seed colour, maturity, and plant types has been marked. Only one variety HPU51 has been released in India. Yang *et al.* (2015) have generated a high-quality draft genome sequence of adzuki bean by whole-genome shotgun sequencing. A total of 34,183 protein-coding genes were predicted. Functional analysis revealed that significant differences in starch and fat content between adzuki bean and soybean were likely due to transcriptional abundance, rather than copy number variations, of the genes related to starch and oil synthesis. The genome sequence of adzuki bean will facilitate the identification of agronomically important genes and accelerate the improvement of adzuki bean.

Faba Bean (*Vicia faba* L.)

Faba bean is supposed to be domesticated with the beginning of agriculture in the Fertile Crescent of near East around 9000-10,000 BC and later its cultivation has spread around the world (Cole, 1970; Tanno and Willcox, 2006). It is grown over a wide geographical range, with significant production zones from 50°N to 40°S and at an altitude of up to 3000 m above sea level, and minor production beyond these ranges. It is grown as an autumn/winter crop in regions with a mild winter such as the Middle East, North Africa, the Mediterranean Region, maritime Europe, southern China and Australia, or a spring sown crop where winters are severe such as continental Europe, northern China and Canada. It is grown under either rainfed or irrigated conditions. The crop is harvested as dry seed which is used for food, particularly in the Middle East and North Africa where it is a staple component of the diet, or as a protein component in feed diets.

Faba bean, a legume crop has two subspecies: *paucijuga* and *eu-faba* and three commonly recognized varieties; the large seeded major, the intermediate equina and the small seeded minor. Faba bean is a partially allogamous species (2n = 12, 14), known by many names (Bond and Pope,1974). *Vicia faba* vars. *equina* and *minor* are usually referred as field beans in Europe, while large seeded major is known as broad beans. In field beans, winter and spring-sown equina types are known as horse beans and the term tick bean is often used to denote the small seeded variety *minor*. Usually, broad beans refer to the whole species *Vicia faba* L. also. Thus, considerable confusion had resulted from this multiplicity of nomenclature and in order to standardize the terminology, now the name 'faba bean' has been accepted internationally to denote the entire species. In India, faba bean is known by various names, such as, *bakla, anhuri, kala matar* in Hindi; *raj-rawan* in Urdu and *kaduhuralikayee* in Kanada. It is also known by various local names in different parts of the country as *baklasem* in Delhi; *chastang, kablibakla, mattzrewari, raj-rawan* in Punjab; *katun* in Kashmir; *chastangralum* in North-West Himalayas; *nakshan* in Ladakh; *bakla* in Kumaun and *hende mater* in Mundari region.

Faba bean is cultivated under rainfed and irrigated conditions and is distributed in more than 55 countries. The harvested area is 2.56 million ha and 4.56 million tons of dry grains are produced. Asia and Africa accounted for 72 per cent of the area and 80 per cent of the production of dry faba bean grains (FAOSTAT, 2012). Faba bean remains in short supply in some countries. For example, Morocco imports around 9 per cent of its annual needs to supplement its present production of 153,000 tons. Egypt imports around 43 per cent of its annual needs to add to the present production of 297,620 tons. Globally, faba bean production showed a decline of 41 per cent, from 5.4 million tons in 1961-62 to 3.2 million tons in the period of 1991 to 1993. This was followed by an increase of 33 per cent, to 4.25 million tons, in the period of 2008 to 2010. However, up to today, the overall production is dominated by landraces, despite a number of improved varieties having been released by various national breeding programmes. The major reasons for the decline in production were the susceptibility of landraces and cultivars to different biotic and abiotic stresses. Among biotic stresses, *Orobanche crenata* is a major factor in the declining production in North African countries like Morocco. Faba bean necrotic yellow virus (FBNYV) was the major cause of disappearance of faba bean from middle Egypt.

Nutritional Significance

The nutritional value of faba bean has been traditionally attributed to it high protein content, which ranges from 20 to 37 per cent, (Crépon *et al.*, 2010). Most of these proteins are globulins (60%), albumins (20%), glutelins (15%), and prolamins (Cubero, 1984). Additionally, faba bean is also a good source of sugars, minerals (Ca, Mg, Fe, and Zn), vitamins (B-complex, vitamin C, and vitamin A). Thus, the chemical analysis of this legume reveals a 50 to 60 per cent carbohydrate content, which is mainly starch. Apart from their taste, it is exceptional source of nutrients (table 4), providing dietary fibre (9.47%), iron (18.75%), manganese (11.35%), phosphorus (10.43%), and vitamins such as folate (14.50%).

Table 4. Nutritional value of faba bean

Proximity	Amount	Proximity	Amount	Proximity	Amount
Water	83.0 g	Iron	1.54 mg	Folic acid	59 μg
Energy	65 Kcal	Manganese	0.26 mg	Ascorbic acid	19.8 mg
Protein	4.8 g	Phosphorus	73 mg	Niacin	1.3 mg
Total Fat	0.55 g	Magnesium	31 mg	Vitamin A	16 μg
Ash	0.92 g	Copper	0.06 mg	Fatty acids (S)	0.15 g
Carbohydrate	10.1o g	Zinc	0.47 mg	Fatty acids (US)	0.32 g
Dietary Fiber	3.6 3 g	Potassium	196 mg	Valine	0.23 g
Calcium	18.2 mg	Sodium	44 mg	Lysine	0.31 g

Faba bean also contains high amount of ascorbate and varying amounts of L-DOPA glucoside (Arese and De Flora, 1990). Small children and old people are at high risk because their gastric juice is less acidic and the beta-glycosidase of the bean is not inactivated. In normal red blood cells, oxidized glutathione (GSH) is rapidly regenerated by a metabolic cycle in which G6PD is an essential component. Glucose-6-phosphate dehydrogenase (G6PD) deficiency is widespread in humans.

Genetic Resources Management and Utilization

ICARDA has the largest collection of faba bean worldwide (32% of the total world collection). This global collection conserves materials from 71 countries, with a high percentage of unique accessions. Presently, over 38,000 accessions of landraces and varieties is conserved worldwide in at least 43 national gene banks. Although 52 per cent of accessions originated in Europe, the range of habitats may be wider in Ethiopia and China, with cultivation up to 3,000 m altitude. The largest genetic diversity study of faba bean landraces was of 802 landraces and varieties from China, North Africa, Europe and Asia, using ISSR markers (Wang *et al.,* 2012). The Chinese landraces were widely separated from a combined grouping of African, European and Asian (outside of China) germplasms which were closely similar though still distinct.

The morphological and agronomic characterization of germplasm of faba bean by ICARDA have shown limited degrees of variation for most of the qualitative and quantitative traits. The highest variation was recorded for first lowest pod length, the number of seeds per plant, and 100 seed weight, which could be confounding effects of different botanic groups, and would indicate a low genetic diversity within the cultivated faba bean groups. However, the use of amplified fragment length polymorphism (AFLP) (Zong *et al.*, 2009) and simple sequence repeat (SSR) markers (Wang *et al.*, 2012) have allowed genetic resources to be distinguished according to their geographic origin and the structuring of collections. Combined genotyping and phenotyping activities must continue on *V. faba* so that core collections can be defined. ICARDA has also developed under the Generation Challenge Program (GCP), a new set of 100 SSRs, which are being used to characterize the faba bean collections representing genetic variation of the species. Rebaa *et al.* (2017) studied genetic diversity of 21 faba bean populations using morphological and molecular markers and obtained 53 alleles in all populations, with an average of 6.62 alleles per locus. Recently many workers have employed molecular markers such as simple sequence repeats and reported useful genetic diversity, which could be used in faba bean breeding programmes (Tufan and Erdogan, 2017; Oliveira *et al.,* 2016; Ammar *et al.,* 2015).

In the Indian germplasm, wide variation was recorded for branches per plant, clusters per plant, seed yield per plant, pods per plant. Genotypes VH 5, VH 7, VH 72, VU 129, HL, LM-1 and ML were found to be desirable. Evaluation of germplasm for seed quality resulted in identification of some promising lines namely, DPBB-5, EC284366, EC284368, DPBB-4, EC284347, EC284366-II, EC284372, DPBB-1 and Palampur local, for direct consumption in the form of various culinary preparations (Awasthi *et al.*, 2000). Faba bean is still an under-utilized crop. Only one variety 'Vikrant' has been released. In Ethiopia faba bean landrace variation showed accessions from the north to be closely related with small seed and lower yield, plant height and greater susceptibility to chocolate spot disease, whereas in the South the diversity of morphologies and seed types was greatest and included those with large seed, superior yield and disease resistance (Keneni *et al.,* 2005). Thus, the clustering of land races in Ethiopia did not correspond to geographic diversity of their origins.

However, worldwide reduction of the cultivated area of faba bean shows a reduction of 50 per cent overall in the area since 1961. This reduction in area could be accompanied by a loss of some landraces, which in turn could be reflected in the change or loss of alleles because of a reduced population size and shrinking in number of distinct habitats or environments. Surveys undertaken by ICARDA within the dryland agro-biodiversity project, in four countries of the Fertile Crescent, Jordan, Lebanon, Syria, and the Palestinian Authority showed that the landraces of several field crops (cereals and food legumes) were replaced by introduced fruit tree species, such as apples, cherries, and olive (Mazid *et al.*, 2006).

Based on the forgoing discussion, emphasis should be given for further improvement in faba bean in areas such as: (i) characterization of phenological, morphological, physiological, and biochemical traits of faba bean that will contribute to adaptation in target environments, (ii) characterization of the effect of gene and QTLs for selecting suitable genotypes with resistance to biotic and abiotic stresses, (iii) defining precisely the breeding targets in abiotic stress prone environments with delineation of the predominate type of stress and identification of the faba bean varieties preferred by farmers, (iv) using simulation modelling and system analysis to evaluate crop response to major abiotic and biotic stress pattern, and (v) collaborative international evaluation, exchange of elite BPLs and open pollinated varieties.

Horese Gram [*Macrotyloma uniflorum* (Lam.) Verdc.]

The genus *Macrotyloma* consist of about 25 species having chromosome number 2n = 20 (Allen and

Allen, 1981). Archaeological investigations have revealed the use of horse gram as food around 2000 BC the *Brahadaranyaka* (c. 5500 BC), a commentary on the Rigveda (c. 8000 BC) mentions *khatakula*, which is the original Sanskrit name for horse gram, thus indicate that horse gram is indigenous to the Indian subcontinent. All the species of the genus *Macrotyloma* are distributed in African continent and *Macrotyloma uniflorum* is the only cultivated species grown in Indian subcontinent. *Macrotyloma uniflorum* (Lam)Verd. commonly known as horse gram (*kulth* or *kulthi*) is an arid food legume grown in diverse environmental conditions of the country (Duke, 1981), ranging from tropical climate of Southern India to wet temperate regions of North Western Himalayas (Himachal Pradesh, Jammu & Kashmir and Uttrakhand). The species is native to South-East Asia and tropical Africa, but the centre of origin of cultivated species is considered to be Southern India (Vavilov, 1951; Zohary, 1970). Horsegram is cultivated in India, Myanmar, Nepal, Malaysia, Mauritius and Sri Lanka for food purpose whereas in Australia and Africa it is grown for fodder purpose (Asha *et al.,* 2006). Wild forms of horse gram *viz*., *Macrotyloma ciliatum* (Wild.) Verdc. (Nair and Henry, 1983; Pullaiah and Chennaiah, 1997) in the Western Ghats and *Macrotyloma sar-garhwalensis* (Gaur and Dangwal, 1997) in the Garhwal Himalaya have also been reported. Formerly, the horse gram was included in the genus *Dolichos* following Linneus. Verdcourt (1980) assigned the horse gram to the genus *Macrotyloma* which is now comprises some 25 species. Horse gram has number of desirable traits like drought tolerance (Reddy *et al.,* 1990), heavy metal stress tolerance (Sudhakar *et al.,* 1992), high protein content, antioxidant activity (Reddy *et al.,* 2005), antimicrobial activity and various medicinal properties make it a crop of interest and potential food source.

The common name originates from its use as an important feed for horses and is equally important for human also. In India, its cultivation is known since prehistoric times. In India it is widely cultivated in the mountainous region of North-western Himalayan region (Himachal Pradesh, Uttarakhand and parts of Jammu & Kashmir) and in Indian peninsular region especially Karnataka, Tamilnadu, Kerala and tribal tract of Chhattisgarh, Jharkhand, Odisha and Andhra Pradesh. It is cultivated in areas with moderate rainfall exceeding 35 mm and is a very hardy and drought resistant crop suited to all soil types. Though its productivity level is low, the crop is highly suited for low input agriculture in marginal environments. The pulse horse gram also called *kulthi, gahat, hurali, kulatha,* and is well known for its food and medicinal value.

Nutritional Significance

Horse gram is rich source of protein and other nutrients such as iron, molybdenum and calcium. Seed contains carbohydrate (57.2%), protein (22%), dietary fiber (5.3%), fat (0.50%), calcium (287 mg), phosphorous (311 mg), iron (6.77 mg) and calories (321 Kcal) as well as vitamins like thiamine (0.4 mg), riboflavin (0.2 mg) and niacin (1.5 mg) per 100 grams of dry matter. The seeds are low in fat but very rich in dietary fiber, and a variety of micro-nutrients and pytochemicals. Horse gram is sharp, bitter and hot. It is beneficial in cough breathing problem due to phlegms, flatulation, hiccups, stones and fever. It also eliminates germs and worms. Drinking semi liquid solution of horse gram powder cures flatulation. If horse beans mixed with powdered dry ginger, asafoetida and "veed salt" is taken it cures the pain of the stomach. If it is used in food it cures disease of the stomach. If the water in which horse gram had been soaked for the whole night (and is mashed in the same water in the morning) is taken daily, taken twice then it cures "stones". The formation of stones in the kidneys or urinary tract is not an uncommon disorder. The stones are formed from the chemicals usually found in the urine such as uric acid, phosphorus, calcium, and oxalic acid. About ninety per cent of all stones contain calcium as the chief constituent. In the tribal areas of Chhattisgarh, *kadha* (decoction) from fresh herb before flowering is preferred. Although dose is decided on the basis of severity, about 10 gram is given to the patients. The traditional healers also recommend the use of seeds and radish seeds. The mixture is boiled in water and when one third part of total amount taken, remains in pot, the patients are advised to drink this solution in order to get quick relief. According to traditional healers regular intake of *kulthi* up to forty days removes stones completely from kidneys and one should include this *dal* (pulse) in his diet in order to prevent the formation of new stones.

Besides treating kidney stone there are many other uses mentioned in reference literatures are: the seed is bitter, acrid, hot (one must avoid its use during hot summer as the protein is very high), dry, astringent to bowels, fattening, anthelmintic, antipyretic and useful in treatment of *stones*, tumours, asthma, bronchitis, hiccup, urinary discharges, heart-troubles, disease of the brain and eyes; intestinal colic, piles, leucoderma, inflammation, liver troubles etc. It is also used for the treatment of cough, leucorrhoea, menstrual de-arrangements and indigestion. However, it is harmful for pregnant woman, or a person suffering from plethora or tuberculosis. It also causes the formation of excessive bile. Horse gram is the poor man's pulse crop in India where the seeds are parched and then eaten after boiling or frying, either whole or as a meal. The seeds are important food for cattle and horses and are usually given after boiling. The stems, leaves and husks are used as fodder. In Myanmar, the dry seeds are boiled, pounded with salt and fermented to produce a sauce similar to soy sauce from soybean (*Glycine max*).

Genetic Resources Management and Utilization

Germplasm Resources Information Network (GRIN) of United States Department of Agriculture (USDA) conserved only 35 accessions of *M. uniflorum* in its gene bank. Protabase, responsible for germplasm conservation for African countries has 21 accessions at National Gene bank of Kenya, KARI, Kikuyu Kenya. However, Australian Tropical Crops and Forages Genetic Resources Centre, Biloela, Queensland has 38 accessions of horse gram. In India, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi is a nodal agency for the collection, conservation and documentation of horse gram germplasm and total 2,625 accessions have been augmented and conserved in the National Gene Bank. Majority of the germplasm (>2,000) accessions were characterized on 22 traits. Critical observation on yield and other yield components in general showed that all the promising lines with higher seed yield belonged to long duration type. The seed yield per plant ranged from 0.22 to 7.31 g in short duration type, from 0.27 to 7.07 g in medium duration ones and from 0.21 to 11.86 g in long duration type (Annual Report, 2006; Dobhal and Rana, 1994a, b) and Anonymous, 2005). Variability observed in qualitative characteristics revealed that growth habit ranged between erect to very viny types, leafiness between sparse to abundant, leaf pubescence from puberulant to densely pubescent and stem colour between green and purple. Traits like erect types, early maturing, and straight pod, tolerant to water logging are found lacking in the germplasm.

Development of genomic resources in any crop is the pre-requisite for the construction of linkage map and implementation of molecular breeding strategies to develop superior cultivars (Sharma *et al.,* 2015). Chahota *et al.* (2017) employed the next-generation Illumina sequencing platform to develop a large number of microsatellite markers in this species. Of the total 23,305 potential SSRs motifs, 5755 primers were designed. Of these, 1425, 1310, 856, 1276, and 888 were of di-, tri-, tetra-, penta-, and hexa-nucleotide repeats respectively. Thirty polymorphic SSR primers and 24 morphological traits were used in 360 horsegram accessions to detect the genetic diversity and population structure. Thirty primers amplified 170 polymorphic alleles with an average of 5.6 alleles per primer having size 80 to 380 bp. The polymorphism information content (PIC) ranged from 0.15 to 0.76 with an average of 0.50, suggesting that SSR markers used in the study were polymorphic and suitable for characterization of horsegram germplasm. Bhardwaj *et al.* (2013) worked on *De novo* transcriptome discovery and their analysis has generated enormous information over horse gram genomics. The genes and pathways identified suggest efficient regulation leading to active adaptation as a basal defence response against drought stress by horse gram.

A wild relative identified as a new species namely, *Macrotyloma sar-garhwalensis* (IC212722) collected from Pauri District, Uttarakhand was analysed for protein content and revealed that seed protein content was 38.35±1.35 per cent which is more than the cultivated varieties. It is a non-twining annual herb and can be utilized in the breeding programmes for improvement of plant type and protein content. The protein content in cultivated horsegram is generally ranged from 16.9-30.4 per cent. Catalogues have been published by NBPGR, New Delhi based on evaluation data generated on 506 accessions evaluated at Delhi and 920 accessions at Akola. Limited hybridization studies have been conducted in horsegram. Best utilization of germplasm for the development of improved varieties has been done in horsegram. Almost 99 per cent varieties released for different states in India originated from local germplasm following their effective and specific evaluation. The varieties developed using germplasm in different states included BR5, BR 10 and Madhu for Bihar; HPK 2, HPK 4, HPK 5 and HPK 6 for Himachal Pradesh; PDM 1 and VZM 1 for Andhra Pradesh; K 82 and Birsa *kulthi* for Jharkhand; S27, S 28, S 39 and S 1264 for Odisha; Co 1, 35-5-122 and 35-5-123 for Tamil Nadu; Hebbal Hurali 2, PHG 9 and KBH 1 for Karnataka; Maru Kulthi, KS 2, AK 21 and AK 42 for Rajasthan and VL Ghat 1 for Uttarakhand. Some of the improved varieties developed through single plant selection from the bulk collected included CO-1, No-35, 5-122, and 123 from Madras; Sel. 33, Sel. 34, Sel. 36 and Sel. 42 from Hyderabad; and black *kulthi* from Mysore. Some more promising varieties/selections developed in the last decade are 8-1-1-8, Belgaum 1-8-3, Bijapur 1-6-5, Hyderabad A-3-2-3; and Hebbal Hurali 1 and 2. Out of these, Hebbal Hurali 1 and 2 were developed by selections made from lines PLKU-32 and EC1460, from the material supplied by NBPGR, New Delhi (Kumar, 2005).

Conclusions and Future Thrust

It is now beyond doubt that our crops base has shrunk to an extent that it may collapse, if the present race for growing only few crops continues. The crops, which have served the humanity for thousands of years, are facing major threat of extinction from the agricultural production system. These, in turn, provide a basis for more productive and resilient production systems that are better able to cope with various climatic changes and various stresses which agriculture in general and fragile agriculture ecosystems in particular is witnessing almost every now and then. UUC provide ample opportunities to sustain the agriculture on long term basis and also to improve the nutrition of large section of societies. Among these underutilized pulse crops we need to prioritize the crops. We suggest that rice bean, adzuki bean and horse gram has potential in the sub-Himalayan tract while moth bean for arid and semi-arid climates. To exploit their potential there is need to create and manage a database of all underutilized plant species, nutritive values, successful and unsuccessful case studies, resilience to climate change and information on genetics. There is a need to create awareness on UUC contribution to local nutrition, income, ecosystem health and farm productivity not only at local level but at policy leave and planning level also. The promotion of any new product and making it a profitable venture is not possible unless it is liked with market-oriented incentives. Further, nothing can be achieved unless we assure funding for research and development and working together across disciplines through network approach.

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Root and Tuber Crops for Food and Nutritional Security - Perspective from Oceania

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ABSTRACT: CePaCT is an internationally recognised genebank established to assist Pacific Island countries and territories to conserve the region's genetic resources and to provide access to the diversity they need. The Centre is conserving the region's major crops with over 2,000 accessions. CePaCT has the largest collection of taro diversity globally and maintains a unique global collection of over 1,100 accessions. Conservation is our centre's core activity, with priority given to the region's staple crops: taro, yam, sweet potato, banana, cassava and breadfruit. Distribution of climate ready crop diversity will assist the farmers to build resilience to climate change and disasters through climate smart agriculture. The Centre strengthens food, nutrition and trade security through sourcing and sharing crop varieties with farmers and partners. CePaCT identifies unique diversity and facilitates the distribution of healthy planting material safely across borders. The Centre also aims at the development and improvement of protocols for screening, breeding, tissue culture, virus elimination, storage methods and rapid multiplication of crops. CePaCT helps building capacity for scientists and students on biotechnologies, including training for countries without tissue culture laboratories on handling and growing tissue culture materials.

Key words: Centre for Pacific Crops and Trees, food and nutritional security, Land Resources Division, SPC

Introduction

Tubers share some traits with root crops but they differ physiologically. Root and tuber crops are important for food security, agriculture and income in developing countries with the help of research and development. It has the ability to adapt to climate change and provides income through direct sale. Beneficiaries include farmers, householders, traders, wholesalers, private sector, consumers, policy makers and researchers. Tuber crops include yams, sweet potato and potato. The tuber represents a swollen root, a single plant can produce several tubers. Several finer root branches can arise from it. Eyes, nodes, internodes, scale leaves, apical buds and axillary buds are absent. Tubers offer loads of energy and vitamins. Fig. 1 shows 9 different varieties of sweet potato at Centre for Pacific Crops and. Trees (CePaCT) genebank, it was planted and harvested at CePaCT field plot. Root crops include cassava and taro. Root crops offer vitamins, minerals and micro-nutrients.

Production of Root and Tuber Crops in Oceania and their Promotion by SPC

Table 1 gives an overview of root and tuber production in Oceania, in comparison to Asia and the world. Production in Oceania makes up 4.3 per cent of world production harvested from 2.6 per cent of the global area devoted to root and tuber crops. It is surprising that yield per hectare is 64 per

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Fig. 1. *Orange and purple fleshed sweet potato conserved at CePaCT*

cent higher in Oceania compared to the global average, despite very difficult growing conditions on atolls of small Pacific Island countries and territories.

Table 1. Area harvested, yield and production of root and tuber crops in Oceania, Asia and the world in 2014

Region	Area harvested (ha)	Percentage of world	Yield (t/ha)	Percentage of world	Production	Percentage of world
Oceania	34,028	2.6	12,493	164	425,106	4.3
Asia	175,922	13.5	8,689	114	1,528,652	15.4
World	1,300,423	100	7,610	100	9,895,977	100

Source: FAO (2017)

SPC-LRD has continued to promote diversity in food supply systems by supporting the establishment of collections and exchange of food crop diversity with a special focus on the banana and the edible aroids diversity. The Pacific Agribusiness Research and Development Initiative (PARDI) taro project delivered a clean seed system for market-ready cultivars in Samoa that successfully identified varieties for use as fresh, chips and/or snack food, thereby expanding the opportunities for using taro in food systems. The Taro Improvement Program in Samoa expanded its breeding programme to include breeding for drought tolerance. CePaCT's collaborations with the Scientific Research Organisation of Samoa (SROS) has led to the identification of four new potential export varieties of taro. Taro annual exports have grown by 11 per cent to over 1,000 tons in 2015, valued at NZD 3.6 million. Abundant local supplies are making taro easily available for families and food-related businesses in Samoa. Selected breeding lines produced from these programmes have been shared regionally in 20 PICs and to another 20 countries outside of the region.

CePaCT significantly supported post-disaster recovery efforts in several hard hit PICs of 2015 through the supply of sweet potato and banana plantlets. In addition, CePaCT is providing growers with access to traditional and improved crop diversity. Taro micro-propagation research has been established to fine-tune the methodology developed by CePaCT which has seen improved efficiency and effectiveness and reduced costs in production systems. CePaCT not only conserves the Pacific region's valuable plant genetic diversity, it also undertakes the important work of distributing the materials, making them available to growers. All germplasm distributed from CePaCT are pathogen-tested for safe distribution. Crops distributed consist mainly of accessions from CePaCT's climate-ready collection, nutrient-rich crops and those that are disease-resistant. In 2016, CePaCT made distributions to the following countries: Tuvalu- over 6,000 tissue cultures of swamp taro, sweet potato and banana were delivered to the Tuvalu Department of Agriculture as part of post *TC Pam* rehabilitation efforts. An additional 1,800 planting materials and vegetables seeds have been distributed to the islands of Nui, Nukulaelae and Nanumaga as part of the TC Pam rehabilitation work. Kaupule pits and nurseries of the three islands were used to multiply planting materials for the communities. Tonga received 500 tissue culture plantlets of new crops (banana, sweet potato, and Irish potato. More than 70 tissue culture plantlets of banana and sweet potatoes were distributed to a community-based organisation based on Matuku Island in Fiji in support of Matuku's whole-island organic initiative.

In Samoa the establishment of the root crops and aroid nursery in the district of Aleisa was recently completed to supply farmers in the district with planting materials of three new export varieties of taro, nine accessions of sweet potatoes (from CePaCT), two local varieties of yams and three cassava varieties (from CePaCT). Samoa also received over 5,000 plantlets of banana, pineapple, Irish potato and sweet potato.

Conservation of Crops for Food Security

SPC is highly committed to the long-term conservation of its region's crop diversity. CePaCT uses *in vitro* technology to conserve collections of some of the region's important staple crops. CePaCT conserves 17 crop species. These include: Aroids (taro- 1136 accessions, swamp taro- 66 accessions, Xanthosoma- 11 accessions, Alocasia- 11 accessions), banana- 157 accessions, yam – 330 accessions, potato - 54 accessions, sweet potato - 324 accessions, breadfruit - 13 accessions, ginger – 1 accession, bele - 10 accessions, pineapple – 7 accessions, sandalwood – 1 accession, vanilla – 4 accessions, cassava – 16 accessions, pandanus – 5 accessions, and sugarcane - 5 accessions. The Pacific accessions originate from 16 Pacific Island Countries (Cook Islands, Fiji, French Polynesia, Kiribati, Marshall Islands, Federated States of Micronesia, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu) and non-Pacific accessions originate from 30 countries (Kenya, Korea, Malaysia, Mexico, Nigeria, Panama, Peru, Philippines, Puerto Rico, Saint Vincent and Grenadines, Seychelles, South Africa, Spain, Sri Lanka, Taiwan, Thailand, Uganda, United States of America, Vietnam, Argentina, Belgium, Bolivia, Brazil, Burundi, Cameron, China, Columbia, Cuba, Dominican Republic and Ecuador). There are a total of 753 accessions from non Oceanic countries in the collection.

About 25 per cent of the accession have been confirmed to be clean from viruses. The source for these germplasms are the Ministries of Agriculture for the Pacific region and the International Potato Center (CIP), Bioversity International, United States Department of Agriculture (USDA), International Institute of Tropical Agriculture (IITA), and the Department of Agriculture, Fisheries and Forestry (DAFF), Australia. CePaCT has the largest collection of taro (*Colocasia esculenta* var. *esculenta*) comprising of germplasm from the Pacific and South-east Asia.

Distribution of Crops for Food and Nutritional Security

All germplasm accessions distributed by CePaCT are pathogen-tested, to ensure that they are safely and widely distributed. All transfers are accomplished by appropriate access agreements. Through the activities of the Centre, farmers are able to compare traditional varieties with those from regional breeding programmes as well as those sourced from outside of the Pacific. Some of the recipient farmers reported that the varieties which they received from CePaCT, taste a better than their traditional varieties. Thanks to CePaCT, farmers gain access to germplasm that is resistant to major diseases, thus removing the vulnerability of their crops to the accelerated spread of pathogens. In addition, crop varieties of interest are introduced from international and national research centres located in other parts of the world and made available to the Pacific Community's member states through CePaCT.

The highest number of crop accessions from CePaCT were distributed to Nauru from 2004 till 2017. The drought and salt tolerant crops established well in their atoll islands. Outside of the Pacific, the highest number of plants was sent to Nigeria. There are 113 varieties of climate-resilient crops for distribution. They include: banana, cassava, giant taro, swamp taro, sweet potato, xanthosoma, taro and yams. Taro is resistant to taro leaf blight (TLB) thanks to TLB-tolerant varieties sourced from Papua New Guinea (PNG), Hawaii and Samoa. Taro accessions imported by CePaCT from South East Asia have expanded the existing genepool with new genetic diversity which enabled a successful taro breeding programme in the Pacific (Samoa). FHIA banana lines are resistant to black leaf streak. Yams are resistant to anthracnose. There are six banana soma clones sourced from Taiwan that are tolerant to fusarium wilt race 4. Nutrient-rich crops include orange- and purple-flesh potato which are high in vitamins, cassava accessions which are high in carotenoids and sweet pineapple accessions from Hawaii. Some of the crops with good market potential include sugarcane from Guadeloupe, producing high yields, a commercial variety of ginger and a commercial variety of potato from the United States. Climate resilient germplasm and biotic stress resistant germplasm with resistance against major diseases, such as black leaf streak resistance are sourced from other countries to help affected countries in the Pacific during natural disasters to secure their food and nutritional security. Evaluation data is collected from recipient countries on the performance of the crop varieties received.

Food Security through Virus Indexing

There is high demand for clean planting material as well as disease-resistant and tolerant varieties of crops of economic importance. Most farmers lack clean planting materials and, therefore, reuse infected material over several generations resulting in very low yield. Tissue culture is the safest way to transfer clean planting material from one country to another country. The virus indexing facility at CePaCT carries out a diagnosis of the virus status of plants. There are three diagnostic methods: (1) Molecular tools which use Polymerase Chain Reaction (PCR), (2) serology tools which use serum and involve ELISA (enzyme linked immunosorbent assays), and (3) symptomology that uses symptoms on a plant to identify the virus. There are two separate rooms for virus indexing with different areas designated to specific roles of the virus indexing process. Aroids, bananas, sweet potato, bele (slippery cabbage) and yam have established protocols which are routinely used for indexing. Another important aspect of clean planting material is virus elimination after virus indexing has confirmed the presence of viruses. Two methods are used for virus elimination; these are meristem extraction and heat therapy. The process of indexing initially starts with isolating plants from the conservation collection for multiplication and goes through three phases of indexing. These phases are at the tissue culture (TC) stage, and at three months and six months of growth in the screen house. At each indexing phase, there are three replicates carried out to achieve consistent results. If the plant shows a negative result after the final indexing phase, it is re-introduced into the conservation collection. Climate ready varieties are included in the distribution collection to support food and nutritional security in the Pacific. These will be mass propagated and distributed. However, if the plant shows a positive result for the virus tested, the phase of virus elimination is used to remove the infection.

Research on Crop Improvement for Food and Nutritional Security

Research is underway to select climate ready varieties to help located in the Pacific Islands countries. Research on testing for drought tolerance was undertaken in four sweet potato varieties sourced from different countries under screen house conditions. Lack of water in the plant environment is called drought which will lead to a change in physiological and biochemical reactions. The three stages of biochemical reactions include: alarm, resistance and exhaustion. The alarm stage is similar to well-watered plants. At the resistance stage there is reduction in photosynthetic capacity. At the exhaustion stage, plants try to adapt to prolonged water stress to stay alive (Amede *et al.*, 2004). Drought often results in reduction of stem extension, diameter of internodes, root extension and production of smaller leafs (Farooq *et al.*, 2009). Water stress affects plant growth and productivity therefore plant breeding aims at increased survival rate as a major objective in the breeding of drought-tolerant crops.

The research done on mass propagation of breadfruit using bioreactor system by Shandil and Tuia (2015), has improved field planting readiness to 30 weeks from 44 weeks at CePaCT. So the bioreactor system was used to enhance readiness for the supply of clean taro (*Colocasia esculenta*) planting material of market ready cultivars. The bioreactor system reduced the field readiness of taro to 20 weeks from 28 weeks. Bioreactor treated plants established well and had higher survival rates in the screen house. The plants had increased height and a good rooting system. Mass propagation of taro helped to meet demands for improved quantity and quality of taro plantlets to farming communities in Samoa, other Pacific countries and the global community (Lutu and Tuia, 2016).

Documentation and Database for Food and Nutritional Security

Availability of data about each crop on the website will help in making an informed choice about germplasm of interest, especially with regard to climate ready varieties for food and nutritional security. The CePaCT database provides standardised accession-level data according to international standards and creates a database that facilitates data access and maintains high documentation standards, including data integrity. The CePaCT documentation system will ultimately streamline the workflow and enhance effectiveness and efficiency.

Promotion of Unique Crop Diversity for Food and Nutritional Security

The Pacific region is blessed with a rich and unique crop diversity sustaining food security over many generations. Major staple food crops in the Pacific include: coconut (*Cocos nucifera*), taro (*Colocasia esculenta*), cassava (*Manihot esculenta*), yam (*Dioscorea* spp.), breadfruit (*Artocarpus* spp.), banana and plantain (*Musa* spp.) and sweet potato (*Ipomoea batatas*). Also important to all Pacific islands is the unique diversity of breadfruit comprising of varieties that can produce all year round. Other aroids, such as the swamp taro (*Cyrtosperma merkusii*), is an important staple crop of the small atoll countries such as Tuvalu and Kiribati. The outbreak of the taro leaf blight disease (TLB), caused by oomycete, *Phytophthora colocasiae*, in Samoa in 1993 was a wake-up call to the Pacific region in realizing the need for greater diversity. The introduction of exotic genetic materials and the use of this germplasm in participatory breeding approaches became the ultimate remedy and a possible long-term solution.

Although the diversity is relatively high in the Pacific region, it still needs genetic diversity from other regions to broaden and build resilience, especially with regard to climate change and natural disasters. The Secretariat of the Pacific Community's (SPC) Centre for Pacific Crops and Trees (CePaCT), is accessing resilient and improved crop diversity from CGIAR Gene banks and utilizing these crops to enhance food and nutritional security in the Pacific region. Similarly, the Pacific is also reaching out and supporting global food security by sharing its crop diversity to other countries in need.

The sharing of plant genetic resources for food and agriculture within and outside of the Pacific is facilitated and supported by the International Treaty on Plant Genetic Resources for Food and Agriculture, the Global Crop Diversity Trust, Bioversity International and other collaborative programmes.

International Network for Edible Aroids

The Pacific is reaching out to support global food security through the International Network for Edible Aroids (INEA). The INEA is a worldwide consortium of scientists and growers who are using edible aroids, particularly *Colocasia* and *Xanthosoma*, as a model to improve clonally propagated tropical crops. The European Union (EU) has contributed €3 million over five years to the INEA. The participating countries include Burkina Faso, Costa Rica, Cuba, Germany, Ghana, India, Indonesia, Kenya, Madagascar, Nicaragua, Nigeria, Philippines, Papua New Guinea, Portugal, Samoa, Slovenia, South Africa, Haiti, Guadeloupe, Bangladesh, Cameroon, Mauritius, Congo and Vanuatu, and the Secretariat of the Pacific Community, Fiji, the Caribbean Agricultural Research and Development Institute, Trinidad, the French Agricultural Research Centre for International Development (CIRAD), Vanuatu, France, and Bioversity International, Italy.

The first year of the project has seen a great deal of activity. SPC's Centre for Pacific Crops and Trees, CePaCT, has sent 50 improved varieties as tissue cultures to each partner. The plants were chosen from breeding programmes in Samoa, Hawaii and Papua New Guinea (PNG), and have tolerance to taro leaf blight. In all, 6,526 plants were distributed, and they are now in the field ready for the next phase of the programme which will involve their evaluation and hybridisation with the best local varieties of each country.

Non-member countries, too, have benefitted from INEA. There have been requests for varieties from Haiti, Guadeloupe, Bangladesh, Cameroon, Mauritius and DR Congo, and they have all received germplasm from CePaCT. Cameroon and Mauritius were devastated by taro leaf blight in recent years so they will benefit greatly from the introduction of resistant lines from the Pacific.

In addition to germplasm distributions, research has begun on genetic diversity at CIRAD, France; on viruses at the German collection of microorganisms and cell cultures; on drought tolerance at the University of Madeira; and on nutrient analysis and breeding at the University of Maribor. Much of this work is being done by students. Relevant technologies and new exotic lines developed will be shared amongst INEA members.

The CePaCT aroid collection has been supported and developed over the years through different donor-funded projects, such as the EU-PRAP (Pacific Regional Agriculture Programme), AusAIDTaroGEN (Australian Agency for International Development Taro Genetic Resources: Conservation and Utilisation) and EU TANSAO (Taro Network for South-East Asia and Oceania). The conservation and regeneration of the CePaCT aroid collection is supported with funds from the Global Crop Diversity Trust. Sharing is facilitated by the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

Restoring Samoa's Food Security

There was a major taro leaf blight outbreak in Samoa in 1993. Prior to the arrival of taro leaf blight, farmers in the Pacific selected taro varieties for a number of traits but not for resistance to the disease. Due to absence of this selection, taro varieties have reduced levels of resistance. When the pathogen began to spread into the region, it encountered a host plant that was genetically vulnerable. Taro leaf blight was first detected in the Western District highlands of Tutuila Island, American Samoa on 15 June 1993 (Hunter *et al.,* 1993). The disease has severely constrained taro production in the country (Gurr, 1993). Within a year of the introduction of the disease it had caused over 95 per cent reduction in the supply of taro to the public market in that country. In less than one month, taro leaf blight was diagnosed and confirmed in Samoa. It was first observed on the island of Upolu at Aufaga Aleipata and two days later in Saanapu and adjacent districts of Alafou, Samusu, Utufaalalafa, Malaela, Lepa and Aufaga. The disease spread rapidly throughout the country, badly affecting all local varieties but was most severe on taro variety, Niue which was unfortunate as this was the variety of choice for commercial production because of its quality and taste. To solve this problem, SPC recruited a staff based in Samoa who did population breeding of taro by crossing Polynesian taro, Micronesian taro and South East Asian taro. Elite lines of taro are selected for food and market security. After harvesting and taste testing, good varieties are selected for both local and export markets. These varieties are sent to SPC-CePaCT's genetic resources programme for maintenance in the conservation collection and are tested for viruses for future distributions.

Pacific Community Supports Fiji through CePaCT

The Centre for Pacific Crops and Trees (CePaCT) improves food and nutritional security in Fiji by adapting to climate change through the provision of crop diversity. The centre provides support to Fiji Koronivia Research Station (KRS) to supply communities with improved crop diversity from its new tissue culture laboratory. CePaCT provided tissue culture plantlets of breadfruit for field research by the Ministry of Agriculture and Pacific Breadfruit project. Climate ready banana and taro varieties were evaluated in the field. CePaCT assisted staff from KRS to build capacity in crop breeding, such as breeding taros for tolerance to taro leaf blight disease and extreme climatic conditions. The centre also promoted indigenous vegetables (bele/slippery cabbage) for the export market of leafy vegetables for nutrition and livelihood support. The provision of bacterial wilt tolerant varieties supported the development of the local potato industry and allowed for import substitution. SPC-CePaCT conserves Fiji's and other Pacific countries traditional and improved crop diversity for future generations.

Technical Support and Training for Food Security

CePaCT provides a credible source of information for the region on the conservation and utilization of crop and tree genetic resources using tissue culture technology. CePaCT, with its connections to international agriculture centres throughout the world, is well placed to source new cultivars and help countries keep abreast of new biotechnology developments as they occur.

CePaCT provides training to countries generally in the form of attachments. These attachments enable staff from countries in which tissue culture facilities already exist or are being developed, to update their knowledge on or to learn about tissue culture technology. For those countries with no tissue culture facilities, staff can be trained in the handling and acclimatization of tissue culture plants.

Nutritious Crops for Export from Fiji

Export of taro from Fiji is being a significant source of foreign exchange. Its importance in smallholder production systems makes it a key food security crop. Almost all parts of the plant can be eaten, the corms are most commonly consumed. Corms can be baked, roasted or boiled and are an excellent source of carbohydrates and low in fat and protein, but large servings of taro corms can be a significant source of protein; taro corms can serve 'as a dietary source of carbohydrates and potassium for all ages and as a major protein source for adults who depend on taro as their staple food (Standal, 1983). The corms provide a good range of vitamins, amino acids and minerals, with abundant levels of potassium. Leaves are also frequently consumed providing a good source of protein, minerals and vitamins. Taro is a major staple food and significant export commodity for Fiji. The major export markets are New Zealand, Australia and the USA, cumulatively 97 per cent of Fiji's total export in taro. Fiji's taro exports average around 3,400 tonnes per annum, with an FOB value of around $5.7 million in 2014 and $3.8 million in 2015.

Markets for Locally Produced Food Crops

Crop products in Fiji are sold through a variety of outlets that could be grouped into municipal fresh produce markets, restaurants, supermarkets and roadside stalls. The fresh produce markets are to a large extent satisfying most of the needs of consumers. Yet there is concern that major foods of high nutritional value in the market places are losing ground to imported foods. The Fiji Plan of Action on Nutrition (FPAN) proposes an investigation of how to strengthen production and marketing cooperatives for local food produce as a means of encouraging and supporting community-based food production enterprises.

Farmers are becoming more market-oriented in supplying the domestic markets for roots and tubers, horticultural produce and other foods. However, it is widely recognised that production remains a major constraint. Supplies are inadequate, prices are high and production tends to be irregular and seasonal. The small size of most island economies means that farmers wishing to expand production and increase their incomes look mainly to the possibility of expanding exports. Lack of domestic demand is also one reason why few agricultural processing ventures have taken less interest. The demand has been insufficient to permit the necessary economies of scale. The two major staple crops in Fiji are dalo and cassava (Foraeta, 2001).

Challenges for Food Security and Recommended Policy Actions Promoted by SPC

The main challenges for food security in terms of production, consumption and other related issues are: increasing population growth, especially in urban areas, putting more pressure on local food availability, land tenure and availability leads to decreased production and increased reliance on processed foods. Increasing food prices due to global market price changes leads to households spending more of their income on buying food, resulting in less income available for children's education and other socio-cultural obligations. This also reduces access to quality of healthy food. Most locally-produced foods (agriculture and fisheries) are heavily dependent on environmental and climatic conditions for sustainable production and supply. As seen in Pacific Island countries and Territories (PICTs), increasing frequency and intensity of climate-related events and climate change reduces agricultural and fisheries productivity. The damages are usually severe and take longer for communities to fully recover. Understanding how climate extremes and climate change affect our food sources will help communities develop adaptation measures to sustain food production and build the resilience of food security systems.

The PICTs are most vulnerable to natural disasters. In the past few years there have been two category five cyclones, Pam and Winston as well as El Niño drought, which was devastating to our region. Promoting disaster risk reduction (DRR) measures for food security will reduce vulnerability and risks and trying to prevent, mitigate and prepare for hazards. To build resilience to these hazards and to protect the countries' food security coping capacity, countries are urged to adopt DRR strategies. The DRR framework builds resilience, protects investments in food security, infrastructure, operation, and reduces hunger and poverty.

It follows from the described challenges and the issues threatening food and nutrition security that the development of food production and associated services in the Pacific region may be defined as the strengthening of food and nutritional security resilience against adverse impacts of disasters and climate change in the Pacific Islands. In this context, the Regional Food Security Policy aims to achieve four overarching food and nutrition security objectives:

1. ***Availability of food***: Promote the sustainable domestic production of safe, affordable, nutritious, good quality Pacific food commodities/products and facilitate food imports.
2. ***Access to food***: Ensure access (grown or purchased) of Pacific Island households and individuals to sufficient, nutritious, affordable food at all times by agricultural development focussing on smallholders and creating employment and income generation from food production.
3. ***Food utilization*:** Improve the ability of individuals to utilize food maintaining its nutritive quality and making it available to consumers. The following policy actions will be promoted: (i) Improve food preservation and preparation; (ii) establishment of proper food standards; (ii) improving public health; (iv) provision of safe drinking water; (v) improve sanitation; and (vi) hygiene and nutrition education.
4. ***Stability of food systems*:** Improve the food and nutrition security resilience of the region to natural and socio-economic shocks and climate change by establishing a system of disaster preparedness and response, including early warning systems and a set of measures to ensure food stability.

Opportunities and Outlook

The Land Resources Division (LRD) of SPC assists Pacific island countries to develop stronger, evidence-based policy capacity in the areas of food security, sustainable resource management, cost/benefit analysis and economic growth, while raising awareness levels around the impact of climate change on agriculture and forestry and supporting the development of resilience in Pacific island crops, livestock and trees. LRD is creating awareness of the climate change mitigation role of forests and adaptation measures to underscore community resilience and livelihoods through sustainable agro-forestry and land management practices.

LRD chairs the regional Food Security Working Group and contributes its technical expertise to the internal Non-Communicable Diseases (NCD) - Food Security (FS) Working Group of SPC, with both working with member countries to develop national level strategies and policies. LRD also has prioritized NCD/FS as a key focus of its technical programmes, e.g. CePaCT creating awareness on nutritional value of local food crops such as bele and developing climate-ready varieties of principal Pacific Island crops, predominantly root and tuber crops for ready deployment and adaptation trials in Pacific countries affected by a range of biotic and abiotic stresses exacerbated by climate change. LRD and CePaCT continue to promote diversity in food supply systems by supporting the establishment of collections and exchange of food crop diversity with focus specifically on the banana and the edible aroids diversity. CePaCT's use of biotechnology tools for culturing and multiplying vegetatively propagated crops and its virus-indexing and disease elimination facility is assuring countries of safe conservation and distribution of the Pacific Islands prime genetic resources for breeding and adaptation to climate change.

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Underutilized Tropical and Subtropical Fruits for Nutrition and Health Security and Climate Resilience - A Bioversity International Initiative†

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ABSTRACT: Fruits, the major component of agro-biodiversity are considered as the cheapest and major source of natural nutritious food and health supporting compounds. Because of their wider distribution and multipurpose use, they occupy an important place in food basket, economy and cultural as well as religious aspects of human civilization. However, out of very large number of reported species, only 30 species have been used and 28 are under commercial cultivation. Because of large scale habitat destruction to meet diverse demands of ever increasing population on one hand and the deleterious effect of climate change on the other, global biodiversity is getting eroded at a very high rate. The combined effect of these, recent crises of malnourishment and undernutrition has become one of the major agenda of the Melanin Development Goal (MDG). Realizing the importance of minor tropical fruit crops in meeting the zero-hunger challenge and climate resilience, large scale programmes have been drawn for mainstreaming the neglected crops in general and fruits in particular. Bioversity International has drawn quite a good number of research activities for promotion of tropical fruits crops. As a part of these ongoing activities, collection, conservation, characterization and mainstreaming neglected and underutilized tropical and subtropical fruits has been initiated. Seven tropical and subtropical states of India have been explored covering 26 districts, 62 farmers, 18 nurseries and 24 research institutions. So far 220 varieties belonging to 100 species and 55 genera of 33 families have been collected and maintained in the *ex situ* genetic diversity park. On site information on all the collections has been documented with respect to botanical and germplasm details. After preliminary characterization, six species namely jack, custard apple, Jewish plum, ber, tamarind and drumstick have been shortlisted for mainstreaming. Details of the study have been discussed in this paper.

Key words: Main streaming neglected and underutilized species, Tropical and subtropical fruits, Zero hunger challenge

Introduction

Fruits, the cheapest and major source of natural nutritious food and health supporting compounds including minerals and vitamins constitute significant part of human nutrition and is highly recommended for healthy and vitamin rich diet (WHO, 2004). As per the report of FAO (2016), overall per capita consumption of fruits and vegetables is lower than the recommended level of 400 g, as a result,

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sizable population is reported to suffering from different health disorders. More than 600 million tonnes of fruits are produced all over the world each year and top six countries producing fruits are China, India, Brazil, USA, Italy and Mexico. Fruit crops are distributed all over the world covering the tropics, subtropics and temperate climatic regions right from humid tropics to cold arid zones. Because of their better adaptability over wider range of soil and climatic conditions, they have been contributing to food basket in the regions of their distribution. Besides being a good source of food, they also yield other products like gums, resigns, beverages, fibre, wood, fuel etc., which are of high economic value. Local people have recognized the role of this important component of biodiversity as the basis of their livelihood. Because of aesthetic and religious values of fruits, they have become part and partial of local religious functions and rituals (Pareek and Sharma, 2009). Other than the few major fruits which have been commercialized, large proportion of underutilized and neglected fruit species form the major components of biodiversity and provide immense support to ecosystem services. Local people especially tribal's have contributed great deal of information and knowledge on multipurpose uses of wild fruits as vegetables, and pickles. Wine and local drinks are prepared medicine after fermentation. Some of the fruit species are also used for medicinal purposes to cure several chronic and serious health ailments. Traditional and ethnic food recipes developed for preparation of several food products are becoming very popular in the present-day world. Fruit trees serve as an excellent source of pollen and nectar for honeybees and contribute immensely for honey production as well as pollination services.

Vietmeyer (1990) and West Wood (1993) have reported that nearly 3,000 tropical and 2,400 temperate fruits and nut species are growing on this planet and hardly 30 are exploited commercially. Despite large amount of fruit diversity found all over the world, hardly 28 species (7 tropical, 7 subtropical and 14 temperate) are only commercially exploited and more than 95 per cent remain less-known and underutilized (Pareek and Sharma, 2009). Distribution of underutilized edible fruits and nuts is given for the 12 regions of diversity of cultivated plants by Zeven and de Wet (1982) and the same is shown in Table 1 and Fig. 1. Pareek *et al.* (1998) listed 1,750 species of underutilized fruits and nuts occurring in the 12 Vavilov centres of diversity. Pareek and Sharma (2009) reported that, Asia and Pacific, Tropical Africa, Central and South America as the major regions of distribution of tropical fruit whereas Himalayan region of South Asia, East and West Asia, Europe, Siberia, The Mediterranean, North Africa and North America for temperate fruits. Nagy and Shaw (1980) reported about 600 tropical and subtropical fruits in their respective areas of diversity.

Table 1. Inventory of underutilized edible fruits and nuts in different regions of diversity

Region	Species enumerated (No.)
Chinese-Japanese	222
Indochinese-Indonesia	226
Australian	57
Hindustani-Indian	344
Central Asian and Near Eastern	38
Mediterranean	30
African	131
European-Siberian	62
South American	263
Central American and Mexican	122
North American	255

Source: Pareek et al. (1998); Zeven and de Wet (1982)

Arora (1985) has reported 337 fruit and nut species belonging to 124 genera of 53 families occurring in tropical, subtropical and temperate regions of Asia. India, the rich biodiversity resource country has as many as 84 species of underutilized fruit species belonging to 34 families and 56 genera (Arora, 2014). Chadha and Pareek (1993), Arora and Ramanathan Rao (1998), Pareek *et al.* (1998), Bose *et al.* (2002), Bhag Mal (2007), Vishal Nath *et al.* (2008, 2009), and Pareek and Sharma (2009) have dealt in detail regarding the minor fruits especially of tropical and subtropical region. Eyzaguirre *et al.* (1999), William and Haq (2000), Padulosi *et al.* (2013) have suggested criteria for bringing them to the mainstream for commercial exploitation and livelihoods of small holder farm families. CFF of Bioversity International and ICUC have drawn worldwide programme to highlight the importance of Neglected and Underutilized (NUS) and several programmes have been initiated both at regional and national levels. The underutilized crops are being considered as 'Crops of the Future' because of their climate resilience, nutritional and health benefits and also income for small and marginal farmers.

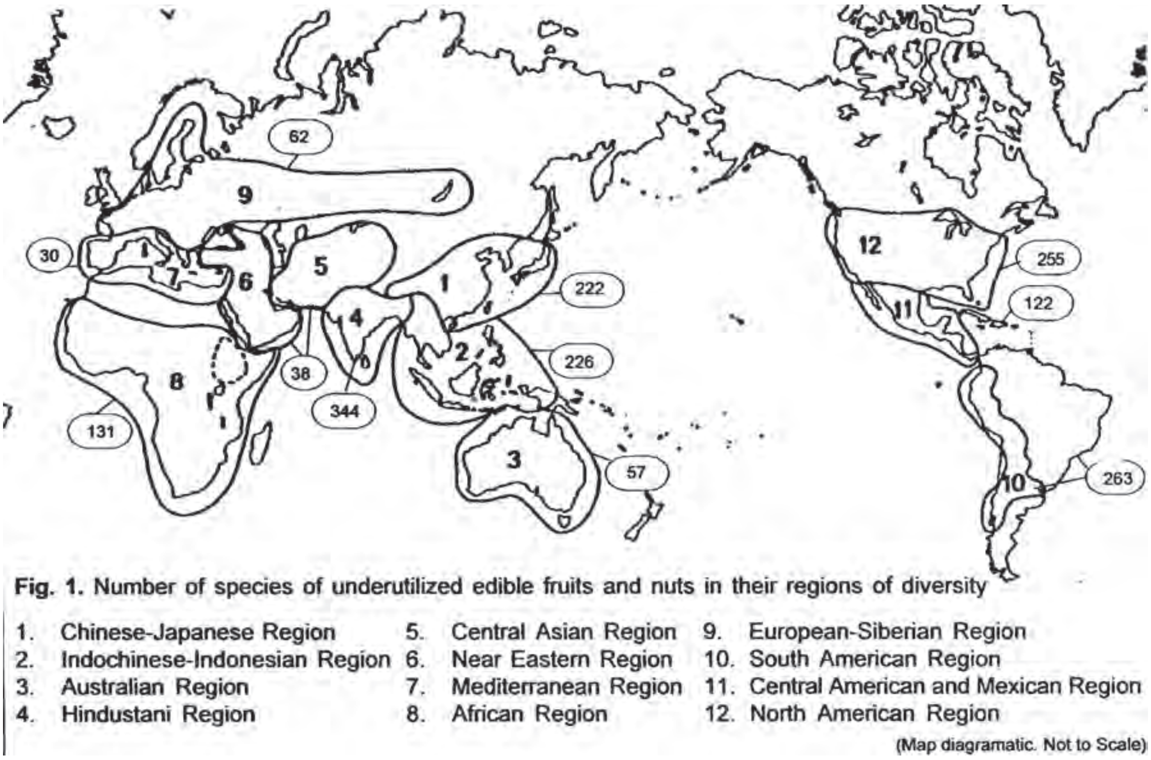

***Fig. 1.** Region wise distribution of underutilized edible fruits and nut species*

Nutritional Composition and Dietary Value

Nutritional composition of these minor fruit crops has been analysed and reported by several workers to emphasize the importance of these crops. This information has been consolidated by Pareek *et al.* (1998). However, for several of these crops complete information is not available and for few, the information is totally lacking. Hence, information on nutritional composition needs to be accomplished as per the USDA National nutrient database for standard reference (Source: USDA National Nutrient Database for Standard reference, SR-15).

Bioversity International's Initiatives

Considering the importance of these minor fruits, Bioversity International has been working on management of fruit trees. For the last 10 years it has initiated good number of programmes in

Important Programmes

- TFT UNEP-GEF Project (2009-2014): Conservation and sustainable use of cultivated and wild tropical fruit diversity: promoting sustainable livelihoods, food security and ecosystem services.
- Community Biodiversity Management (CBM)
- IFAD-NUS Project in 4 Phases from 2001 to 2016: Reinforcing the resilience of poor rural communities in the face of food insecurity, poverty and climate change through on-farm conservation of local agrobiodiversity.
- BFN UNEP-GEF Project (2012-2017): Mainstreaming biodiversity for nutrition and health.
- India UNEP Project 2016-2021: Mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability
- Big idea on NUS-Fruit tree diversity for nutrition and food: A new proposal
- Neglected plants-food for future

temperate regions of Central Asia (Uzbekistan, Tajikistan, Kazakhstan, Kyrgyzstan, Turkmenistan and China), on tropical fruit tree conservation in South and South-East Asia (India, Indonesia, Malaysia and Thailand), in Latin America and in West and Central Asia.

Since, tropical and sub-tropical fruit crops are difficult to conserve as a seed, due to the inherent seed physiology and seed viability, *in situ*/on-farm conservation supported by *ex situ* conservation in gene bank as backup is necessary. Further, challenges faced by large number of small holder farmers who are involved in on-farm conservation need to be addressed. Accordingly, a programme on exploration, collection, conservation and characterization of the genetic diversity of the minor fruits of tropical and subtropical regions for sustainable use has been initiated at its Bengaluru Project office. Details of the activities undertaken and the findings of this programme are discussed below.

Fig. 2. Location map of collection areas

Exploration and Collection

Exploration and collection of underutilized fruit species has been completed covering 26 districts of 7 states. In all, 62 custodian farmers, 18 nurseries and 24 institutions have been visited for the study and collection of the material (Table 2 and Fig. 2).

Table 2. Explored areas and sources

States / provinces	Districts (no.)	Farmers (no.)	Nurseries (no.)	Research Stations/ SAU's
Kerala	6	10	4	6
Karnataka	7	25	9	7
Tamil Nadu	4	10	2	4
Maharashtra	3	4	1	4
Rajasthan	3	10	-	2
Gujarat	2	5	-	2
Madhya Pradesh	1	-	2	2
Total	26	64	18	26

At the time of collection, detailed information about the sight, custodian farmers and species maintained *etc.*, were collected as indicated below:

Onsite Information Collected:

- Details of custodian farmer
- No. of species/varieties maintained
- Sources of material
- Age and stage of the plant(s)
- Morphological details

- Floral characters
- Fruiting season, duration and yield details
- Fruit characters
- Uses, local preparations/products being prepared and consumed
- Market information
- Economics and income
- Sharing of plants among other farmers

Ex situ Genetic Diversity Park

An *ex situ* genetic diversity park has been established at its Bengaluru centre for conservation, characterization, food value analysis, mainstreaming, multiplication and distribution of these neglected and underutilized species of tropical and subtropical region. As of now 223 varieties belonging to 103 species, 56 genera and 33 families of fruits species have been collected and maintained in the genetic diversity park (Table 3). Among them, family Anacardiaceae with five genera, five species and 20 varieties; Annonaceae with seven species and 24 varieties; Moraceae with three genera 11 species and 42 varieties; Myrtaceae with four genera 14 species and 34 varieties; Sapotaceae with three genera, five species and 13 varieties; Rutaceae with three genera, seven species and 14 varieties and Clusiaceae with one genera, six species and eight varieties are the dominant ones. Many of these species/varieties are yet to be studied for their multipurpose benefits as they are reported to possess high nutritional values and are potential source of vitamins, minerals, antioxidants etc. Some of the species are reported to possess medicinal properties and found useful in mitigating specific health disorders. Some of these species are still found in semi domesticated / wild condition. However, due to ethno-botanical and medicinal properties, they have been grown traditionally in the kitchen gardens, backyards of houses and near water sources of the farm land. Jack fruit, clustered apple, *Garcinia,* Java plum (jamun), tamarind, java apple (rose apple), drumstick, ber, lemons *etc*., are found commonly grown around the dwelling houses mainly because of their multipurpose use. Species belonging to the genus *Garcinia, Morus*, etc., have been used to extract industrial products. In Annonaceae family, about five species are found cultivated in backyards or in the kitchen gardens and serve as a rich source off seasonal edible fruits besides, *Annona muricata* which is exploited as a source of medicine used for curing cancer. For all the species maintained in the diversity park, following information has been collected and furnished as per the details given below:

Table 3. List of families, genera, species and varieties maintained in Genetic Diversity Park, Bengaluru, Karnataka, India

Families	Genera (no.)	Species (no.)	Varieties (no.)
Actinidiaceae	1	1	1
Annonaceae	1	7	24
Anacardiaceae	5	5	18
Apocynaceae	1	2	4
Arecaceae	2	2	2
Boraginaceae	1	2	3
Cacataceae	1	1	1
Celastraceae	1	1	1
Clusiaceae	1	6	8
Dilleniaceae	1	1	1
Ebenaceae	1	2	2
Elaeocarpaceae	1	1	1
Euphorbiaceae	1	1	1
Flacourtiaceae	1	1	2
Lauraceae	1	1	2
Leguminosae	3	3	6
Malpighiaceae	2	3	3
Malvaceae	1	1	1
Meliaceae	1	1	1
Moraceae	3	12	55
Myrtaceae	4	14	31
Oxalidaceae	1	2	3
Passifloraceae	1	1	1
Phyllanthaceae	3	6	9
Proteaceae	1	1	1
Puniceae	1	1	4
Rhamnaceae	1	3	5
Rosaceae	3	3	3
Rubiaceae	1	1	1
Rutaceae	3	7	12
Sapindaceae	3	4	5
Sapotaceae	3	5	12
Thymelaeceae	1	1	1
Total	**56**	**103**	**223**

Information Compiled for Each Collection

- Botanical name
- Common name and vernacular (local) name(s)
- Habit
- Origin and geographical distribution
- Flowering and fruiting period
- Mode of propagation
- Recognized varieties/landraces/farmer's varieties if any
- Source of germplasm material maintained
- Food/nutritional value composition
- Uses-as food, medicine, culinary, industrial, etc.

As per the interaction with farmers during exploration trips, following aspects need to be considered for empowerment of custodian farmers for effective *On-farm/In situ* conservation;

- On-farm conservation involving custodian farmers is reported to be the cheapest and effective method for sustainable use of this fruit diversity.
- Documentation of farmer's practices along with associated traditional knowledge and their validation is imperative.
- Need for capacity building and promotional opportunities.
- Better publicity and recognition of custodian farmer's efforts/activities.
- Long term arrangements for establishment mother plot orchard, multiplication and supply of quality seed/planting material to harness this wealth.
- Establishment of value chain and marketing facilities for sustainable income.
- Networking of all custodian farmers with:
    - ♦ Other stake holder farmers/self-help groups
    - ♦ Nursery men/seed banks
    - ♦ Marketing agencies
    - ♦ Food industry

Since the role of custodian farmers is imperative in sustainable production, commercialization and conservation, they need to be supported for better economic returns. Further, the minor fruit species needs to compete with popularly and commercially exploited species which enjoy maximum support in the form of subsidies, minimum support price, post-harvest processing incentives *etc*., a level playing ground is essential for popularization of these minor fruits to fetch good return to the farmer on par with other major fruit crops. Hence, it is imperative to extend the available policy support to these minor fruit crops also.

Mainstreaming of Potential Crops

The ultimate objective of the study is to identify the potential fruit species and popularize them for inclusion in the daily food basket for improving the nutrition and health of the people besides investigating their resilience to the changing climate. Eyzaguirre *et al.* (1999), William and Haq (2000) and Padulosi *et al.* (2013) have suggested criteria for mainstreaming the neglected and underutilized species. As per this criterion, the important aspects to be considered are food and nutritional composition, local adaptability for large scale cultivation and yield potential, market potential; local acceptance both for cultivation and consumption and broad genetic base for climate resilience.

Based on the preliminary studies of all the species and varieties collected six species namely jack fruit, custard apple, *ber, jamun* (java plum) tamarind and drumstick have been identified as potential crops for mainstreaming. In-depth studies have been initiated on characterization of all the available genetic variability along with landraces and wild relatives; (Table 4 and Fig. 3). Associated ethnobotanical and traditional knowledge; food and nutritional composition (Table 5) local food preparations and recipes, information of custodian farmers who are maintaining the germplasm of these species and good cultivation practices besides, the propagation protocols etc., has also been complied.

Table 4. Potential underutilized fruits for mainstreaming

Crops	Species (no.)	Varieties (no.)
Jackfruit (*Artocarpus* species)	6	32
Custard apple (*Annona* species)	7	24
Ber (*Ziziphus* species)	3	08
Jewish plum (*Syzygium* species)	9	17
Tamarind (*Tamarindus indica)*	1	05

Table 5. Food and nutrition value of potential underutilized species

Food components	Jack fruit	Custard apple	Jewish plum	Tamarind	Ber
Water (g)	72-94	69-75	83.7-85.8	17.8-35.8	81-83
Calories (Kcal)	72-98	88-96	62.00	-	63.00
Protein (g)	1.3-2.0	1.53-2.38	0.7	2.0-3.0	0.8-1.8
Fat (g)	0.1-0.4	0.26-1.10	0.15-0.3	0.6	0.07
Carbohydrates (g)	16.0-25.4	19-25	14.0-16.0	41.1-61.4	14.17
Fibre (g)	1.0-1.5	1.14-2.50	0.3-0.9	2.9	0.6
Calcium (mg)	20-37	19.4-44.7	8.0-15.0	34.0-94.0	25.6
Phosphorus (mg)	18-38	23.6-55.3	15.0-16.2	34.0-78.0	26.8
Iron (mg)	0.5-1.1	0.28-1.34	1.2-1.62	0.2-0.9	0.8-1.8
Vitamin-A (IU)	152-540	5.0-7.0	80.0	-	34.0-35.0
Thiamine (mg)	0.03-0.09	0.1-0.13	0.01-0.03	0.33	0.02
Riboflavin (mg)	0.03-0.05	0.11-0.17	0.01	0.10	0.02-0.04
Niacin (mg)	0.4-4.0	0.65-0.93	0.2-0.29	1.00	0.7-0.9
Ascorbic acid (mg)	8.0-10.0	34.0-42.0	5.7-18.0	44.00	65.0-76.0

Fig. 3. *Variability in potential underutilized species*

Way Forward

Several organizations and researchers associated with biodiversity conservation for future prospectus are thinking loud for broadening the biodiversity base of crops to mitigate the dual problem of health and nutrition insecurity and the adverse effects of climate change and also to support the livelihood of small holder farmers. Hence, neglected and underutilized species (NUS) are assuming vital importance and being recognized as 'Future Smart Foods' (FSF). International Centre for Underutilized Crops (ICUC); Global Facilitation Unit (GFU), Bioversity International, Rome and FAO have started large number of consultations and discussions both at regional and international level for mainstreaming of these potential species. Thus, following publications namely; Proceedings of International Consultation entitled "Enlarging the basis of food security - role of underutilized species" held at MSSRF, Chennai, India (1999); Global Research on Underutilized Crops - An Assessment of Current Activities and Proposals for enhanced Cooperation by Williams and Haq, (2000) of ICUC; Neglected and Underutilized Plant Species: Strategic Action Plan of the International Plant Genetic Resources Institute, Rome, Italy, IPGRI (2002); Fighting Poverty, Hunger and Malnutrition with Neglected and Underutilized Species by Padulosi *et al.* (2013) of Bioversity International, and IPGRI, GFU and MSSRF (2005); Meeting the Millennium Development Goals with Agricultural Biodiversity jointly initiates by International Plant Genetic Resources Institute; Global Facilitation Unit for Underutilized Species, Rome, Italy and M S Swaminathan Research Foundation, Tamil Nadu, Chennai, India, assume greater importance. This is mainly because of fast erosion of biodiversity due to habitat destruction and imbalance in ecosystems all over the globe. In the recent publication entitled "Diversity in Underutilized Plant Species-an Asia-Pacific Perspective" Arora (2014) has emphasised a good insight into the need for global network in conservation and utilization of these crops.

Bioversity International is making an all-round effort through a special "Big idea" programme of "Moving from orphan to high potential crops" (Un-Published Note No. EE/PO 1.2.1 of Bioversity International). This programme is mainly aimed at mainstreaming some of these potential crops and making them more popular to substitute or supplement the major food crops covering Africa, Latin America, and Asia through active participation of custodian farmers and networking them. All the organizations/ institutions working worldwide on the subjects related to this vital aspect need to be networked and given responsibility to work in the local areas towards generating the needed information. Many of the CGIAR institutions, APAARI members and other NARS institutions need to be involved in this global programme. Following are the few issues which need attention both at global and regional level and definite action needs to be drawn at national level:

Research and Development Issues

- Prioritizing the potential fruit species country/region wise to address commonly accepted researchable issues.
- Documentation of available worldwide information on ethno botanical aspects and traditional knowledge for exchanging the same among researchers working on these fruit crops.
- Promoting the concept of on-farm/*in situ* conservation of fruit biodiversity through custodian farmers and involving farmer-cum-nursery men for production and distribution of quality planting material.
- Establishment of *ex situ* genetic conservation parks in the diversity rich regions as a backup for the future research and development needs.
- Concept of virtual gene bank could be considered as a viable link between *in situ* and *Ex situ* conservation approach.
- Initiating worldwide investigations on food composition and nutrition value and also analysis of special molecules available in these individual crops and their varieties including their health beneficial properties through biomedical approach.
- Capacity building of custodian farmers in general and women in particular for consumption, cultivation and conservation of these crops.
- Networking all the stake holders in the value chain for better coordination and building organic linkages.

Policy Issues

- Creation of a common global level platform for consolidation, sharing and exchanging of the available information on the status of the NUS of tropical and subtropical region.
- Developing an acceptable model of benefit sharing for better reward to all the stake holders.
- Developing food value chain and branding of value added products for better availability to consumers and good returns to the growers/producers.
- Creating a level playing ground on par with other major crops by providing production incentives, minimum support price etc which will enhance the visibility and availability of these crops.
- Convincing policy making bodies to include some of these nutri-rich underutilized crops in common/social food security programmes such as public distribution systems, mid-day meals, hospital menus, grains for work etc.
- Attracting the attention of donors for liberal funding on research programmes aiming at improving, popularizing and mainstreaming these fruit crops.
- Establishment of a single global level body for initiating a long-term network programme for overall development and promotion of these fruit crops as "Crops of the Future" or "Future Smart food".

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Potential of Seabuckthorn (*Hippophae* L.) - A Multipurpose Underutilized Crop of Dry Temperate Himalayas

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ABSTRACT: Seabuckthorn (*Hippophae* L.) grows widely in Europe and high altitude cold regions of Indian Himalayas, China and Central Asia. The potential of seabuckthorn in control of soil erosion and conservation of biodiversity, wild life, soil and water have been harnessed in China and Mongolia. Fruit and leaves, being rich in variety of vitamins and antioxidants have been utilized for the production of over 200 health food, cosmetics and medicines (1.5-2.0 billion USD) in Russia, China, Germany, Mongolia, India and Finland. Seabuckthorn widely occurs in mostly natural forest in high altitude (2500-4500 m) cold deserts regions of Himalayan states like Himachal Pradesh, Jammu & Kashmir (Ladakh), Uttrakhand (UK), Sikkim and Arunachal Pradesh in India. Fruit collection has increased from 50 tons in 2001 to 600 tons in 2016, mostly in Ladakh Himalayas in J&K. Seabuckthorn juice and cosmetics are quite popular in the country. Preclinical studies have been carried out on wound healing, skin diseases, gastric ulcer, cardiovascular and diabetes and high altitude related health problems; there is a need to speed up clinical study in human beings. There is a need to identify new molecules and improve oil extraction methods. Further, there is a need to popularise the Russian seabuckthorn varieties due to their high productivity and oil values. Cultivation of improved seabuckthorn has been slow due to policy issues; most of the demand of raw material is being fulfilled by importing raw material. In view of high ecological potential and demand in local and global market, efforts are required to improve cultivation technologies, develop more promising high yielding forms and carry out large scale cultivation, which will help in combating climate change, the ecological rehabilitation of fragile mountainous lands, improve livelihood of farmers, create employment opportunities and provide nutritional security and health protection.

Key words: Environmental conservation, health products, seabuckthorn, vitamins

Introduction

Seabuckthorn (*Hippophae* L.), a nitrogen fixing thorny, deciduous shrub or small trees, is a diverse plant growing in cold and high - altitude regions of Himalayan countries and low altitude regions of Europe. On one hand, it has high potential in combating climate change and environmental conservation, improve livelihood of farmers, on the other hand it has potential in providing nutritional security and health protection. Medicinal values were discovered by Tibetan doctors as early as in 8th century and however, it was Russian scientists who used seabuckthorn health products during space flights during 1970s, which attracted global attention. Since then many countries including China, Russia, Germany, India, Mongolia and Finland have carried out systematic research on various aspects of this diverse species so as to harness its full potential for environmental conservation, economic upliftment of rural economies and health protection. The fruit oil and leaves are quite rich in vitamin C, E, K, A, carotenoids, omega fatty acids, polyphenols and phytosterols etc. The nutritional values of seabuckthorn fruit oil are much higher than other oils (Table 1).

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Table 1. Comparison of seabuckthorn oil with other crop oils

Vitamins	Seabuckthorn seed oil	Seabuckthorn pulp oil	Olive oil	Walnut oil	Wheat embryo oil	Corn oil
Carotenoids (mg/100 g)	78.2	373.2	11.9	0.36	0.4	50.9
β-carotene (mg/100 g)	2.5	82.2	nil	0.17	nil	0.29
Vitamin E (mg/100 g)	206.6	213.0	6.0	21.3	144.5	34.0

The most important feature of seabuckthorn is the antioxidant properties of its oil and leaf extracts (Singh, 2006). Besides, application in environmental conservation, it has been used globally in health food, cosmetics and health protection industries. It was clinically tested in Russia, India, China, Germany, Finland and many other countries. A number of health food, medicinal and cosmetic products have been recently produced from different parts of seabuckthorn extracts in India and globally. The present review describes the morphology-chemical characteristics and medical properties of seabuckthorn and its cultivation technologies.

Global Distribution and Adaptation of Seabuckthorn

Seabuckthorn has been reported growing widely in Europe and high-altitude regions of Asia. It is adapted to high altitude regions in Asia (2,000-5,500 m), However, this plant grows in low altitude regions in Europe. Therefore, plant is naturalized in snowfall or low temperature conditions, which meet the chilling requirement of the plant. It tolerates temperature as low as -40°C during winter. Despite seabuckthorn's winter hardiness, it has high temperature requirement for active growth during summer. There is natural distribution of seabuckthorn in the regions with the temperature isolines over 25°C on the average in the summer. Therefore, optimum temperature during summer for natural distribution of seabuckthorn is between 15-25°C. The maximum radiation in the sunny days of May-July is 23.5-26.5 k cal/cm^2 between the isolines (Rongsen, 1992). Seabuckthorn is indigenous in about 40 countries like India, Russia, China, Central Asia, Finland, Latvia, Germany, and Sweden. The plant has also been brought to USA, Canada, Bolvia, Japan and Korea (Singh, 2003). Seabuckthorn is well adapted to riversides, hill slope, lakes, seashores and other marginal lands, where conditions are suitable for many other agricultural crops. There are about 3 million ha land under seabuckthorn globally, 90 per cent of which are forests, mostly plantations found in China. Other important seabuckthorn growing countries are Russia (area under cultivation 40,000 ha), Mongolia (30,000 ha), India (15,000 ha), Germany (2000 ha). Russian seabuckthorn is most common species (ssp. *mongolica*) being cultivated in over 20 countries.

Systematic Classification

The genus *Hippophae* belongs to family Elaeagnaceae. The genus *Hippophae* L. with two species, *H. rhamnoides* L. and *H. canadensis* L., was founded by C. Linnaeus, as recorded in *Species Plantarum* in 1753. Nuttall shifted the *H. canadensis* L. to the genus *Shepherdia* Nutt., as *H. canadensis* with the 4-fid calyx and eight stamens, was different from the other species of the genus *Hippophae* L. D. Don described a Himalayan species of *H. salicifolia* D. Don from Nepal in 1825. von Schlechtendal, D.F.L. described another species of *H. tibetana* Schlecht from Qing-Zang Plateau (*Linnaea* 32: 296) in 1863. The type specimen was collected from Xizang Autonomous Region of Tibet. Rousi (1971), based on his studies on 2,200 specimens of seabuckthorn, collected in 33 herbaria, 34 populations growing in gardens and 8 mass collections in nature, published "*The genus Hippophae L. A taxonomy study*". In his classic monograph, he recognised 3 species, *H. rhamnoides* L., *H. salicifolia* D. Don and *H. tibetana* Schlecht. *H. rhamnoides* L. was classified into nine subspecies, seven of which, subsp. *carpatica*, *caucasia*, *turkestanica*, *mongolica*, *sinensis*, *gyantsensis* and *yunnanensis* were newly described

Fig. 1. *Seabuckthorn's global distribution*

Source: Rongsen (1992)

subspecies. Lian (1988, 2000) and Lian and Chen (1996) classified and discovered a new species and two new subspecies, *H. goniocarpa* Lian, X.L.Chen et K.Sun, *H. goniocarpa* subsp. *litangensis* Lian et X.L.Chen and *H. neurocarpa* S.W.Liu et T.N.He subsp. *stellatopilosa* Lian et X.L.Chen.

Ethnobotanical Uses

In ancient Greece, seabuckthorn leaves were used for feeding horses, which gave them better health and shining skin, therefore a Latin name "*Hippophae*", which means shining horse.

The medicinal value of seabuckthorn berries was recorded in much detail as early as the 8th century in the Tibetan medical classic "*rGyud Bzi*" (The Four Books of Pharmacopoeia) written during '*Tang Dynasti*' (618-907), describing on medical prescriptions for various health problems like skin wound, blood circulation systems, anti-inflammation and strengthen and coordinate the balance of functions among liver, stomach, kidney, spleen and heart (Rongsen, 1992).

General Uses

Live stocks in Lahaul-Spiti, feed on its green foliage during the early winter, when all the fodder resources dry up. Studies have revealed that crude protein content of seabuckthorn leaves (18-25%) (Singh *et al*., 1999) is higher than red clover (17.1%), and equal to white clover (24.7%), whereas the fat content of seabuckthorn leaves (3-5%) is significantly higher than both red clover (3.6%) and white clover (2.7%) (Rongsen, 1992). Seabuckthorn is high quality fuelwood plant, as it produces a high biomass, has high calorific value and fast regeneration after cutting. The plant meets the increasing need of firewood for the farmer's daily life. A four-year old plantation on marginal land produced 8-10.5 tones of firewood, equal to 6-8 tones of standard coal. Branches of seabuckthorn plants are important fuel wood in the whole cold deserts of India. In China, a six-year old plantation of seabuckthorn produced 18 tons of dry fuel wood/ha/yr, which is equivalent to 12 tons of standard charcoal. The average calorific value of dry seabuckthorn wood is 4,785 K calories/kg, which is more than most of the tree species (Rongsen, 1992).

Seabuckthorn has a strong root system, which grows vertically up to 3 m and horizontally up to 10 m, giving birth to over 40 new plants of several generations. This helps in binding soil on steep slope, hence widely used for afforestation in Loes Paltau in China (Rongsen, 1992). Seabuckthorn also plays an important role in the conservation of biodiversity. Plants of 42 families, 114 genera, 148 species of 11 trees, 10 shrubs, 127 herbs and 1 fern have been found growing with seabuckthorn in Lahaul (Kumar, 2011). Seabuckthorn has an outstanding ability to develop the roots even in poor sites, because of its ability to fix atmospheric nitrogen through the presence of symbiotic bacteria *Frankia* (*Actinomycetes*) in the root nodules and add about 180 kg of nitrogen per ha per year, which is equal to soybean (Jike and Xiaoming, 1992). Many wild animals use seabuckthorn for food and shelter. About 50 bird species are entirely dependent upon seabuckthorn fruits as a food and 80 bird species are partly dependent on seabuckthorn in Loess Plateau region of China. A number of wild animals take shelter in seabuckthorn stands for protection.

As seabuckthorn fruit and leaves are quite rich in vitamins (C, A, K and carotenoids.) and antioxidants, a number of seabuckthorn health food have been developed in Indian and global market, soem of them are clean juice, thick juice, condensed juice, pulp oil, seed oil, residue oil, raw powder, pigment, yellow colour and flovone, syrup juice, mixed juice, health protection drinks, carbonated juice and soda water, sweet wine, medium dry wine, carbonated wine, champagne, beers, carrot jams, cheese, butter, tea, dye, cakes and chocolates. Multi-vitamin juices are quite popular in India, China, Russia and Germany. Seabuckthorn seed and pulp oils, being rich in vitamins, anti-oxidants and omega fatty acids, have been reported to promote skin regeneration, improve blood circulation, healing of wound and decrease skin inflammation. Based on its nutrients, many medical studies, testing its effects on the skin, showed that seabuckthorn extracts could effectively improve the micro-circulation of blood capillaries and nourish the skin and hair. Globally scientists utilized its nutrients and medical effects to develop several kinds of seabuckthorn beauty creams and cosmetics. Seabuckthorn beauty creams made the skin fair, clear and delicate.

Global Trade

Global business on seabuckthorn is expected to be 1.5-2 billion USD, dominated by China. Approximately 75 per cent of the global seabuckthorn products are produced in China. The marketing of these products takes place mainly in the Chinese local market. Internationally, the products are sold in South Asia, Middle East, Japan, Korea and North America, Belgium and Finland. The German suppliers export the products locally and globally mainly in Western Europe and North America. The Russian market the products in the locally and also export to Mongolia, Korea and North America. Baltic countries export the products to the Scandinavian countries, Germany and North America. Oils produced by CO_2 extraction is about 10-15 per cent more expensive than oils produced by other methods. The extraction of oils by solvents is only used in China and partly in Russia (EAN-SEABUCK). In Western Europe like Germany, the production of cosmetic products is well developed, while in the other countries, there is an enormous market potential. On the other side, the market of nutraceuticals is an important market segment, clearly shown by the turnover in China; The North American and the Japanese market offer chances for nutraceutical products.

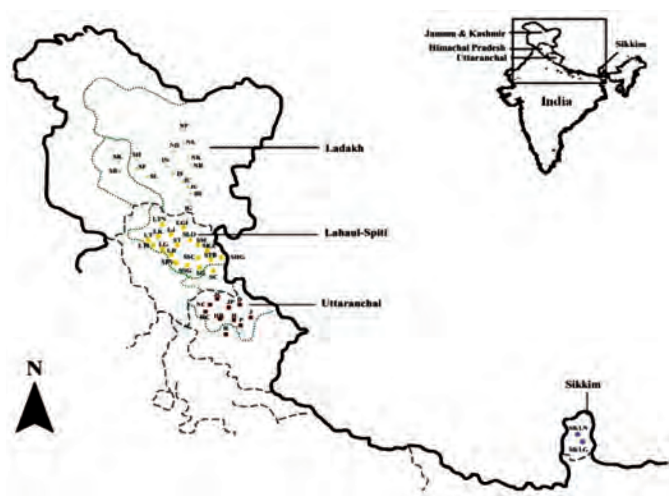

Fig. 2. *Seabuckthorn distribution in Himalayas*

Source: Raina et al. (2011)

Research and Development in India

Distribution of Resources

In Indian Himalaya, seabuckthorn has been reported in states of Himachal Pradesh, Ladakh (J&K), Uttarakhand, Arunachal Pradesh and Sikkim (Fig. 2). There are about 15,000 ha of seabuckthorn under thick forests in Indian Himalaya. Ladakh, high altitude cold desert, has maximum seabuckthorn (*H. rhamnoides*) resources of India in all the five valleys, i.e. Indus, Nubra, Zanskar, Changthang and Suru. Indus valley has seabuckthorn resources distributed from Thiksey to Shey, Choglamsar, Spituk, Phyang, Nimmu, Bazgo and Saspol. Highest resources were found in Nubra valley (10,500 ha), where the plant grows along the riversides of Nubra and Shyok rivers in Warsi, Panamik, Sumur, Tegar, Bogdang, Turtuk and Pachathang areas. *H. tibetana* was measured in alpine zone of the region. Seabuckthorn grows widely in cold desert and dry temperate areas of Lahaul-Spiti, parts of upper Kinnaur and Chamba (Pangi) districts of Himachal Pradesh. *H. rhamnoides* grows widely (2,500-3,800 m) in Ladakh and Lahaul-Spiti in Himachal Pradesh, whereas, *H. salicifolia* grows in Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. *H. tibetana* grows at 3700-4500 m in these states (Singh, 2003).

Ethnobotanical Studies

Seabuckthorn is known as *chharma* (Himachal Pradesh), *bardiphal* (Uttrakhand) or *tsestallu* in Ladakh and as *tarobo* or *achuk* in Sikkim, Indian Himalaya. It has been described as a medicinal plant by the name "*Amalavetas*" growing in Himalayas, as mentioned in ancient Indian System of Medicine, "Ayurveda" written during 500-5,000 BC (Uniyal and Uniyal, 2001). It is known to have a rich history of application in treating numerous diseases in human beings. The fruits have been used for more than 1,000 years in Tibetan and Amchi System of medicine in India. It is used for the treatment of a number ailments in Indo-Tibetan border areas of Himachal Himalaya (Lal *et al*., 2001) and Ladakh Himalaya (Gurmeet, 2011) by traditional doctors of "Amchi System of Medicine" a part of Indian System of Medicine for the treatment of wounds, intestinal disorders etc.

Taxonomical Enumeration

Seabuckthorn is one of the three genera in the small nitrogen fixing family Elaeagnaceae. There are six species of seabuckthorn in the world: *H. salicifolia, H. rhamnoides*, *H. goniocarpa, H. gyantsensis*, *H. neurocarpa* and *H. tibetana* (Lian, 2000). In India, there are three species:

1. *H. salicifolia* is a tree having a height of 4-9 m (Fig. 3a). This species is found in Lahaul-Spiti, Kinnaur and Kullu in Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. It is mild thorny in Himachal Pradesh. It looks like willow in appearance. Midrib of leaf is clear, leaf's adaxial surface densely covered with stellate hairs and leaf's margin revolute. Fruits are yellow (Fig. 4) and richest source of vitamin C (800-27 00 mg/100 g), but medium to poor in oil (1.5-3.0%).

Fig. 3a. *H. salicifolia*

Fig. 3b. *H. rhamnoides* sub sp. *turkestanica*

Fig. 3c. *H. tibetana*

Fig. 4. *Comparison of fruits of H. rhamnoides ssp. turkestanica (India) and ssp. mongolica (Russia)*

2. *H. rhamnoides* subsp. *turkestanica* is found in Himachal Pradesh and Ladakh. It is adapted to hardy sites and hardy shrub (Fig. 3b) or some times become tree. Leaves are alternate, narrower, 2-7 mm wide, both surface silvery. Fruits are reddish-orange in colour, the length of most fruits is often greater than breadth.
3. *H. tibetana* plants are dwarf, 20-60 cm high (Fig. 3c). It grows on river bottoms, on river banks and steppes on higher mountains, at the elevations of 3,500-4,400 m in Spiti, Himachal Pradesh, Ladakh, Uttarakhand and Sikkim. Branches are pointing upwards, usually broom-like. Leaves are whorled, linear. Fruits are dark tangerine, with 5-9 brown-black stellate ornamentation at apices.

Genetic Diversity in Himalayas

A number of studies on genetic diversity in natural populations of seabuckthorn growing in Himalayas have been carried out by various experts. Raina *et al*. (2011) collected 348 genotypes of *Hippophae rhamnoides* ssp. *turkestanica*, *H. salicifolia* and *H. tibetana* from 194 locations at 46 major sites across 1,500 km from north-east to north-west Himalayas at an altitude of 3,000–5,000 m. A total of 151, 50, and 41 AFLP loci were detected in *Hippophae rhamnoides* ssp. *turkestanica, H. salicifolia* and *H. tibetana*, respectively; of these, 92.6, 30.6 and 25.1 per cent were polymorphic.

High yielding varieties: Presently, in Himachal Pradesh, high yielding (4-6 kg/plant) cultivars of *H. rhamnoides* ssp. *turkestanica* and *H. salicifolia* have been mass propagated and provided to farmers for cultivation under orchards (Rana *et al*., 2010). Cultivar "Drilbu" of *H. salicifolia* has high potential in juice market as it is quite rich in vitamin C (800 mg/100 g), besides being mild thorny, high yielding (5-7 kg) and rich in some important nutrients (Singh *et al*., 2010). Further, we have introduced thornless and high yielding 14 Russian vareties *(H. rhamnoides* ssp. *mongolica*), are under testing stage in the field in Himachal Himalayas In India (Table 2), DRDO has also made selections of high yielding forms like DIH-SBT-5, DIH-SBT-7 and DIH-SBT-10 in Ladakh Himalayas.

Table 2. Comparison of Indian (*H. rhamnoides* ssp. *turkestanica*) and Russian seabuckthorn (*H. rhamnoides* ssp. *mongolica*)

Parameters	Indian seabuckthorn	Russian seabuckthorn
Thorns/10 cm of 2 yr old branch	5-8	1-3
Fruit yield (Kg/plant)	2-6	5-12
Fruit harvesting (Kg/day/person)	10-20	100-150
Fruit weight (g/100)	11-22	60-110
Vitamin C (mg/100g)	250-450	75-137
Oil (%)	2.5-4.5	2.5-6.2
Productivity (Tons/ha)	1.5-5.00	9-18

Propagation

Plant is propagated through seeds, stem cuttings and root suckers and tissue culture. Which method, we have to use depends the purpose of propagation. A high rate of germination under field conditions can be obtained either by soaking the seeds in water at room temperature for about 7 days unless the seeds are semi-germinated. This technique is useful when sowing of seeds is carried out in spring or indoors in a green house. Seeds should not be sown deeper than 1-2 cm.

Diameter and length of the cuttings influence the rooting rate. The cuttings are collected from the 2-3-year-old branches of the plant. Generally, cuttings of about 20 cm length and 1.0-1.5 cm in diameter are collected for propagation from hardwood cuttings. To improve the rooting rate, base part of the cuttings is dipped quickly into 500 ppm NAA (Singh, 1995) or IBA at 50-200 mg/litre before their plantation, which accelerates root formation in the cuttings. Cuttings are planted obliquely and 80 per cent below ground in the soil mixture of polybags. Soil mixture is made of soil: sand: FYM: 5:4:1. Massive nurseries can be raised from the green cuttings under controlled temperature and humidity conditions in mist chambers. The method needs artificial mist sprays and a plastic film house with other equipments. In this method, softwood cuttings (15-20 cm. long) are collected from plants, when the shoots begin to become woody (few months to 1 year old). The lower leaves are removed; leaving 2-4 leaves at the top and dip the lower base of cuttings into rooting hormone (500 ppm IBA) before plantation in media like sand or perlite. The special attention is given to the moisture of the soil media (Singh *et al*., unpublished).

Tissue Culture

Among different culture media with various growth hormone combinations tested in the experiments conducted by Singh and Gupta (2014), WPM medium with 3 per cent sucrose, was found to be most suitable for the induction of multiple shoots (Fig.), with hormone combination of BAP 1.0: IAA 0.5 ppm. WPM with 2 per cent sucrose and 1.5 ppm IBA was investigated to be suitable for the induction of rooting in seabuckthorn shoots. However, more research work is needed to improve multiple shoot frequency as well as improvement of rooting induction.

Cultivation Methods

Plant spacing of 4 m × 2 m resulted in highest canopy volume generation. When plant to plant spacing is decreased below 1.5 m, the overlapping in plant canopies occurs. Significantly higher canopy volume of seabuckthorn plants was obtained, when planted in the pit size of 2.0' × 2.0' × 2.0' in all the four years of experimentation. Using black polythene sheet or *Artemisia* as mulch in basins of seabuckthorn plants significantly suppressed the weed density and biomass and it was concluded that it can economically replace three hand weedings required to check the growth of weeds. Black polythene mulch, *Artemisia* as mulch and hand weeding being at par, had significantly effect on weed suppression (96.0-97.6%) as compared to control. Experimentation on initial nutritional requirement of plantations was initiated using Farmyard manure (FYM) and vermicompost for 3 years and only FYM during 2012 and 2013, as suggested by the project monitoring team. The results from initial years revealed that irrespective of organic source (FYM/Vermicompost) of nutrient, effect of 50 kg N was at par with 75kg N/ha in terms of biomass index obtained. Thus, results indicated that despite seabuckthorn being a leguminous plant, it requires 50 kg N/ha for initial establishment. In general, increase in the dose of FYM increased the canopy volume per tree. The highest values were observed at the 40 kg FYM/basin. During both the years, 20 kg FYM was at par with 30 kg/basin. Results revealed that pruning intensity beyond 25 per cent did not increase the fruit yield. Rather there was decrease in yield to 33 per cent or 50 per cent. Increasing the severity decreased the yield by 21 and 9 per cent in *H. salicifolia* and H. *rhamnoides* species, respectively. Effect of 10 per cent pruning on fruit was found at par with 25 per cent pruning (Singh *et al*., unpublished).

Intercropping

Seabuckthorn is known to allow the healthy growth of grass and other herbaceous vegetation under its canopies due to nitrogen fixing ability of the plant. Limited information is available regarding interaction with other crops (Singh, 2001). Seabuckthorn (*H. salicifolia*) trees are known to improve the growth of buckwheat, however badly affecting the growth of peas and potatoes up to 4 and 2 m respectively distance from tree rows. Seabuckthorn mix forests can also be raised with other forest trees like willow, poplar and rubinia etc. As there is an acute shortage of fodder in cold desert region of Himachal Pradesh, India and other Himalayan states, hence, growing of the improved grasses and forage species between seabuckthorn rows will minimize the scarcity. Tall fescue and orchard grass on an average, and red clover recorded higher forage yield over the control (local grass), are the best to be grown under dry temperate conditions of dry temperate regions (Saini *et al*., 2011). These grasses can be well grown with seabuckthorn orchards as well as in the non-grassland/barren lands.

Harvesting Tools

Fruits ripen during September in India, Russia, Germany, India and China. Over-ripe fruit are difficult to harvest, as the skin is easily punctured during the harvesting, affecting the quality of raw material. About 15 per cent of the berries burst during the harvesting operations, even during the hand picking. The frozen berries during late winter are shaken by hitting a plant with wooden stick and knocked off the branches and collected in a container. The harvesting is generally done before noon (5 AM - 12 AM). About 30 of fruits can be harvested by this traditional method in 8 hours. For increasing capacity and efficiency, an indigenous manual harvester i.e. comb, wire clip, branch shaker and clipper with handle type were designed by Vatsa and Singh (2017). The capacity of the branch shaker and clipper were 5.0 and 6.2 kg/h with *H. rhamnoides* and; 4.8 and 6.7 kg/h with *H. salicifolia*, respectively, which was 55-121 per cent higher as compared to traditional method. A clipper with handle was suitable for local forms and a wire loop was suitable for Russian seabuckthorn.

Biochemical Values

While several studies have proven strong antioxidant properties of seabuckthorn (Geetha *et al.,* 2002), seabuckthorn fruit and leaves have been found rich in antioxidants like superoxide dimutase enzyme, vitamin C, E, carotenoids, flavonoids etc. High contents of vitamin C 950 mg/100 g (Singh, 1995) and 2740 mg/100 g (Singh and Sawhney, 2005) have been recorded for *H. salicifolia,* in Lahaul, Himachal Pradesh Himalayas, India. *H. rhamnoides* ssp. *turkestanica* in Ladakh Himalaya, India have been found very rich in Vitamin C upto 1400 mg/100 g (Dwivedi *et al*., 2005). Chauhan *et al*. (2001) reported a medium value of 516 mg/100 g in *H. rhamnoides* ssp. *turkestanica*. The content of vitamin C ranged from 56 to 3909 mg/100 g FW and thus 1 to 70-fold variation was found in seabuckthorn (*H. rhamnoides* ssp. *turkestanica*) growing in Ladakh Himalayas (Korekar *et al*., 2014). The most valuable product of this plant is fruit oil, as it possesses anti-oxidant, wound healing, anti-tumor, anti-ulcer, and curing cardiovascular disorders. In Lahaul valley of Himachal Pradesh, total oil in fresh fruits varied from 2.9-4.6 per cent in *H. rhamnoides* ssp. *turkestanica* and much lower of 2 per cent in *H. salicifolia* (Singh and Singh, 2004).

Sea buckthorn fruit pulp has about 1.5-2 per cent oil, whereas seeds have 8-10 per cent oil in Indian seabuckthorn. Unsaturated fatty acids comprise about 85 per cent of total fruit oil. Singh and Gupta (2015) analyzed the fatty acids of Lahual form (semi-arid) of *H. rhamnoides* ssp. *turkestanica* and Spiti form (arid) of *H. rhamnoides* ssp. *turkestanica* and also *H. salicifolia* (from Lahaul) growing in Himachal Himalaya, India. Pulp oil of *H. salicifolia* is richest source of Linoleic acid (15.0 per cent of total oil) and α-linolenic acid (1.3%). However, Palmitoleic acid was a major dominating unsaturated fatty acid (46.4-37.1%), being maximum in pulp oil of Lahaul form (46.4%). In seed oil, Spiti type is richest source of linoleic acid (39.8%) and α-linolenic acid (25.4%). The high content of palmitoleic acid, which is uncommon in the plant kingdom, distinguishes the pulp oil from the seed oil of seabuckthorn. Palmitoleic acid is a main constituent of skin fat and it is recommended for the skin softening and anti-wrinkle products.

Value Addition

A number of food products have been developed from seabuckthorn fruit juice in India and abroad. Selvamuthukumaran *et al.* (2007) prepared seabuckthorn mixed fruit jelly by blending the seabuckthorn juice with papaya, watermelon or grapes in varying ratio maintaining a constant level of total soluble solids (TSS) and acidity in the final product. Selvamuthukumaran and Khanum (2014) developed the seabuckthorn fruit juice powder by spray drying process to evaluate the shelf stability. For packaging, the developed product was packed in paper foil polyethylene pouch, sealed under different modified atmosphere packaging conditions, viz. air, CO_2, N_2 and vacuum, and stored at room temperature. Physico-chemical features of juice powder showed that the sugars significantly increased, whereas the vitamins C and E, carotenoids, total phenols and anthocyanins significantly decreased during storage in above conditions.

Seabuckthorn fruit was also processed by Selvamuthukumaran and Khanum (2014) for development of antioxidant rich jam by employing response surface methodology as a statistical tool. The ingredients, viz. sugar and carrageenan were chosen as independent variables, while sensory attributes, i.e. taste and consistency as dependent variables. Effects of various independent variables on chosen response show that the ingredient sugar had more prominent effect on taste score and carrageenan on consistency score, respectively. The optimum conditions to yield maximum scores of taste and consistency of jam were sugar of 85 gm and carrageenan of 3.4 gm per 100 gm of recipe. Jam contains more natural antioxidants with good texture when compared to commercial products.

Dhaliwal *et al.* (2015) developed acceptable and nutritious RTS drink, squash, syrup and toffees (Fig. 5), which can be prepared using pure seabuckthorn pulp by blending with peach pulp (50:50) with 18.00, 41.00, 71.00 and 85°B total soluble solids. Verma *et al.* (2015) found that the nutritional quality as well as sensory scores for various attributes increased significantly ($P \leq 0.05$) with increase in the blending proportion of the seabuckthorn pulp in the sand pearsebuckthorn blended squash. Sharma and Joshi (2015) prepared wine from seabuckthorn pulp by blending with apple pulp in the ratio of 50:50 were adjudged the best compared to other methods like chemical de-acidification and water dilution. Blending, the pulp with apple pulp reduced the necessity of dilution up to 1:6 without compromising nutritional quality of the wine.

Fig. 5. *Vitamin rich food products*

Clinical Research in India

Seabuckthron fruit, oil, leaves and juice are rich in various bioactive compounds like vitamin A, C, E, K, carotenoids, tocopherols, tocotrienols, essential polyunsaturated fatty acids and other bioactive components, which have synergic effects and help in the protection from various health disorders like skin, cardiovascular, diabetes and gastric ulcers etc. Geetha *et al.* (2002) studied the antioxidant and immunomodulatory properties in the male albino rats. The alcoholic leaf extract of seabuckthorn (500 g/ml) inhibited chromium induced free radical production, apoptosis and restored the antioxidant status and potential of mitochondrial transmembrane. Varshneya *et al.* (2011) also found the reducing activity of seabuckthorn extracts increased in a dose-dependent manner and was maximum in 70 per cent methanol extract. The leaf extract of seabuckthorn had the significant anti-inflammatory activity in adjuvant induced arthritis (AIA) rat model and lipopolysaccharide induced inflammatory response in murine macrophages (Ganju *et al*., 2005; Padwad *et al*., 2006)

Results on leaf alcoholic extract of seabuckthorn have found regulated antigen presentation ability of macrophages in aged mice, which have shown its immune boosting and anti-aging activity (Mishra *et al*., 2011). Seabuckthorn fruit has also showed immunoprotective effect against T-2 toxin-induced immunosuppression in 15-day-old chicks (Ramasamy *et al*., 2010).

The plant products, which improve the physical endurance, mental function and non-specific resistance of the body to stress, have been defined as adaptogens. Saggu *et al*. (2007) administered orally in rats at a dose of seabuckthorn leaf extract 100 mg/kg BW both in single and 5 doses, showed significant anti-stress and adaptogenic properties. Preliminary studies have also found anti-cancer effects of seabuckthorn oils and fruit extract. The bark extract of *H. salicifolia* was found to have significant inhibitory effect on the mouse fibrosarcoma in India by Ambaye *et al*. (1962).

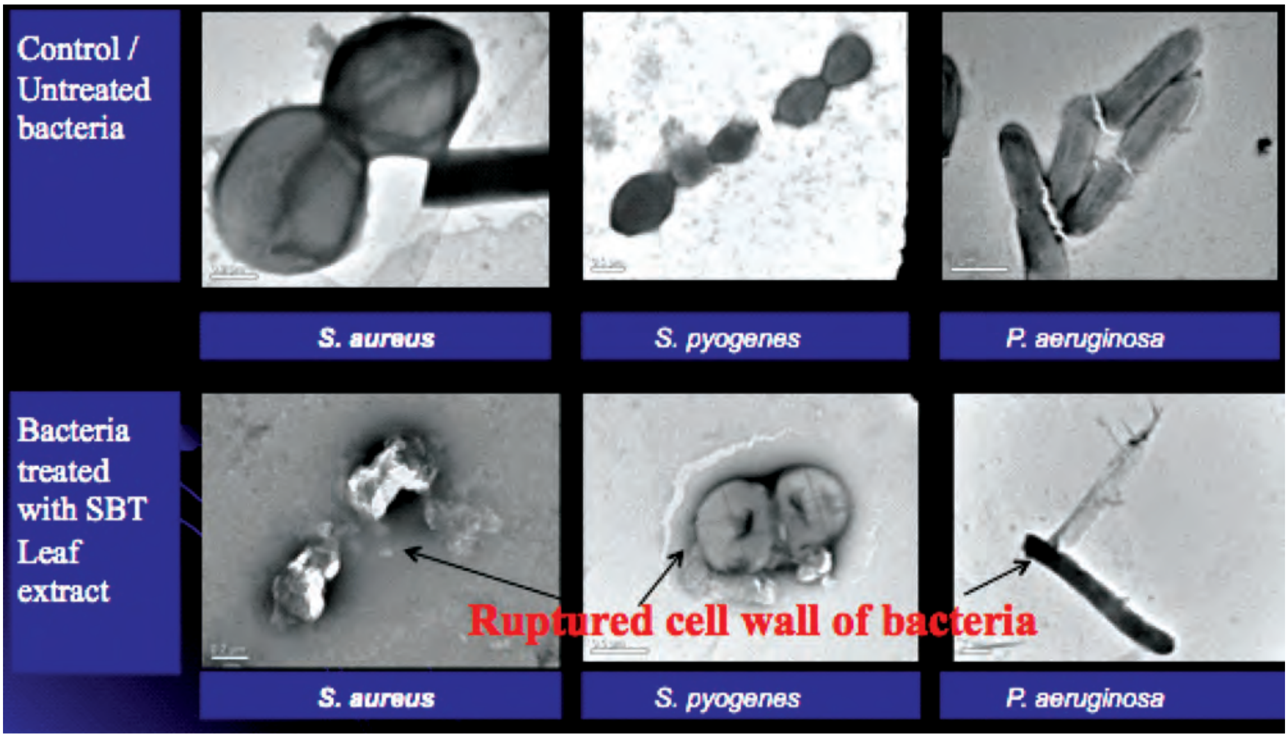

Fig. 6. *Anti-microbial activity of the leaf extract*

Anti-bacterial activities of fruit were studied by a number of Indian experts. Upadhyaya *et al*. (2010) used the aqueous and hydroalcoholic leaf extracts, which had growth inhibiting effect against *Bacillus cereus, Pseudomonas aeruginosa, Staphylococcus aureus* and *Enterococcus faecalis.* The anti-bacteria property of leaf has been studied by Verma *et al*. (2010), who found 2-5 per cent leaf extract having inhibition activity against *Staphylococcus aureus* bacteria (Fig. 6). Jain *et al.* (2008) also found antimicrobial activity and inhibitory effect in a HIV infection in a cell culture.

The leaf extract countered the radiation damage to hemopoietic system and restored the ferric reducing activity of plasma (Goel *et al*., 2002). Bala *et al.* (2015) administered standardized seabuckthorn leaf extract (SBL-1)'s single dose (30 mg/kg body weight) 30 minutes before ^{60}Co-gamma-irradiation (lethal dose, 10Gy) which showed protection of more than 90% mice population. Gupta *et al.* (2002) studied the effect of seabuckthorn ointment for the healing of cutaneous wounds in dogs. The exudation in the ointment treated animals subsided completely by 7th day after treatment as compared to control group. Gupta *et al.* (2006) also measured the healing of dermal wound by flavones in rats. The topical use of seabuckthorn flavone (isolated from fruit pulp) (1.0%, w/v) showed a positive healing effect on the dermal wounds in experimental rats. In India, another study showed the safety and wound healing activity on experimental burn wounds in rats by seed oil co-administration by topical (200 µl) and oral methods (2.5 ml/kg BW) (Upadhyay *et al*., 2009).

Peptic ulceration is a defect of the gastric or duodenal mucosa as a result of the failure of the mucosal defence mechanism against peptic digestion. Tyagi (2006) found the healing effect of seabuckthorn seed oil on the gastric erosions and ulcerations in dogs. Dogra *et al*. (2013) orally administrated the lansoprazole @ 1.5 mg/kg, sucralfate @ 1 g/animal, misoprostol @ 10 µg/kg, famotidine @ 1 mg/kg, and seabuckthorn seed oil @ 5 mL/animal, 2 times a day, respectively. Seabuckthorn oil was found to be the best therapeutic agent for dexamethasone-induced GUE in dogs followed by famotidine, lansoprazole, misoprostol, and sucralfate. Kumar *et al.* (2015) found that dexamethasone induced GUE lesions in dogs heal faster with the application of combination of Famotidine and SBT oil.

Basu *et al.* (2007) found that seed oil application for 18 days showed reduction in plasma cholesterol, LDL-C, atherogenic index (AI) and LDL/HDL ratio in normal rabbits. The HDL-C levels, HDL-C/TC ratio (HTR) and vasorelaxant activity of the aorta were significantly improved. These results show that supercritical CO_2 extracted seed oil of seabuckthorn has significant anti-atherogenic and cardioprotective activity. Malik *et al.* (2012) used seabuckthorn pulp oil (5, 10, and 20 mL/kg per d) orally for 30 days along with ISO (85 mg/kg, subcutaneously, at 24-hour interval) on 29th and 30th day. Seabuckthorn oil significantly modulates hemodynamic and antioxidant derangements at the dose of 20 mL/kg per d.

Studies on hypoglycemic by Sharma *et al.* (2011) found that seabuckthorn caused a significant ($p < 0.05$) reduction in blood glucose and TBARS levels in the STZ-diabetic rats, as evident by histopathological examination, the degenerative changes of pancreatic beta cells in STZ- diabetic rats were lowered to near normal morphology by the application of seabuckthorn. Dubey *et al.* (2011) developed a seabuckthorn drug "Orlistat", which enhanced adiponectin concentration and insulin sensitivity with a decrease in leptin level in human patients.

Geetha *et al.* (2008) had histological and biochemical findings, which showed that both seabuckthorn seed oil and leaf alcoholic extract ameliorated CCl4-induced liver injury. Maheshwari *et al.* (2011) recognised oral application of phenol rich fraction at dose of 25–75 mg/kg BW significantly protected from CCl4 induced elevation in alanine aminotransferase, aspartate aminotransferase, gamma-glutamyl transpeptidase and bilirubin in serum and increased the hepatic antioxidants. Upadhyay *et al*. (2009) investigated the safety and toxicological studies of CO_2-SFE extracted seabuckthorn seed oil. Observations found no adverse effects in any of the groups administered with SBT SFE-seed oil in acute and sub-acute oral toxicity studies.

Market in India

In India, area under seabuckthorn is about 15,000 ha, producing about 15,000-20,000 tons, but collection is mere 600 tons, likely to increase to 1000 tons soon, mainly in Ladakh region of J&K (Stobdan and Srivastava, 2015). The fruit collection in Himachal Pradesh is small (15-20 tons), Uttarakhand (10-15 tons) and Sikkim (5-10 tons). However, demand in Indian market is about 2,000-3,000 tons of fruits, therefore, companies are getting it from other countries. There is a proposal to increase collection of fruit upto 1,000-1,500 tons, by converting natural forest into productive stands and also by speeding up cultivation of improved seabuckthorn in Himalayan states. In India, seabuckthorn industry was started by "Lehbery brand" by Indage, which was a hit in Indian market, However, it suffered during recession in 2008. Presently, there are 4-5 companies in Indian market, producing mainly cosmetics and juice. Synthite, based in Cochin is producing oil by CO_2 method and exporting to Europe and America. Tashi is a cosmetic producer. Patanjali Ayurved, a big company has also planned to invest on seabuckthorn. Depending on the availability of seabuckthorn fruit supply, a number of seabuckthorn food and cosmetics are expected in Indian market soon. Some drugs are likely to be launched by Indian companies. Demand for seabuckthorn leaves is upto 3000-5000 tons. The oil extracted by CO_2 method is used for cosmetics purpose and oil capsules. Leaves are being used for tea production. Therefore, market for seabuckthorn raw material and products are emerging quite fast especially domestic and also export market to USA, mainly oil and cosmetics.

Future Directions for Research and Policy Issues

While seabuckthorn has been introduced as a cultivation crop by farmers particularly in Russia, China, Germany etc., there is a need for introduction of local and Russian seabuckthorn varieties for commercial cultivation in alley cropping and agroforestry systems, for which there is a need for policy support under Horticulture schemes of state and central governments. Further research is required for the control of pest and diseases as well as identification of bioactive molecules, as wide efficacy has been observed against many diseases. While preclinical studies have proven wide efficacy of seabuckthorn oil and leaf extract, further clinical trials are required especially in areas of cardiovascular, diabetes and skin diseases. Experts are also required to improve the extraction of oil from fruit pulp and seeds. The harvesting tools are required to improve the harvest quantity and quality and also reduce labour cost. India need to collaborate with Chinese seabuckthorn Research Institutes for exchange of improved seabuckthorn and training in advance technologies of propagation and cultivation particularly in dry and fragile mountainous lands. In view of high ecological potential and demand in local and global market, efforts are required to improve cultivation technologies, develop more promising high yielding forms of seabuckthorn and carry out large scale cultivation with adequate funding of state and central governments under Compensatory Afforestation Fund of Ministry of Environment, Forest and Climate Change, Government of India, which will help in the ecological rehabilitation of fragile mountainous lands, improve livelihood of farmers, create employment opportunities and provide nutritional security and health protection to the people. Further, in view of high ecological and economic potential of seabuckthorn, there is a need to introduce this multipurpose wonder plant in Asia-Pacific countries with similar geographic and climate conditions.

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Country Status Reports – South Asia

Country Status Report - Bangladesh

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Introduction

Bangladesh is situated between 20°34' and 26°38' in the North latitude and between 88°01' and 92°41' East longitudes. Agriculture is the mainstay of the economic development of Bangladesh. It identifies as the topmost priority sector for poverty alleviation and livelihood improvement. Agriculture contributed about 16 per cent of GDP, generates 47 per cent of total employment opportunity and provides food security to the increasing population. Bangladesh is an abode of 5000 species vascular of plants and is the secondary centre of origin of a good number of crop plants (Razzaque and Hossain, 2007). There are more than two hundred crops grown in Bangladesh. Among these about one hundred are minor crops, including fruits and vegetables that are grown in the country. There are many indigenous plants grown naturally and less utilized in agriculture. Many underutilized species are more resilient to environment stresses such as droughts, salinity and poor soils better than many cultivated species and provide important additional nutrients to the local diet. These plant species have a great genetic diversity as well as vast heritage of indigenous knowledge. Since ancient time many indigenous vegetables are wildly growing as weeds. The weed survey report in Bangladesh has indicated that out of 95 species of weeds, 19 species are widely used as vegetable throughout the country (Goffar, 1984; 1987). These edibles weed vegetables contribute enormously to the vitamin intake for poor villagers. During famine they live on mainly these weedy vegetables. Underutilized fruits have alternative means to increase farm income by diversifying products, hedging risks, expanding markets, improving human and livestock diet, and creating rural based industries. Although many of these species are presently "underutilized", their future role in agricultural development will be highly promising.

Area, Production and Productivity

A good number of minor and underutilized crops (UUC) are grown in the country. Many of these are important for food security, especially for the rural people and the poorer sections of the population. The production status of most of them is hardly monitored and very few are recorded (Table 1).

Table 1. Area, production and productivity of some underutilized crops in Bangladesh

Crop / local name	Area (hectare)	Production (mt)	Productivity (t/ha)
Cereals			
Barley	3,56	317	0.9
Jower	93	102	1.1
Bazra	36	48	1.3
Cheena and *kaon*	1,182	1,229	1.0

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Crop / local name	Area (hectare)	Production (mt)	Productivity (t/ha)
Foxtail millet	261	203	0.8
Pulses			
Pigeon pea (*arhar*)	539	566	1.1
Pea (*motor*)	7,260	7,372	1.0
Oilseeds			
Linseed	6,562	4,475	0.7
Spices			
Coriander	18,099	17,642	1.0

Source: BBS (2016)

Significant Achievements

Germplasm collection, characterization, evaluation, conservation and documentation as well as variety development are essential for sustainable agriculture. Many of the cultivars/landraces of underutilized cereals, pulses, oilseeds, spices etc. are conserved in genebanks are not available in the field. Their potential to contribute to improved livelihoods, especially to rural smallholders and some are promising to be developed into market crops. Bangladesh Agricultural Research Institute (BARI) has already collected and conserved a good number of germplasm and also developed some varieties of different UUC (Tables 2 and 3). Very recently Horticulture Research Centre of BARI collected 28 different indigenous vegetables as well as medicinal plant species from across the country and evaluated the performance of 12 indigenous leafy vegetables (Table 4) (Goffar *et al.*, 2017). Documentation of 49 underutilized vegetables (Rahim *et al.*, 2013) and 46 fruits species (Rahim *et al.*, 2011) has been carried, and some salient features are given in Tables 5 and 6.

Table 2. Number of collected and conserved germplasm and developed varieties of underutilized/minor cereals, pulses, oilseeds, tuber crops and spices in Bangladesh

Crops name	Scientific name	Germplasm (No.)	Varieties developed (No.)
Cereals			
Foxtail millet	*Setaria italica*	568	3
Proso millet	*Panicum miliaceum*	203	1
Sorghum	*Sorghum vulgare*	187	-
Barley	*Hordeum vulgare*	63	7
Buck wheat	*Fagopyrum esculentum*	6	-
Pearl millet	*Pennisetum glaucum*	3	-
Finger millet	*Eleusine coracana*	2	-
Pulses			
Pea	*Pisum sativum*	172	3
Cowpea	*Vigna unguiculata*	82	1
Pigeon pea	*Cajanus cajan*	85	-
Horse gram	*Macrotyloma uniflorum*	13	-
Faba bean	*Vicia faba*	35	
Rice bean	*Vigna umbellata*	6	-
Vetch	*Vicia sativa*	3	-
Oilseeds			

Crops name	Scientific name	Germplasm (No.)	Varieties developed (No.)
Niger	*Guizotia abyssinica*	21	1
Linseed	*Linum usitatissimum*	20	1
Sunflower	*Helianthus annuus*	16	2
Safflower	*Carthamus tinctorius*	4	1
Castor	*Ricinus communis*	1	-
Tuber crops			
Mukhikachu	Colocasia esculenta	15	2
Olkachu (Elephant foot yam)	*Amorphophallus campanulatus*	2	-
Spices			
Cinnamon	*Cinnamomum verum*	5	1
Bay leaf	*Cinnamomum tamala*	4	1
Culantro, eryngium	*Eryngium foetidum*	-	1
Black pepper	*Piper nigrum*	-	1
Fenugreek	*Trigonella foenum-graecum*	5	2
Fennel	*Foeniculum vulgare*	7	2
Black cumin	*Nigella sativa*	3	1
Bunching onion	*Allium fistulosum*	-	1
Plum	*Prunus domestica*	3	1
Long pepper	*Piper longum*	3	-

Source: Unpublished data collected from Bangladesh Agricultural Research Institute (2017)

Table 3. Number of germplasm collected and conserved and developed into varieties of underutilized and minor fruits

Crops name	Scientific name	Germplasm (no.)	Developed variety (no.)
Sapota	*Manilkara achras*	18	3
Lemon	*Citrus limon*	50	3
Lime	*Citrus aurantifolia*	8	-
Sweet lime	*Citrus paradisi*		1
Pummelo	*Citrus grandis*	125	5
Mandarin	*Citrus reticulata*	30	3
Sweet orange	*Citrus mauricata*	25	1
Jara lemon	-	6	-
Colombo lemon	-	12	-
Ada zamir	*Citrus assamensis*	10	-
Karun zamir	-	19	-
Ashkar zamir	-	8	-
Carambola	*Averrhoa carambola*	50	2
Golden apple	*Spondius dulcis*	14	2
Custard apple	*Annona squamosa*	18	-
Bullock’s heart	*Annona reticulata*	20	-

Crops name	Scientific name	Germplasm (no.)	Developed variety (no.)
Burmese grape	*Baccaurea sapida*	21	1
Pomegranate	*Punica granatum*	9	-
Wax jumbo	*Syzygium samarangense*	33	3
Longan	*Nephelium longana*	7	2
Velvet apple	*Diospyros discolour*	12	1
Karonda	*Carissa carandas*	22	-
Cowa	*Garcinia cowa*	13	-
Indian dellenia	*Dillenia indica*	14	-
Aonla	*Emblica officinalis*	30	1
Bael	*Aegle marmelos*	100	1
Wood apple, elephant's foot apple	*Feronia limonia*	24	1
Tamarind	*Tamarindus indica*	7	1
Lukluki	*Flacourtia jangomes*	20	
Jamun	*Syzygium cumini*	25	1
Passion fruit	*Passiflora edulis*	3	1
Toikar	*Garcinia pedunculata*	7	1
Cashewnut	*Anacardium occidentale*	8	-
Rose apple	*Syzygium jambos*	12	-
Indian olive	*Elaeocarpus floribundus*	15	1
Palmyra palm	*Borassus flabellifer*	7	-
Monkey jack	*Artocarpus lakoocha*	11	-
Star gooseberry	*Phyllanthus distichus*	12	-

Source: Unpublished data collected from scientists of Bangladesh Agricultural Research Institute (2017)

Table 4. Yield and yield contributing characters of different indigenous leafy vegetable

Crops / local name	Scientific name	Total plant wt. (g)	Plant height (cm)	Branch/ plant (no.)	Leaves/ plant (no.)	Days to harvest	Yield (t/ha)
Bathua (green)	*Chenopodium album*	68.3	69.00	12.60	196	45	17.32
Bathua (red)		112.4	77.00	8.45	45	55	19.70
Thankuni	*Hydrocotyle asiatica*	15.0	21.00	-	19	70	1.60
Lafashak	*Malva verticillata*	36.0	55.00	7.55	32	35	5.20
Pudina		13.2	13.60	13.33	42	45	3.15
Nunia	*Portulaca oleraceae*	105.0	28.30	-	Numerous	65	16.75
Helencha	*Enhydra fluctuans*	32.0	13.60	12.00	Numerous	55	5.60
Malancha	-	38.5	51.50	12.60	Numerous	60	7.90
Shialmutra	-	86.0	38.00	7.00	22	55	16.85
Shaknotey	*Amarunthus viridis*	127.0	41.00	1250	Numerous	45	21.30
Kata notey		156.0	37.00	14.33	Numerous	45	21.30
Pat shak	*Corehorus capsularis*	4.7	24.00	-	16	35	1.25

Source: Goffar et al. (2017)

Table 5. Salient features of different underutilized vegetables documented in Bangladesh

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Use
Leaf amaranth	*Amaranthus viridis*	Annual herb	Tropical humid low land	Seed and stem cutting	Leafy vegetable
Spiny amaranth	*Amaranthus spinosus*	Branched herb	Tropical humid low land	Seed	Leafy vegetable
Joy weed	*Alternanthera sessilis*	Annual herb	Tropics damp shady areas	Seeds and rooted stem	Young shoots and leaves as vegetable
Indian pennywort	*Centella asiatica*	Perennial creeper	Full sun and wet sandy soil	Seed and vine cutting	Vegetable and medicinal value
Giant taro	*Alocasia macrophylla*	Massive perennial	Tropical and partial shady areas	Suckers	Fleshy aerial stem as vegetable
Voodoo lily	*Alocasia fornicate*	Perennial rhizomatous	Temperate zone as long as summer is warm	Offset, corms and seed	Corms, stolon and leaves as vegetable and ethnomedicine
Wild elephant foot yam	*Amorphophallus bulbifer*	Corms	Tropical to sub-tropical and well drained soil	Offsets and leaf bulbils	Young petioles and unexpanded leaves as vegetable
Elephant foot yam	*Amorphophallus campanulatus*	Perennial stemless herb	Tropical to sub-tropical and warm humid conditions	Whole corms and pieces of corms	Corm, petiole, twig and unexpanded leaves as vegetable; as tonic
Taro	*Colocasia esculenta* var. *esculenta*	Herb	Partial shady place and moist soils	Corms	Corms & leaves as vegetable
Eddoe/ Wild taro	*Colocasia esculenta* var. *antiquorum*	Perennial evergreen herb	Temperate zone as long as summer is warm	Offsets, stolon, sucker, rhizomatous corm and rootstock	Tender leaves, petioles, spathes and corms as vegetable. Special diet for women due to rich in vitamins and iron
Thamal garothamal arykachu	*Colocasia esculenta* var. *esculenta*	Perennial evergreen herb	Temperate zone as long as summer is warm	Offsets and corms	Corms, leaves and stem as vegetables; leaves rich vitamins and minerals
Kantaokachu	Lasia heterophylla	Rhizomatous or tuberous perennials	Wet and sterile soil. Fairly drought tolerant	Offsets	Lower hard modified stem as vegetable; ethno-medicine
Bengal arun	*Typhonium trilobatum*	Herb	Wet soils. Fairly drought and saline tolerant	Offsets	Tender leaves, petioles and corms/ rhizomes as vegetable; as medicine
Tannia	*Xanthosoma atrovirens*	Herb	Tropical and wide variety of soils	Sucker and corm or cormels	Leafy vegetables
Blue taro	*Xanthosoma violaceum*	Herb	Shady places and marshy land	Rhizomes, tubers, corms or bulbils	Tender leaves as vegetable or used in soups and stews
Marsh herb	*Enhydra fluctuans*	Perennial herb	Hot, humid weather and wet soil	Seed and stem cutting	Leaves as vegetables and medicine
Watercress	*Nasturtium officinale*	Perennial herb	Full sunshine and moist soil	Seed and stem cutting	Leafy vegetables; rich in iron, calcium and folic acid

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Use
Pigweed	*Chenopodium album*	Annual herb	Temperate and sub-tropical zone	Seed	Tender leaves and young shoots as vegetable; medicine
Swamp cabbage	*Ipomoea aquatica*	Perennial herb	Moist soil	Seed and stem cutting	Leafy vegetables; rich in iron, vitamin A, used as medicine
Ivy gourd	*Coccinia grandis*	Perennial climbing vine	Moist soil and sunny place	Seed and fragment of vine	Young leaves, twigs and tender green fruits as vegetable and soup, rich in beta-carotene
Wild teasle gourd	*Momordica cochinchinensis*	Perennial and dioecious vine	Hot and humid weather and red acidic soil	Moniliform or beaded root cutting	Pulp of fruit as vegetable and seeds and leaves as medicine
White yam	*Dioscorea alata*	Vigorously twining herbaceous vine	Dry season; well drained soil	Tuber cuttings, small tubers or bulbil	Tubers, bulbil as vegetable and desserts; medicine
Air potato	*Dioscorea bulbifera*	Vigorously twining herbaceous vine	Tropical weather and loamy soil	Tubers and bulbil	Tubers and bulbil as vegetable; folk medicine, rich in vitamin C, B_6, minerals- K, Mg
Cassava	*Manihot esculenta*	Perennial shrub	Shady and well drained soil	Stem cutting and seed	Tubers as vegetable and snack chips; rich in Vitamin C, B_6 and minerals K, Fe, Mg
Pigeon pea	*Cajanus cajan*	Perennial shrub	Tropical weather and well drained soil	Seeds	Green seed as vegetable and matured seed as soup (*dhal*); leaves as medicine
Sword bean	*Canavalia ensiformis*	Climbing perennial legume cultivated as annual	Tolerant to waterlogging and salinity	Seeds	Young pod as vegetable and matured seed as soup (*dhal*)
Beggar weed	*Desmodium triflorum*	Annual and prostrate herb	Humid tropics and wide range of soil	Seeds and stolon	Tender shoots and leaves as vegetable; folk medicine.
Potato bean	*Pachyrrhizus erosus*	Hairy twining herbaceous plant	Wet tropics and well drained soil	Seeds and sprouted roots	Young tubers as vegetable and pickles
Winged bean	*Psophocarpus tetragonolobus*	Herbaceous perennial	Tropical weather and well drained soil	Seeds	Tender pod as vegetable and dried seeds used for coffee like drink
Sesbania	*Sesbinia grandiflora*	Perennial; fast growing tree	Tropic and warm subtropic and heavy clay soil	Seeds	Leaves, seed pods and flower as vegetable; folk medicine
Drone	*Leucas aspera*	Annual herb	Tropical and subtropical	Seeds	Tender leaves and shoots as vegetable. Leaves and flower as folk medicine
Wild lady's finger/ okra	*Abelmoschus moschatus*	Annual or biennial herb/ shrub	Humid tropical and subtropical climate and sandy loam soil	Seeds	Tender pods, young leaves and new shoots as vegetable; folk medicine.

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Use
Roselle	*Hibiscus sabdariffa* var. *sabdariffa*	Annual herbaceous subshrub	Tropical and subtropical climate and sandy loam soil	Seeds, cuttings	Tender leave, twigs as vegetable, juicy calyces used for juice, jelly; folk medicine
Chinese mallow	*Malva verticillata* var. *crispa*	Herb	Sunny places and any soil	Seeds	Tender twigs and leaves as vegetable; folk medicine
Carpet weed	*Mollugo verticillata*	Delicate and prostrate herb	All kinds of soil	Seeds and stem cuttings	Tender leaves and twigs as vegetable. Rich in vitamins, Fe and Ca
Drumstick	*Moringa oleifera*	Slender and drooping branched tree	Tropical and subtropical climate; well drained soil	Cuttings	Fruits and tender leaves as vegetable; folk medicine
Water lotus	*Nelumbo nucifera*	Herbaceous perennial	Warm climate and submerged soil	Seeds and rhizomes	Matured fruits as food stuffs; folk medicine
Water lily	*Nymphaea nouchali*	Herb	Warm climate; submerged soil	Seeds and rhizomes	Flower stalk as vegetable, rich in Fe and Ca. Mature fruits used as fresh, processed food; roots as folk medicine
Floating primrose willow	*Ludwigia repens*	Creeping/ floating herbaceous plant	Tropical and subtropical climate and variety of soils	Seeds and creeping stem	Leafy vegetable; folk medicine
Wood sorrel	*Oxalis acetosella*	Hardy perennial	Shady places and wet soils	Seeds and runner cuttings	Leafy vegetable; folk medicine
Sour grass	*Oxalis corniculata*	Herbaceous plant	Tropical and subtropical climate and wet soils	Runner cuttings	Tender leaves and twigs as vegetable, salad and folk medicine; rich in vitamin C
Ostrich fern	*Dryopteris filix-mas*	Feather like leaves growing from grounds	Hot and humid weather; moist soil	Rhizomes	Leafy vegetables
Purslane	*Portulaca oleracea*	Succulent and herbaceous plant	Hot and humid weather; moist well grained soil, drought; salinity tolerant	Seeds and cuttings	Leafy vegetable; folk medicine
Stinkvine	*Paederia scandens*	Perennial twining vine	Hot-humid weather; loamy soil	Seeds and stem cuttings	Leafy vegetable; folk medicine
Water hyssop	*Bacopa monnieri*	Perennial creeping herb	Semi shade place; moist soil	Seeds and runner cuttings	Leafy vegetable; folk medicine
Nightshade	*Physalis heterophylla*	Annual plant	Forests and waste places; drought tolerant	Seeds	Tender fruits as vegetables; folk medicine
Wild eggplant	*Solanum torvum*	Shrub	All kind of soils; drought tolerant	Seeds	Tender fruits as vegetables and cuisine
Yellow berried nightshade	*Solanum xanthocarpum*	Spiny diffused herb	Shade place; dry or moist soil	Seeds	Tender fruits as vegetable and folk medicine

Table 6. Salient features of different underutilized fruits documented in Bangladesh.

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Utilization
Kainadam, cashewnut	*Anacardium occidentale*	Evergreen tree	Tropical and subtropical climate; variable soils	Seeds	Nut used for preparation of bread, cake, pastry; medicine
Amra, golden apple	*Spondias dulcis*	Fast growing tree	Sunny places; all types of soil	Seeds and cleft grafting	As fresh fruit and also used for jelly, pickles, soups, stews etc
Ata, bullock's heart	*Annona reticulalta*	Deciduous or semi-evergreen tree	Subtropical warm climate; variable soils	Seeds and grafting	Ripen fruits as fresh and also used for jelly, jam etc. and medicinal value
Sharifa, Custard apple	*Annona squamosa*	Semi-deciduous or evergreen tree	Subtropical warm climate; well drained soils	Seeds and grafting	Ripen fruits as fresh and also used for jelly, jam, juice; medicinal value
Karamcha, *Karanda*	*Carissa carandas*	Slow growing shrub	Hot-humid weather; salt tolerant	Cuttings and seeds	Ripen fruits as fresh and also used for jelly, jam, pickles. Rich in Fe and vitamin C
Kamranga, Carambola	*Averrhoa carambola*	Slow growing evergreen tree	Tropical and subtropical climate; well drained soils	Seeds and cleft grafting	Ripen fruits as fresh. Rich in antioxidants and Vitamin C
Billimbi	*Averrhoa bilimbi*	Short trunk with upright branched tree	Tropical; well drained soils	Seeds, cuttings and air layering	Fruits as fresh and used in curries, juice
Kawphal, *cowa*	*Garcinia cowa*	Evergreen tree	Subtropical humid climate; variable soils	Seeds	Ripen fruits as fresh and used in jam, rich in vitamin C and minerals
Taikor	*Garcinia pedunculata*	Large evergreen tree	Tropical; well drained soils	Seeds	Fruits as fresh and used in jam, jelly, pickles
Daophal	*Garcinia xanthochymus*	Small evergreen tree	Subtropical humid climate; variable soils	Seeds	Fruits as fresh and used in jam
Chalta, elephant apple	*Dillenia indica*	Dense rounded crown tree	Tropical and subtropical climate; well drained soils	Seeds and cuttings	Fruits as fresh and used in pickle, chutney and medicinal value
Bilati gab, velvet apple	*Diospyros discolor*	Perennial tree	Tropical-subtropical climate; well drained soil	Seeds, grafting, layering, budding	Ripen fruits as fresh
Deshi gab, River ebony	*Diospyros peregrina*	Perennial, medium evergreen tree	Hot-humid climate; saline soil	Seeds	Ripen fruits as fresh and used as gum for fishing net; medicinal
Jalpai, Indian olive	*Elaeocarpus floribundus*	Small to medium evergreen tree	Tropical climate; loamy soil	Layering and cleft grafting	Ripen fruits as fresh and used for pickle, chutney etc
Lotkon, Burmese grape	*Baccaurea sapida*	Middle-sized tree	Warm humid tropical-subtropical climate; well drained soil	Seeds, grafting and layering	Ripen fruits as fresh and used for juice

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Utilization
Orboroi, star gooseberry	*Phyllanthus acidus*	Intermediary between shrubs-tree	Tropical-subtropical climate	Seeds, grafting, layering, budding	Mature fruits as fresh and used for juice; rich in vitamin C
Amloki, aonla	*Phyllanthus emblica*	Deciduous tree	Tropical and subtropical climate and well drained soil	Seeds, grafting, budding	Matured fruits as fresh and used for juice, pickles and folk medicine; rich in vitamin C
Boichi, governor's plum	*Flacourtia indica*	Tree or shrub	Hot-humid climate; different soil	Seeds, budding grafting, layering and cutting	Fruits as fresh and used in jam, jelly
Tomytomy, sapida	*Flacourtia inermis*	Small to medium tree	Well drained loamy soil and salt tolerant	Seeds, air layering and cutting	Fruits as fresh and cooked; antioxidant, rich in vitamin C
Lukluki, flacourtia	*Flacourtia jangomes*	Small to medium evergreen tree	Different climate and different soils	Seeds, budding grafting and air layering cutting	Fruits as fresh and used in jam, jelly
Tetul tamarind	*Tamarindus indica*	Long leaved bushy tree	Dry weather and well drained soil	Seeds, budding, grafting and cutting	Fruits as fresh and used in jam, sauce
Paniphal water chestnut/ caltrop	*Trapa natans*	Submerged stem anchored into mud by fine roots	Mainly in fresh water lakes	Sucker	Fruits as fresh and medicinal value
Chapalish	*Artocarpus chaplasha*	Tall deciduous tree	Moist condition andwell drained soil	Seeds, budding and grafting	Fruits as fresh
Dewa, monkey jack	*Artocarpus lakoocha*	Deciduous tree	Subtropical zone and any soils	Seeds	Fruits as fresh and used in chutney; medicinal value
Deshidumur, fig	*Ficus carica*	Deciduous tree	Subtropical climate and well drained soil	Seeds and layering	Fruits as fresh and medicinal value
Jam, jamun	*Syzygium cumini*	Fast growing tree	Tropical and subtropical climate and well drained soil	Seeds and budding	Fruits as fresh and used in jam, jelly, seeds used as folk medicine
Golapjam, rose apple	*Syzygium jambos*	Shrub to medium-large tree	Tropical climate; well drained soil	Seeds, air layering and cleft grafting	Fruits as fresh
Amrul, Malay apple	*Syzygium malaccense*	Fast growing tree	Tropical humid climate and well drained soil	Seeds and air layering	Fruits as fresh and used in chutney, pickle
Jamrul, Wax-jambu	*Syzygium samarangense*	Medium sized tree	Tropical and subtropical climate and well drained soil	Air layering and cutting	Matured fruits used in jam, jelly

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Utilization
Tal, palmyra palm	*Borassus flabellifer*	Robust tree	Tropical climate and any type of soil	Seeds	Jelly like parts of seeds in green fruits as fresh and juice of ripe used for dessert
Betphal, rattan	*Calamus manillensis*	Vine plant	Hot and humid weather and any type of soil	Seeds and sucker	Ripe fruits as fresh and young twigs as vegetables. Rich in vitamin C and minerals
Deshikhejur, data palm	*Phoenix sylvestris*	Tree	Moderate winter and hot summer and well drained	Seeds and offshoots	Ripe fruits as freshand sap used as fresh drink or for jaggary
Dalim, Pomegranate	*Punica granatum*	Shrub	Drought and salt tolerant	Seeds, air layering and cutting	Seeds of ripe fruits as fresh and processed product; rich in vitamin C, B_5 and potassium
Bael, stone apple	*Aegle marmelos*	Deciduous tree	Tropical, subtropical climate	Seeds, air layering and root cutting	Matured fruits or dried and medicinal value
Ada jamir	*Citrus assamensis*	Tree with thick glossy leaves	Wide range of soils	Seeds, layering and cutting	Matured fruits and medicinal value
Kagzilebu, lime	*Citrus aurantifolia*	Bushy, spreading type	Tropical climate and wide range of soils	Seeds, layering and cutting	Used for culinary purpose, jam, jelly; rich in vitamin C
Jambura, pummelo	*Citrus grandis*	Tree	Partial shady place; wide range of soils	Seeds, layering and cutting	Matured fruitsas fresh; medicinal value
Rough lemon	*Citrus Jambhiri*	Tree	Humid-semi humid region; wide range of soils	Seeds, layering and cutting	Matured fruits as fresh; rich in vitamin C, minerals- K, Ca
Satkara	*Citrus macroptera*	Tree	Tropic-subtropic humid; wide range of soils	Seeds, budding layering and cutting	Mature fruits as salad and curry; rich in vitamin C minerals- Ca
Kotbel, wood apple	*Feronia limonia*	Tree	Monsoon season; wide range of soils	Seeds, budding layering and cutting	Matured ripen fruits as fresh; medicinal value, rich in vitamin C minerals- Ca and P
Ashphal, longan	*Nephelium longan*	Tree	Tropical-subtropical climate; sandy soil	Seeds, budding layering and cutting	Matured ripen fruits as fresh and medicinal value. Rich in vitamin A
Mahua	*Madhuca longifolia*	Deciduous tree	Tropical-subtropical climate; drought tolerant	Seeds, veneer grafting	Flower as vegetable and used for making liquor. Flower and fruit for medicinal value.
Sofeda, sapota	*Manilkara zapota*	Long lived tree	Tropical humid climate; saline tolerant	Seeds, budding layering and grafting	Matured ripen fruits as fresh; rich in vitamin A and B
Bakul, Indian medlar	*Minusops elengi*	Evergreen tree	Tropical humid climate; moisture stress condition	Seeds, air layering and cutting	Fruits and seeds have medicinal value

Crops name/ local name	Scientific name	Plant types	Growing environment	Propagation	Utilization
Khirni	*Minusops hexandra*	Evergreen or semi-deciduous tree	Tropical-subtropical climate; well drained soil. Saline tolerant	Seeds and veneer grafting	Fruits and seeds have medicinal value
Phalsa	*Grewia asiatica*	Shrub or small tree	Drought tolerant	Seeds and air layering	Matured ripen fruits as fresh; medicinal; rich in vitamin C and carotene

Moreover, varieties of different underutilized fruits have been developed at Germplasm Center of Bangladesh Agricultural University (BAU) and Horticulture Research Center of BARI (Rahim *et al.*, 2011). Examples include BAU Cashew nut 1, BAU Amra 1, BAU Kamranga 1,2 and 3, BARI Taikor 1, BAU Jolpai 1, BAU lotkon 1 and BARI Lotkon 1, BAU Orboroi 1, BAU Amloaki 1, BAU Tetul 1 and 2, BARI Tetul 1, BAU Jamrul 1, 2 and 3, BAU KagziLebu 1 and 2, BAU Pumemelo 1 and 2, BARI Pumemelo 1, 2, 3 and 4, BARI Satkara 1, BAU Kotbel 1, BARI Kotbel 1, FTIP BAU Longan 1 and 2, BARI Longan 1 FTIP BAU Sapota 1, 2 and 3, BARI Sapota 1.

Challenges and Opportunities

A major threat to Bangladesh's future agricultural production is posed by the effects of global climate change. Its effects are already evident from variations in rainfall patterns and increased severity of floods, drought and salinity. Coupled with the rapid population increasing which requires increased attention to alternative production scenarios. Many of indigenous plant species are naturally growing and traditionally used in Bangladesh. Although these crops may play a vital role in ensuring food, and nutrition security but not adequately researched. Therefore, there is need to pay attention both national and international research centers investigating ways to introduce these crops into agricultural systems for and nutrition with economic benefit.

Marketing, Commercialization and Trade

There is neither a definite marketing channel nor commercial activities for almost all the UUC. Most of the UUC grow naturally or are traditionally cultivated in different localities, where they are utilized for family consumption and some are being sold in local market. Very few are marketed in city areas.

Strategies Adopted to Harness their Potential

The development of UUC primarily needs to identification of potentiality as useful crops and the associated local knowledge. Thereafter, germplasm collection, conservation, characterization, evaluation, development of varieties and agronomic testing need to be conducted followed by a series of steps to promote commercialization. The information on the potential value of UUC regarding nutrition, rural income, post harvest processing and marketing methods could be collected and documented as well as disseminate to end users for sustainable farming system.

Major Focus Areas

Although, utilization of biodiversity contributes to the improving productivity, food security and nutrition, but many of the people have little or no information and knowledge about the value of biodiversity. Thus, it is needed to make people aware about the importance of biodiversity. Moreover, among the different UUC, particular focus needs to be given to fruit and vegetable species. Because most of the underutilized fruit and vegetable species having good source of different vitamins and minerals which will be helpful to reduce the hidden hunger.

Infrastructure, Capacity Building and Financial Investment

- Need to strengthen institutional capacity
- Need sufficient funding for research and development
- Need to document appropriate data on associated biodiversity
- Need to disseminate the importance and benefits of UUC
- Train and develop skill for maintaining the biodiversity and utilizing UUC
- Need to create efficient marketing channel for commercialization of UUC

Contribution of UUC to Food, Nutrition and Livelihood Improvement

Different UUC contribute to a considerable extent to food and nutrition. These are the source of carbohydrate, protein, vitamins, minerals and offering medicinal and income generating options. Rahim *et al.* (2011) stated that underutilized fruits offer alternative means to increase farm income by diversifying products, hedging risks, expanding markets, improving human and livestock diet, and creating rural based industries. Thus, the potentiality of UUC could be utilized through production, processing and marketing which will contribute to food security and the livelihood improvement especially rural smallholders and reduce the nutritional deficiency.

Future Thrust

- Strengthened the germplasm collection, characterization, evaluation, documentation and variety development
- Genetic finger printing facilities to be made available for assessing diversity
- Preservation facilities (*in situ*, *on-farm*, *ex situ*, field genebank, *in vitro*, cryopreservation) for genetic material need to be strengthened
- Processing, value addition and product development of different UUC need to be initiated
- Commercialization and marketing for promoting the economic benefit
- Regional and international cooperation like technical and financial support required for maintenance of biodiversity as well as research and development of UUC

Conclusions

Different indigenous plants are mainly grown naturally and less-utilized in Bangladesh agriculture. Most of those plants species are tolerant to stress environment like droughts, salinity, marshy land and poor soils and provide important additional nutrients like vitamins and minerals as well as medicinal value. Some of the cultivars/landraces of UUC are conserved in gene banks, documented and also developed some varieties which are needed to disseminate to the end users. It should also be strengthened the research and development facilities for harnessing potentials of UUC in respect of food and nutrition especially to reduce the hidden hunger of rural peoples in Bangladesh.

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Country Status Report – Bhutan

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Introduction

Bhutan is a landlocked mountainous country situated between China and India. It has an area of 38,394 sq. km. Being a mountainous country, it has numerous microclimate and elevations ranging from 150 to >7,000 m. More than 70 per cent of the area is covered by forest and only around 2.9 per cent is cultivated. Although small in size, Bhutan has a wide range of agro-ecological zones with various crop and livestock farming. It is also recognized as a global biodiversity hotspot.

The country's economy is largely based on agriculture, where 62 per cent of the populations are directly engaged for their livelihood (GNH, 2013). It contributes up to 16.77 per cent of the GDP and account for 4.3 per cent export (MoAF, 2015). The agriculture sector continues to play an essential role in reducing poverty and bringing prosperity for Bhutanese people. About 12 per cent of the populations live under the poverty line of US $ 28/person/month, which is predominantly a rural phenomenon.

With the goal of increasing food production and push for commercialization, new high yielding crop varieties are being promoted. The dietary habits of people are changing with the enhanced income and better access to market. Most Bhutanese prefers to eat rice, leading to high import. Consumption of other cereals such as maize, millet, barley etc. is considered a poor status symbol. The dietary diversity for Bhutanese people is decreasing due to dependence on a few commodities dominated mostly by rice, commercial vegetables and meat. A total of 68 per cent of the dietary energy requirement comes from cereals mainly rice and 17 per cent from oil and 15 per cent from livestock products, vegetables, fruits and pulses combined (DoA, 2015). Other cereals and vegetables, including wild edible plants have been overlooked in the process of development and achieving better livelihood.

Poor food diversity has led to high prevalence of hidden hunger or malnutrition in Bhutan - 21.2 per cent of children under the age of 5 years are stunted and 9 per cent are underweight. Stunting is highest in poor and rural households concentrated in the eastern part of the country. About 44 per cent of children (under 5 years) and 35 per cent of non-pregnant women (between the age group of 15 to 49) are suffering from iron deficiency and anemia. Similarly, 22 per cent of pre-school children and 17 per cent of pregnant women are deficient in vitamins. Most of these conditions are due to the insufficient intake of micronutrients, which can be sourced from neglected underutilized species (NUS). Under nutrition and malnutrition prevalence is felt most acutely in rural areas. It is feared that a reduction in food diversity will result in more nutrition-related disorders in rural areas and also a loss of many traditionally important crops and the knowledge about their uses and sustainable conservation impacting the environment.

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Bhutan is also highly vulnerable to the effect of climate change due to its geographical features and high economic dependency of the country's economy on climate sensitive sectors such as agriculture, forestry and hydropower. This risk is pronounced as the livelihood of 62 per cent of the population depends directly on agriculture and crop composition is restricted to few food commodities. Therefore, it is important and timely that NUS is given due recognition and brought into mainstream agriculture to address the food and nutritional security in the poor and rural section of the population of Bhutan (Pradhan and Chettri, 2018).

Area, Production and Productivity

The data on neglected and underutilized crops (UUC) are poorly documented and fragmented. The information on NUS itself is very weak and limited. There is no proper inventory of NUS in the country. In one of the report, some 38 crops (Annexure 1) have been identified as NUS belonging to different food groups (Pradhan and Chettri, 2018) but this is not the exhaustive list; there are many more which are available in the country and important for household food security and nutrition.

AAS (2016) collects information on few NUS/UUC, and the area and production of a few is given in Table 1. The area under these minor cereals and crops are decreasing. In 2005 the area under barley, buckwheat and millet was reported as 8,450, 16,063 and 16,982 acres, respectively. The area under cultivation of these crops has decreased by more than 50 per cent to as high as 80 per cent within a span of 11 years.

Table 1. Area and production of NUS crops

Name	Area (acres)	Production (mt)	Yield (kg/acre)
Barley	2,451	1,702	696
Buckwheat	6,897	3,705	537
Millet	3,245	1,714	528
Soybean	544	275	466
Rajma bean	1,565	994	635
Mung bean	952	482	506
Sweet potato	31	29	940
Tapioca	278	415	1,490
Walnut (no. of tree)	24,072	181	21 kg/tree

Source: AAS (2016)

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

As per the Plant Genetic Resources of Bhutan, published by National Biodiversity Centre (NBC, 2008) the nodal agency for biodiversity conservation and sustainable utilization, there are total of 258 landraces/ traditional varieties of NUS under cereals, pulses and oilseeds (Table 2). However, proper characterization and molecular studies have not been carried out, as such there are possibilities of recording the same varieties known by different names in different place across the country. Further, as there is no inventory of NUS crops, the landraces/ traditional varieties could also vary. Similar study is underway for fruits and vegetables. Efforts are made by NBC to conserve these landraces/traditional varieties in farms and gene bank.

Table 2. NUS and recorded landraces

Crops	No. of landraces/ traditional varieties
Barley	32
Buckwheat (sweet)	10
Buckwheat (bitter)	11
Finger millet	37
Foxtail millet	36
Little millet	4
Amaranthus	17
Common beans	76
Soybean	11
Mung bean	23
Total	**258**

Variety Development

No major research initiatives have been taken to develop NUS varieties. Few improved varieties were released in the past (Table 3) but its up-scaling has always been a challenge mainly due to poor seed system and limited financial and human resources. Even the basic seeds of some of these varieties are difficult to source now.

Table 3. List of varieties released for NUS crops

Crop	Release variety	Year of release
Soybean	One daughter	1994
	Khangma libi 2	2002
	Brag	2002
	Khangma Libi 1	1999
Millet	*Limithang Kongpu*-1	2002
	Limithang Kongpu-2	2002
Mung beans	*Limithang Mung* 1	2002
	Limithang Mung 2	2002
Upland paddy	*Kambja* 1	2017
	Kambja 2	2017

Cultivation Practices

There are no recommended cultivation practices for the NUS/UUC. Farmers grow these crops using the traditional knowledge following the existing farming systems or seasonal calendar. Recently, the Department of Agriculture (DoA) has released two new varieties of Upland paddy along with production packages. The use of external inputs are minimal or nil. Farmers maintain their own seed or borrow from neighbours; no proper seed system is in place to produce seeds for such crops.

Processing, Value Addition and Product Development

There are no major interventions made with regard to processing, product development or add value to the NUS/UUC. Farmers or farmers group generally makes flour, e.g. buckwheat, millet and barley. Some support for packaging is provided. Few enterprising private individuals have taken initiatives to process minor and traditional crops, mainly in the form dehydrated products. Government has been emphasizing on the processing and value addition of agricultural commodities produced in the country, including NUS but its outcome is yet to be realized. The small scale of production and limited market have been the limiting factors.

Disease and Pest Management

Since no scientific studies are taken on NUS, there is no documented information on pest and diseases. Generally, UUC such as buckwheat, millet, pulses etc. are grown in small and rural areas; as such by default they are organic. Use of chemicals is normally discouraged or used as a last resort in case of mass outbreak of pest and diseases.

Challenges and Opportunities

Ensuring food self-sufficiency and security, including nutritional security are the major goals of the Government of Bhutan. Currently, Bhutan is approximately 70 per cent food self-sufficient if all the cereals in the food basket are accounted for. But with the improved household income brought in by economic development, the people's food habit have changed. The most preferred cereal is rice and Bhutan is only about 50 per cent self sufficient in rice. The minor cereals and traditional fruits and vegetables have not received required attention, as a result, their role in food security has diminished.

Cereals account for 68 per cent of dietary energy and balance 32 per cent is derived from vegetables, pulses and livestock products (DoA, 2016). Of all the food consumed in Bhutan, 37 per cent is by the urban population, with the remainder consumed in rural areas. Rice accounts for a larger share of the food consumed in rural households than in urban households, indicating potential risks for protein and micronutrient deficiencies and poor nutrition status in rural households.

Malnutrition is one of the major challenges for Bhutan (Table 4). Despite being on track to address the health issues such as reducing wasting, stunting, breast-feeding, etc. 21.2 per cent of children under the age of five are stunted and 9 per cent are underweight. Iron deficient anemia is a serious problem in children and women. About 43 per cent of children between 6-59 months and 34.9 per cent of non-pregnant women are anemic (DPH, 2015). Vitamin A deficiency occurs in 22 per cent pre-school children and 17 per cent of pregnant woman in Bhutan. Most of these health issues result from acute malnutrition.

Table 4. Nutritional status of children and women in Bhutan

Health indicator	Prevalence (%)
Stunting	21.2
Under weight	9
Wasting	4.3
Anaemia in children (6- 59 months)	43.8
Anaemia in non-pregnant women (15- 49 years)	34.9
Over weight	4.7
Vitamin A deficiency (pre-school children)	22
Vitamin A deficiency (pregnant women)	17

NUS by nature are a good source of various types of vitamins, minerals and proteins. Many NUS/ UUC have medicinal properties and considered as a health food.

Bhutan's major economy sector like agriculture and hydropower are heavily dependent on climate and like anywhere in the world, Bhutan is not spared by the impacts of climate change. This risk is pronounced as the livelihood of 62 per cent of the population depends directly on agriculture and hydropower contributes 13.4 per cent to national GDP. Various studies have identified increasing average temperature, erratic rainfall patterns, and increased risks of climate related hazards in Bhutan (MoAF, 2016). The lack of irrigation water and high incidence of pest and disease discourage farmers from growing vegetables and other crops. The increasing incidences of climate related hazards in agriculture sector have increased the risk of food insecurity for farmers especially poor ones living in remote villages. Under, such scenario, promoting NUS and exploiting their potential to adapt to changing climatic conditions would be an alternative means to secure food and nutrition for people especially in rural areas.

Introduction of new high yielding crop varieties in a push to commercialize agriculture and increase food production has reduced the cultivation of traditional crops. It is leading to a fear of losing its diversity and the traditional knowledge about its food value and environment conservation.

Marketing, Commercialization and Trade

Due to the small scale of production and limited access to market, the commercialization and trade of NUS is still in infant stage. On this front the government has always been encouraging and supporting the private sector. Private entrepreneurs have also taken initiatives in promoting and marketing few traditional crops, mainly related to health such as herbal tea, turmeric powder, moringa tea and host of organically grown food crops.

Given the small consumer base within the country, the volume of trade is limited. Access to international markets is limited due to difficult and expensive logistic facilities and small scale of trade.

Under the royal patron of Queen's project on "One Gewog One Product" initiative has been empowering local communities to manage their indigenous art craft and food to enhance livelihood. The project is providing support to improve the quality and marketing. Local and underutilized crops such as buckwheat, millet, and many other commodities have found their potentials. But the productions of such commodities are still low and have not received much attention in term of scientific research to enhance production, which needs to be strengthened.

Largely, the formal market for the agriculture sector in Bhutan is underdeveloped, with the trading of agricultural goods mostly through intermediaries. The Food Corporation of Bhutan (FCB) facilitates the sale of few commercial agriculture commodities such as potatoes, vegetables and fruits but there is scope for it to expand its coverage and services to support NUS. The government is also encouraging the establishment of farmer groups and cooperatives to enhance the scale of production and facilitate better prices for NUS.

Strategies Adopted to Harness their Potential

NUS crops do not form a major commodity in the current food basket, but realizing its potential for food, nutrition and adaptation to the changing climatic condition, it will receive a renewed support for its development during the coming 12^{th} five year plan and beyond. The DoA has provided commodity status to minor cereals and pulses. Providing a commodity status means increased support for development, such as dedicated financial and human resources. It also means providing institutional support and continuity of the programme and better knowledge management.

Major Focus Areas

Realizing the importance of NUS crops in social, environment, economy and the well-being of the rural people, the National Biodiversity Centre in collaboration with DoA has initiated several conservation programmes. *In situ* and *ex situ* conservation of traditional varieties is being carried out. Farmers' groups are encouraged and supported to grow traditional crop varieties and produce their own seeds. Further, to encourage and motivate farmers, exhibition, exposure visits and training are organized focusing on traditional and underutilized crops.

The government is providing support in training farmers on organic production of NUS such as buckwheat, millets, etc. so that it becomes commercially viable and profitable enterprise. Farmers are supported to form a group so that they can make a scale of production and fetch a better price. The priority for development of NUS may be given to nine identified NUS (Annexure 2) considering their contribution to nutrition (Annexure 3), economy, social importance and capacity to adapt to climate change.

Infrastructure, Capacity Building and Financial Investment

NUS usually belong to a minor group of crops, which does not form an important food commodity at the national level. As such, the resources provided to such crops are negligible and fragmented. Supports provided to this group of crops are subsumed under other major programmes, e.g. National Organic Programme providing support for organic production of buckwheat, millet, which is often small in scale and ad-hoc in nature. The capacities of the stakeholders involved in the NUS value chain are limited. Infrastructures, mainly to support postproduction and marketing are weak.

Future Thrust

NUS are closely intertwined with the cultural habit of the people and their knowledge about the local ecosystem and food resources. Therefore, conserving and studying NUS not only save them from extinction, but also the local ecosystems, social and cultural values and contribute to economy and livelihood development of peoples mainly the farmers. Therefore, to enhance the profile of NUS, the concerned agencies need to:

- Involve in developing new varieties and better production practices
- Map and document availability, utilization and cultural and economic value of NUS in different agro-zones
- Evaluate and document the economic and nutritional properties of NUC. It is important to garner support from government and donors for its promotion and up-scaling
- Collection and conservation of germplasm on-farm as well as in gene bank

- Improve the marketing system especially organize small grower in rural areas and provide better access to market
- Promote NUS in dietary systems to improve nutrition intake and health
- HR capacity building and development for research and development

To achieve the above desired outputs, we need to take following actions:

- Create awareness among the producers, consumers, research and development workers and policy maker about the benefits of conserving and using NUS, its economic and nutrition value
- Invest in capacity development of all stakeholders
- Enhance research programme
- Enhance conservation both on-farm and in gene bank
- Develop supportive policy and programme
- Improve production and market value chain

Conclusions

With the presence of various agro-ecological zones and microclimatic conditions, a variety of crops and edible plants, domestic and wild are available in Bhutan. They play an important role for farmers for food and nutrition security and also household economy. Large percentage (approximately 34%) of farming households experience food insecurity and these minor cereals and other crops provide the safety net.

With the high dependency of dietary energy on cereals, mainly rice, these minor and traditional crops can play an enormous role. Farmers and urban population have realized the nutritional and health benefits of NUS. It is also important for household income and environmental conservation as well. However, the contribution of NUS in food security, nutrition contribution and household economy are undermined. Proper support in term of research, documentation and incorporating it into the national food basket in required. To achieve these and bring focus on NUS, the positive aspects of NUS need to be scientifically evaluated and documented. Therefore, it is timely, that the national government, international partners and private sector should join hands in promoting and conserving NUS.

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Annexure 1. List of NUS/crops

English (common name)	Scientific name
Cereals	
Finger millet	*Eleusine coracana*
Sweet buckwheat	*Fagopyrum esculentum*
Bitter buckwheat	*Fagopyrum tataricum*
Barley	*Hordeum vulgare*
Quinoa	*Chenopodium quinoa*
Foxtail millet	*Setaria italica*
Amaranth	*Amaranthus* spp.
Proso millet	*Pennisetum glaucum*
Roots and Tubers	
Tapioca	*Manihot esculentus*
Sweet potato	*Ipomoea batatas*
Greater yam	*Dioscorea alata*
Taro	*Colocasia esculenta*
Pulses	
Kidney beans	*Phaseolus vulgaris*
Mung beans	*Vigna radiata*
Urd beans	*Vigna mungo*
Soybean	*Glycine max*
Lentil	*Len culinaris*
Horse gram	*Macrotyloma uniflorum*
Rice beans	*Vigna umbellata*
Field pea	*Pisum sativum*

English (common name)	Scientific name
Horticulture (fruits)	
Walnut	*Juglans regia*
Banana	*Musa* spp.
Jackfruit	*Artocarpus heterophyllus*
Amla	*Phyllanthus emblica*
Lime	*Citrus aurantifolia*
Persimmon	*Diospyros kaki*
Peach	*Prunus persica*
Pear	*Pyrus* spp.
Passion fruit	*Passiflora edulis*
Horticulture (vegetable)	
Drumstick (*moringa*)	*Moringa oleifera*
Pumpkin	*Cucurbita pepo*
Chayote squash	*Sechium edule*
Mustard green (*sag*)	*Brassica juncea*
Chilli	*Capsicum annuum*
Bitter gourd	*Momordica charantia*
Cucumber	*Cucumis sativus*
Stuffing cucumber (slippery gourd)	*Cyclanthera pedata*
Amaranthus	*Amaranthus* spp.

Annexure 2: List of prioritized NUS

English Name	Scientific Name	Reason for prioritization
Sweet buckwheat	*Fagopyrum esculentum*	Nutrition, economic, social
Quinoa	*Chenopodium quinoa*	Nutrition, economic
Soybean	*Glycine max*	Nutrition, adoptability, social
Lentil	*Len culinaris*	Nutrition, economic, social
Kidney beans	*Phaseolus vulgaris*	Nutrition, economic, adoptability
Mung beans	*Vigna radiata*	Economic, social, nutrition
Walnut	*Juglans regia*	Nutrition, economic
Banana	*Musa* spp.	Economic, health, cultural and social
Drumstick / *moringa*	*Moringa oleifera*	Nutrition, adoptability, economic

Annexure 3: Nutritional composition of identified NUS

English Name	Scientific Name	Nutrition Composition																
		Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Crude Fibre (g)	Ca (mg)	Fe (mg)	K (mg)	Zn (mg)	β-carotene equ. (μg)	Vit. C (mg)	Vit. E (μg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B3 (mg)	Vit. B6 (mg)	Folate (μg)
Cereals																		
Finger Millet	*Eleusine coracana*	378	11	4.2	72.8	8.5	8	3	195	1.7		0		0.42	0.29	4.72	0.38	85
Sweet Buckwheat	*Fagopyrum esculentum*	343	13.25	3.4	71.5	10	18	2.2	460	2.4				0.101	0.425	7.02	0.21	30
Bitter Buckwheat	*Fagopyrum tataricum*																	
Barley	*Hordeum vulgare*	352	9.9	1.2	77.7	15.6	29	2.5	280	2.13				0.191	0.114	4.604	0.26	23
Quinoa	*Chenopodium quinoa*	368	14.1	6.1	64.2	7	47	4.6	563	3.1			2.4	0.36	0.32	1.52	0.49	184
Foxtail Millet	*Setaria italica*	351	11.2	4	63.2	6.7	31	2.8			32			0.59	0.11	3.2		
Amaranth	*Amaranthus* spp.	371	13.56	7.02	65.25	6.7	159	7.61	508	2.87		4.2	1.19	0.116	0.2	0.923	0.591	82
Proso Millet	*Pennisetum glaucum*	378	11	4.22	72.9	1	8	3										
Roots and Tubers																		
Tapoica	*Manihot esculenta*	130	2	3.9	22				92									
Sweet Potato	*Ipomaea batatas*	121	1.6	0.1	20	3	30	0.61	337	0.3	6			0.078	0.061	0.557		11
Greater Yam	*Dioscorea alata*	108	1.53	0.17	27.8		17	0.54	816	0.24	83	17.1	0.35	0.112	0.032	552		23
Taro	*Colocasia*	112	1.5	0.2	26.46	4.1	43	0.55	591	0.23	35	4.5	2.38	0.095	0.025	0.6		22
Nuts and Pulses																		
Kidney Beans (RAJMA)	*Phaseolus vulgaris*	1392	23.58	0.83	60.01	24.9	143	8.2	1406	2.79		4.5	0.22	0.529	0.219	2.06	0.397	394
Mung Beans	*Vigna radiata*	1452	23.86	1.15	62.62	16.3	132	6.74	1246			4.8	0.51	0.621	0.233	2.251	0.382	625
Urd Beans	Vigna mungo		25.21	1.64	58.99	18.3	138	7.57	983	3.35				0.273	0.254	1.447	0.281	216
Soybean	*Glycin max*	446	36.49	19.94	30.16	9.3	277	15.7	1797	4.89	1	6	0.85	0.874	0.87	1.623	0.377	375
Lentil	*Len culinaris*	353	25	1	63	10.7	56	6.5	677	3.3		4.5		0.87	0.211	2.605	0.54	479
Horse Gram	*Macrotylomau niflorum*	321	22	0.5	57.2	5.3	278	6.77			71			0.42	0.2	1.5		
Rice Beans	*Vigna umbellata*																	
Field Pea	*Pisum sativum*	81	5.42	0.4	14.45	5.1	25	1.47	244	1.24	449	40	0.13	0.266	0.132	2.09	169	65
Horticulture (fruit)																		
Walnut	*Juglans regia*	654	15.25	65.21	13.71	6.7	98	2.91	441	3.09	12	1.3	0.7	0.341	0.15	1.125	0.537	98
Banana	*Musa* spp.	89	1.09	0.33	22.84	2.6		0.26	358	0.15		8.7		0.031	0.073	0.665	0.4	20
Jackfruit	*Artocarpus heterophyllus*	95	1.72	0.64		1.5	24	0.23	448	1.3	61	13.8	0.34	0.105	0.055	0.92	0.329	24

English Name	Scientific Name	Nutrition Composition																
		Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Crude Fibre (g)	Ca (mg)	Fe (mg)	K (mg)	Zn (mg)	β-carotene equ. (μg)	Vit. C (mg)	Vit. E (μg)	Vit. B1 (mg)	Vit. B2 (mg)	Vit. B3 (mg)	Vit. B6 (mg)	Folate (μg)
Amla	*Phyllanthus emblica*	48	1	0.5	10	5	25	0.9	198	0.12		478				0.3	0.1	6
Lime	*Citrus ourantifolia*	30	0.7	0.2	10.5	2.8	33	0.6	102			29.1		0.03	0.02	0.2	0.046	8
Persimmon	*Diospyros kaki*	70	0.58	0.19	18.59	3.6	8	0.15	161	0.11	253	7.5	0.73	0.03	0.02	0.1	0.1	8
Peach	*Prunus persica*	39	0.91	0.25	9.54	1.5	6	0.25	190	0.17	162	6.6	0.73	0.024	0.031	0.806	0.025	4
Pear	*Pyrus* spp.	57	0.36	0.14	15.23	3.1	9	0.18	116	0.1		4.3	0.12	0.012	0.026	0.161	0.029	7
Passion Fruit	*Passiflora edulis*	97	2.2	0.7	22.4	10.4	12	1.6	348	0.1	743	30			0.13	1.5	0.1	14
Horticulture (Vegetbles)																		
Moringa (leaf)	*Moringa oleifera*	270	9.4	1.4	8.28	2	185	4	337	0.6		51.7		0.257	660	2.22	1.2	40
Moringa (pod)		150	2.1	0.2	8.53	3.2	30	0.36	461	0.45		141		0.053	0.074	0.62	0.12	
Pumpkin	*Cucurbita* spp.	26	1	0.1	6.5	0.5	21	0.8	340	0.32	3100	9	0.44	0.05	0.11	0.6	0.061	
Chayote Squash	*Sechium edule*	19	0.82	0.13	4.51	1.7	17	0.34	125	0.74		7.7	0.12	0.025	0.029	0.47	0.076	93
Mustard Green (sag)	*Brassica juncea*	26	2.56	0.47	4.51	2	118	0.87	162	0.22	7400	25.3	1.78	0.041	0.063	0.433	0.098	9
Chilli	*Capcicum annuum*	40	1.9	0.4	8.8	1.5		1	322		534	144					0.51	
Bitter Gourd	*Momordica charantia*	19	0.84	0.18	4.32	2	9	0.38	319	0.77	68	33	0.14	0.051	0.053	0.28	0.041	51
Cucumber	*Cucumis sativus*	16	0.65	0.11	3.63	0.5	16	0.28	147	0.2		2.8		0.027	0.033	0.098	0.04	9
Stuffing Cucumber (slippery gourd)	*Cyclanthera pedata*						480	5.2	7400									
Amaranthus	*Amaranthus* spp.	371	13.56	7.02	65.25	6.7	159	7.61	508	2.87		4.2	1.19	0.116	0.2	0.923	0.591	82

Source: USDA nutrient database

Country Status Report - India

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Introduction

Neglected and underutilized crops (UUC) are domesticated plant species that have been used over centuries for their food, fibre, fodder, oil or medicinal properties, but have been reduced in importance over time owing to several constraints. Plant wealth of 80,000 species has been used by human beings for food, fibre, industrial, cultural and medicinal purposes (Kermali *et al.,* 1997). Of these, 30,000 species have so far been identified as edible and about 7,000 species have been cultivated and/or collected for food at one or other time (FAO, 1997). At global scale, agricultural output has become increasingly homogeneous with fewer than 30 plant species accounting for more than 95 per cent of humankind's food needs (Harlan, 1992). Just three crops; wheat, maize and rice, provide over 60 per cent of our food supply and 10 crops, namely, wheat, rice, maize, sorghum, millet, potato, sweet potato, soybean, sugarcane and sugar beet, provide 75 per cent of the total plant-derived energy (calorie) intake and a large number of, otherwise once domesticated species, remain underused. Globally, more than 100 species have been grouped as underutilized which include cereals and pseudocereals, vegetable and pulse crops, root and tuber crops, oilseed crops and fruit and nut species. Since the beginning of 20th century, significant efforts have been made in improving productivity of a few crops through international cooperation, leaving out a large number of crops, which now are being termed as 'underused' crops. Dependence on a few crops may lead human population to nutrition imbalances and possibly into trouble due to climate change and emergence of new virulence of pathogens.

The above scenario has raised a global concern on crop diversification and stressed on exploitation of underutilized, neglected and less-known species, life support species and new crop resources (Paroda *et al.,* 1988). There is an increased focus on exploring opportunities to tap the potential of such valuable plant resources to meet the demand of an ever-increasing population. Some of these crops are rich sources of protein, amino acids, minerals and vitamins. Thus, the role of underutilized species in enlarging the base for food and nutritional security has now become a global issue (MSSRF, 1999; Padulosi, 1999). In the developing countries which are diversity rich and hold enormous indigenous knowledge, the research and development in underutilized species is gaining momentum because of their adaptability to local agro-ecosystems, farming systems, and degraded and marginal lands (Bhag Mal *et al.,* 1997). Also, local crops have high genetic diversity, low pest-risk, multi-purpose uses and scope for value addition, are well-tuned to native/traditional farming practices with low inputs, and provide security to rural communities (Evy, 2000). These concerns obviously stress on a well-integrated natural resource management programme by the national agricultural research systems, giving priority to underutilized crop species as per national needs (Singh and Thomas, 1978; Bhag Mal, 1992, 2007; Arora *et al*., 2006).

India exhibits extreme variations in edapho-climatic conditions and floristic diversity. The altitudinal variations are observed from below sea level to above vegetation limits in the Himalayas. Due to this vast array of geographical, physiographical, agro-ecological and ethnic diversity, India is a seat of diversification of plant wealth. Of over 17,000 species of higher plants occurring in different phyto-

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*Country Report presented by Dr Kuldeep Singh (for biograph see page 101) geographical zones of India, about 33-40 per cent are endemic. The All India Coordinated Research Project on Ethno-biology has recorded about 8,900 species used by tribal communities, of which 3,900 are used for food purposes (Pushpangadan, 2002). A synthesis of wild edible plants of India by Arora and Pandey (1996), enumerated over 1,500 species in which various plants parts (categorized below) are used:

(i) **Roots and tubers:** 145 species, of which 33 are cultivated and/or maintained by native communities in home gardens/backyards.

(ii) **Leafy vegetables:** 521 species, of which 72 are domesticated/semi-domesticated.

(iii) **Flowers and buds:** 101 species, of which 15 are cultivated, and occur in protected form in backyards.

(iv) **Fruits:** 647 species, of which 107 are cultivated and some are only grown as homestead cultigens.

(v) **Seeds and nuts:** 118 species, of which 25 are cultivated and/or occur in protected form in backyards.

In India, a number of UUC have been taken up for improvement and popularization under All India Coordinated Research Network (AICRN) programmes (Table 1). Under AICRN on Potential Crops, over three dozen plant species (Table 1) were prioritized for acclimatization studies at different centres during the last 30 years. Of these, rice bean was promoted to the National Pulse Improvement Programme, two tree species, bamboo and casuarina, were taken up for research by the programme on agro-forestry, the industrial plants jojoba and jatropha were adopted by National Oilseeds and Vegetable Oils Development (NOVOD) Board and oilseed tree *Simarouba glauca* was identified for large scale plantation by the Departments of Forests in Tamil Nadu, Karnataka and Odisha. At present, research work is being conducted on 16 potential species.

Table 1. List of crops prioritized for research under All India Coordinated Research Network (AICRN) programmes

Crop group	Crops (species)
Pseudocereals	Grain amaranth (*Amaranthus* spp.), Buckwheat (*Fagopyrum* spp.)
Grain legumes	Rice bean (*Vigna umbellata*), Adzuki bean (*Vinga angularis*), Faba bean (*Vicia faba*), Winged bean (*Psophocarpus tetragonolobus*) Moth bean (*Vigna aconitifolia)*, Horse gram (*Macrotyloma uniflorum)*
Small millets	Finger millet (*Eleusine coracana*), Foxtail millet (*Setaria italica*), Proso millet (*Panicum miliaceum),* Little millet (*Panicum sumatrense*), Barnyard millet (*Echinocloa frumentacea*), Kodo millet (*Paspalum scrobiculatum*)
Oil seeds	*Bhanjira* (*Perilla frutescens*), Paradise tree (*Simarouba glauca*), seed type water melon (*Citrullus lanatus*)
Vegetable	Spine gourd (*Momordica dioica*)
Fodder crops	*Pillipasara* (*Vigna trilobata*), *V. glabrescens, Eupatorium,* Salt bush (*Atriplex* spp.), *Leucaena leucocephala, Colophospermum mopane, Cassia sturtii, Sesbania* spp., *Indigofera* spp.
Industrial Plants	Jojoba (*Simmondsia chinensis*), Guayule (*Parthenium argentatum*), Jatropha (*Jatropha curcas*)
Energy/timber plants	Bamboos (*Bambusa* spp.), Frans (*Casuarina equisetifolia*), Tapioca (*Manihot esculenta*)

Among the crops presented in Table 1, this year we report status of only three selected crop groups which are being improved under the themes, potential crops/small millets/arid legumes. These include pseudocereals, grain legumes and small millets

Pseudocereals

The food grains comprising the grain amaranth (*Amaranthus* species), buckwheat (*Fagopyrum* species) and chenopods (*Chenopodium* species) belonging to three different families, Amaranthaceae, Polygonacae and Chenopodiaceae, respectively, are referred to as pseudocereals as distinguished from true cereals which belong to the family Poaceae. All these crops are important components of traditional farming systems in the hilly areas and form the mainstay of diet of the tribal people. These are usually grown in mixture with other crops such as upland paddy, maize, minor millets as well as in backyards (Singh and Thomas, 1978). Grain amaranth and quinoa possess wider adaptability and have the potential to be successfully cultivated on a large scale in the plains also. These crops possess an exceptionally high nutritional value with higher content of protein, lipids and minerals as well as balanced composition of essential amino acids as compared to cereals. Owing to high nutritional value, these could become an important ingredient of food and have ample scope for utilization in the form of processed food products.

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Germplasm is the backbone of any crop improvement programme, so is true for the UUC. Details of the germplasm collection of selected UUC in the National Gene Bank at National Bureau of Plant Genetic Resources (NBPGR), New Delhi are presented in Fig. 1. A total of 6,800 accessions of pseudocereals, comprising amaranth (5,822), buckwheat (1,000) and chenopodium (197) were augmented to the germplasm collection through collecting from different parts of the country and

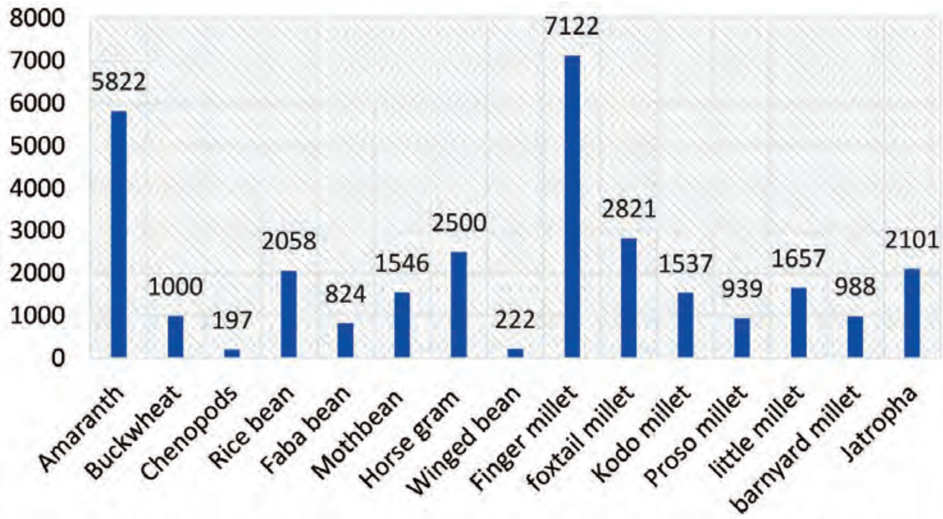

Fig. 1. *Status of the germplasm of selected UUC conserved at NBPGR, New Delhi, India*

introduction from abroad. Most of the accessions were evaluated at multi-locations in plains and hills. Based on the performance, many lines have been released as varieties.

Area, Production and Productivity

These crops are grown in isolated niches and figures on their area and production are normally not reflected in the country's statistics on area, production and productivity of different crops in the country.

Significant Achievements

Since the inception of All India Coordinated Research Project on Under Utilized and Under Exploited Plants in 1982, the major thrust of research has been to address the local needs of region specific UUC. In addition, significant efforts were also made for introducing and acclimatizing new UUC (Arora *et. al,* 2006). The project has made significant achievements in the area of mandatory research. Major achievements made under different aspects are summarized as below:

(i) **Germplasm collection, characterization, evaluation, conservation and documentation:** A total of 6,800 accessions of the three UUC (amaranth, buckwheat and chenopods) were augmented to the germplasm collection through explorations from different parts of the country and introduction from abroad (Fig. 1). Most of the accessions were evaluated at multi-locations in plains and hills. Based on the performance, many lines were released as varieties.

(ii) **Variety development:** Significant efforts have been made for developing high yielding varieties through breeding in grain amaranth at the research centres at Ranichauri, Bangalore, Bhubaneswar and SK Nagar. Forty two improved varieties were released/identified at the national/ regional level in different UUC by the Central/State Variety Release Committee(s) based on their superior performance in multi-location testing. The details of the varieties released are given in Table 2.

Table 2. List of the released varieties of pseudocereals

Crop/ Variety	Year of release	Av. yield (q/ha)	Characteristic(s)	Developed by
Grain amaranths				
Annapurna	1984	22.50	High yield potential, high protein (15%) drought tolerant and wider adaptability	NBPGR, Shimla
GA-1	1991	19.50	High seed yield and drought resistant	SDAU, S.K. Nagar
Suvarna	1992	16.00	Drought tolerant, high yield	UAS, Bangaluru
PRA-1	1997	14.50	High grain yield	UUHF, Ranichauri
PRA-2	2001	14.50	High grain yield	UUHF, Ranichauri
GA-2	2002	15.50	High grain yield	SDAU, S.K. Nagar
PRA-3	2003	16.50	High grain yield	UUFH, Ranichauri
Durga	2006	21.00	High grain yield and early maturing	NBPGR, Shimla
Kapilasa	2006	13.26	High grain yield and early maturing	OUA&T, Bhubaneswar
VL Chua 44	2005-06	13.20	Early maturing (110-120 days), escapes from leaf webber and has non-spiny bract for easy threshability	VPKAS, Almora
GA-3	2008	12.58	High grain yield	SDAU, S.K. Nagar
RMA- 4	2008	13.90	High grain yield	JAU, Mandor
RMA-7	2010	14.66	High grain yield	JAU, Mandor
KBGA-1	2012	15.00	Early maturity	UAS, Bangaluru
Buckwheat				
Himpriya	1991	12.00	High grain yield, medium maturing *F. tataricum*	NBPGR, Shimla
VL Ugal 7	1991	8.00	Early maturing, moderate yield *F. esculentum*	VPKAS, Almora
PRB 1	1998	12.00	High yielding *F. esculentum*, medium maturity	UUHF, Ranichauri
Himgiri	2006	11.12	Early maturing (81-95 days) *F. tataricum*	NBPGR, Shimla
Sangla B-1	2006	12.65	Medium in maturity (104-108 days) and high yielding *F. tataricum*	CSKHPKV, Sangla
Chenopodium				
Him Bathua	2013	5.60	High yielding and medium in maturity	NBPGR, Shimla

(iii) **Cultivation practices:** Agronomic trials on major UUC (grain amaranth and buckwheat), have led to optimization of date of sowing, plant population, fertilizer requirements including organic manures, weed control, water management and intercropping. Crop-wise details of salient findings are as follows:

- **Grain amaranth:** A spacing of 45 × 15 cm was found optimal for planting grain amaranth. Fertilizer dose of 100:40:20 kg NPK/ha in hills and 60:40:20 kg NPK/ha in plains was found to be optimal for growing grain amaranth. Also, several crop rotations have been worked out and area specific crop rotations are recommended.

- **Buckwheat:** Mid-April to mid-May in higher and mid-hills was observed to be optimal sowing time. In tartary buckwheat, clipping increased the yield by 3.5 q/ha and it also helped it to respond to a higher dose of N fertilizer (60 kg/ha). In hill region, fertilizer dose of N:P:K @ 40:40:0 kg/ha is optimum for higher yields. Pre-emergent application of alachlor @ 1.5 kg/ha is effective in controlling weeds both in common and tatary buckwheat.

(iv) **Quality analysis, processing, value addition and product development:** Chemical analysis for nutritional quality traits and for some of the anti-nutritional factors was carried out for the germplasm as well as entries of different crops tested in coordinated trials. The genotypes which were found superior in quality parameters were identified for their use in breeding programme (Table 3).

Table 3. Genotypes of pseudocereals identified as superior based on quality parameters

Crop	Trait	Best Check (value)	Selected Genotypes (Value)
Amaranth	Oil (%)	Annapurna (8.4)	IC041998 (11.1), IC042334 (10.6), IC042292-4 (9.7), IC042329 (8.8), IC042339 (8.8)
	Protein (%)	Annapurna (13.3)	RGAS-92-10-1 (14.76), SKGPA-60 (14.1), SKGPA-5 (13.8), IC038423 (13.8)
	Polyphenols (%)	Annapurna (0.058)	SKGPA- 8 (0.046), SKGPA-17 (0.046), SKGPA-13 (0.047), SKGPA-29 (0.047), IC042323 (0.047), PRA-2011-1 (0.049)
	Ca (mg/ 100g)	Annapurna (309)	MGA-4 (503), RMA-37 (444), RGAS-92-10-1 (442)
	Fe (mg/ 100g)	Durga (9.9)	BGA-19 (28.1), RMA-38 (21.4), RGA -3(17.2), IC038394 (15.7)
	Zn (mg/ 100g)	Durga (6.8)	IC95383 (8.6), BGA-18 (7.8), IC32195 (7.7), IC120689 (7.7)
	Antioxidant activity (DPPH %)	Durga (27.6)	IC035468 (29.3), PRA 2010-1 (28.5), PRA-2011-2 (28.4)
	K (mg/ 100g)	PRA-3 (643.0)	IC042328 (647.0)
	Fibre (%)	Suvarna (4.6)	RMA-27 (5.9), RMA-19 (5.6)
Buckwheat	Ca (mg/ 100g)	PRB-1 (95.2)	EC218742 (100), EC125937 (98), IC274444 (98), IC202286 (98)
	Zn (mg/ 100g)	Sangla-B-1 (4.0)	EC125397 (4.4), EC216631 (4.3), EC058322 (4.2), IC204089 (4.1)
	Fe (mg/ 100g)	Shimla B-1 (4.5)	IC042424 (6.10), IC108500 (6.9), IC108500 (6.9), IC107994 (6.7)
	Crude fiber (%)	PRB-1 (10.88)	Reshwal IC485355 (12.15), IC108500 (12.0)
	Iron (mg/ 100g)	Sangla-B-5 (7.0)	IC204088 (8.8), IC016550 (8.6), IC204086 (8.5), IC204079 (8.4), EC125937 (8.2)
	Polyphenols (mg/ 100ml)	VL-7 (0.19)	EC386667 (0.12)
	Antioxidant activity (%)	VL-7 (21.14)	EC018864 (21.26)
	Ca (mg/ 100g)	VL-7 (95.6)	EC218742 (100)
	Magnesium (mg/ 100g)	Himpriya (214)	IC58322 (258)
	Polyphenols (%)	Himpriya (1.5)	IC108500 (1.4), IC266947 (1.4), IC341674 (1.4), SMLBW-5 (1.4)
Chenopods	Protein (%)	PRC-9801 (17.8)	NIC-015022 (20.2), IC540834 (18.9), IC540582 (18.8), NIC-22496 (18.6)
	Ca (mg/ 100g)	PRC-9801 (316)	NIC 022508 (352), IC258253 (329), IC107296 (327.3)
	Iron (mg/ 100g)	PRC-9801 (26.17)	IC540823 (43.86), NIC-022498 (42.03), EC359445 (38.97), IC540834 (38.97)
	Zn (mg/ 100g)	PRC-9801 (2.2)	SMLCP-2 (5.55), NIC-022498 (4.28), IC341710 (4.13), NIC-022516 (3.5)
	Fibre (%)	PRC-9801 (9.80)	IC447573 (10.80), IC415403 (10.75), IC469275 (10.65), IC106340 (10.55)
	Chromium (%)	PRC-9801 (3.99)	IC540823 (4.30), IC540834 (4.17), EC201680 (4.08), IC415477 (4.0)

Challenges and Opportunities

Challenges

- Pseudocereals are mostly grown in the mid- and high-hills as rainfed crops. Where ever irrigation facilities are being created, these crops get replaced by off season vegetables, which fetch better prices.
- Grain amaranth and *Chenopodium album* are photo sensitive and grow very tall if sown early. This results in lodging and yield losses whenever onset of rains is early during May–June.
- Both amaranth and chenopodium are small-seeded and are difficult to process at household level in the absence of appropriate machinery for processing, grinding etc.
- All the three pseudocereals are prone to shattering which causes losses whenever there is delay in harvesting.

Opportunities

- Amaranth and chenopodium have wide adaptability and can be successfully grown in the arid and semi-arid plains during winter season with limited irrigation support. Amaranth has been successfully introduced in North Gujarat and > 10,000 tons of amaranth grain is produced and marketed every year in Banaskantha district alone.
- Due to awareness generation of about the health benefits of *Chenopodium quinoa,* an Andean species of grain chenopod, demand has been created in the high end markets of USA, Europe and Japan. The crop can be successfully cultivated in the hills during rainy season and in the plains during winter season. It has the potential for production of >30,000 tons/annum, expected growing domestic demand as well as for export.

Marketing, Commercialization and Trade

Pseudocereals are normally consumed during religious fasts (commonly known as 'Navratras' in India) when people do not consume cereals. In the absence of organized system for marketing and trade of pseudocereals, farmers normally exchange these with other cereals like rice.

Strategies Adopted to Harness their Potential

- Identification of improved varieties for different agro-ecological niches and supply of quality seed to the farmers in order to increase/stabilize production and productivity.
- Identification of agronomic niches for their economically viable production as sole crops in higher hills and arid plains and as intercrops in mid hills and semi-arid plains.

Major Focus Areas

- Initiation of hybridization programmes to breed high yielding varieties with desirable traits for the region e.g. dwarf types for hilly region and early maturing types of amaranth for the plains region.
- Identification of accessions superior in nutrient/mineral content for cultivation by the farmers.
- Development of DUS (distinctiveness, uniformity and stability) guidelines to facilitate varietal development and spread in cultivation.

Infrastructure, Capacity Building and Financial Investment

- Infrastructure available for research on pseudocereals is skeletal and is a major stumbling block in developing high yielding varieties/ trait specified material for use in crossing programme. Provision of high end glass houses at different centres with temperature and humidity control can go a long way in development of better varieties, which at present are mostly selections from germplasm.

- Training of plant breeders, who now use conventional breeding methods, in the use of biotechnological tools, can hasten the process of development of targeted breeding materials.
- The present level of contingency (Grant in aid General) provided to scientists (~ Rs 100,000 per annum) in grossly insufficient to carry out all aspects of coordinated research (germplasm collection and evaluation, crop improvement, production and protection) as every centre has to carry out research work on 4-6 potential crops.

Future Thrust

- Development of seed standards to facilitate large scale seed production and supply of quality seed.
- Development of dual/multipurpose varieties, as these crops have multiple uses like vegetable, staple food grain, fodder, industrial and medicinal.
- Germplasm enhancement to develop non-shattering, dwarf, disease and insect pest resistant varieties.
- Development of database on indigenous technical knowledge (ITK) on uses and cultivation practices of pseudocereals.
- Value addition and product development to promote utilization of pseudocereals.
- Special Ph.D. student scholarships for working on UUC can help in invoking interest in young students to work on these crops.

Grain Legumes

Among the grain legumes, moth bean (*Vigna aconitifolia),* horse gram (*Macrotyloma uniflorum),* rice bean (*Vigna umbellata*), winged bean (*Psophocarpus tetragonolobus*), and faba bean (*Vicia faba*) have received considerable attention in recent years (Kumar, 2009). Moth bean is grown on plain lands and on sand dunes and also in different combinations with crops, trees, fruit crops and grasses and is recognized for its twin tolerance to drought and heat. It is, therefore, the ultimate choice of the marginal and sub-marginal farmers for realization of sustained production under the extreme hostile and harsh agro-climatic situations. Besides, conserving soil and water, it is also used in several confectionary items, forming essential components of day to day snacks. Its green fodder is at par to alfalfa and dry fodder is better than cowpea and cluster bean. It can provide 7-8 t/ha of hay. Horse gram (*kulthi*) is a traditional tropical grain legume, well known for its hardiness and adaptability to poor soil, adverse climate condition that are unsuitable for most other crops. It is extensively grown in peninsular India and also cultivated up to 1,700 m elevation of Himachal Pradesh. This hardy legume thrives well in almost all types of soil, except highly alkaline soils. Rice bean is adapted well to the hilly regions of Himachal Pradesh as well as the North-eastern States of India. Faba bean grows well in temperate regions of the country during summer and in North Indian states during winters.

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

ICAR-NBPGR maintains 1,546 germplasm of moth bean, 2,500 of horse gram, 2,058 of rice bean, 824 of faba bean and 222 of winged bean. Most of these accessions have been characterized and are being evaluated for several agronomically important traits.

Area, Production and Productivity

The area of moth bean ranges from 1.31 million ha in 2011-12 to 0.86 million ha in 2014-15 and its production range from 0.44 l million tons to 0.34 million tons, respectively. The productivity ranged from 339 kg/ha to 393 kg/ha. Rajasthan state is the major area for moth bean cultivation, occupying 85 per cent area and contributing 78 per cent in total production. Area under horse gram varies between 4-5 million ha annually and the production in between 2-2.6 million tons in recent years. Productivity of horse gram ranges from 428-529 kg/ha. Major production of horse gram is from the state of Karnataka.

Significant Achievements

(i) **Germplasm collection, characterization, evaluation, conservation and documentation:** ICAR-NBPGR maintains 1,546 germplasm accessions of moth bean, 2,500 of horse gram, 2,058 of rice bean, 824 of faba bean and 222 of winged bean. Most of these accessions have been characterized and are being evaluated for several ergonomically important traits.

(ii) **Varietal development:** A number of varieties have been developed in all the four grain legumes, through selection as well as pedigree breeding. Important varieties developed and released for cultivation for the above crops are presented in Table 4.

Table 4. Details of the varieties released in underutilized grain legumes

Crop	Varieties
Moth bean	RMO-257, CAZRI Moth-3, RMO-423, GMO-2, CAZRI Moth-2 and RMO-435
Horse gram	AK 21, AK 42, CRIDA-18R and VLG-15 and BJPL-1, Chhattisgarh kulthi-3, Phule Sakas, CRHG-22, AK-53, VL Gahat 19, Indira Kulthi 1, VL Gahat 15, CRIDA-1-18R, VL Gahat 8, VL Gahat 10
Rice bean	RBL-1, PRR-1, PRR-2, RBL-6, RBL 35, RBL 50, BRS 1, VRB-3, Palam Rajmung-1
Faba bean	VH 82-1, HFB-1
Winged bean	AKWB-1, Indira Winged bean-1, Chhattisgarh Chaudhari Sem

(iii) **Cultivation practices:** Cultivation practices have been standardized for all the grain legumes. For moth bean, 1st fortnight of July is best suited where in seed rate of 15-20 kg/ha is recommended with row-to-row and plant-to-plant spacing of 45 × 15 cm. With recommended package of practices, yield potential up to 8-10 q/ha is realized. For horse gram seed rate of 20-25 kg/ha and spacing of 30 × 10 cm is recommended. Pre-emergence weed control can be achieved by spray of pendimethalin @ 0.75 kg a.i./ha coupled with one hand weeding at 30-35 DAS. Under standard agronomic practices a yield potential of 8-10 q/ha is realized. In rice bean, 30 cm row to row spacing is optimal and fertilizer dose of 40 kg N/ha and 40 kg P_2O_5/ha gave highest yields. Pre-emergent application of pendimethalin @ 1 kg a.i./ha coupled with one hand weeding 5 weeks after seeding resulted in effective control of weeds. Varieties like VRB-3 under optimum agronomic practices yielded as much as 17 q/ha in north-west hills. For faba bean, application of pendimethalin @ 0.75 kg a.i./ha coupled with one hand weeding 5 weeks after seeding proved effective in control of weeds. In winged bean, highest yield was obtained by planting the crop in 30 × 30 cm spacing at Bangalore, whereas a spacing of 45 × 20 cm resulted in highest yield at Bhubaneswar.

(iv) **Processing, value addition and product development:** Moth bean offers a variety of edible products such as dried seed (whole), decorticated seed (*mogar*), mature and immature green pods (as vegetable), leaves, pods shells and branches as fodder for animals, flour for *papad*, nuggets (*mangori*) and snacks (*bhujia*). Moth bean is a very important industrial crop. In Bikaner city (Rajasthan) alone, there are more than 600 industrial units engaged in preparing *bhujia, papad, mogar* and nugget, giving direct and indirect employment to nearly 100,000 people involving annual transaction of over Rs 500 million. Horse gram grain contains 20-24 per cent of protein and is one of the cheapest sources of protein for both humans and animals. It is consumed both in boiled and fried preparations. Unlike most other Asian grain legumes, it is not converted into split *dhal*/pulses, rather roasted gram is grounded with salt, chilli, sometimes with coconut and consumed with rice and millets. Horse gram is also a constituent of the Ayurvedic medicine cystone is known to reduce acidity, in curing whooping cough and constipation.

Rice bean germplasm was analyzed for, protein content, tannin, cooking time, antioxidant activity, Fe, Zn, Ca, Cu, Crude fibre, meithionine, tryptophan, polyphenols and ash. Significant variation was observed in the germplasm for all the traits (Table 5). Likewise, nutrient profile data has been generated in other crops as well.

Table 5. Genotypes with superior quality parameter in rice bean germplasm

Trait	Selected genotypes (value)
Protein (%)	BRB-004 (23.93), Selection-6 (21.8), HBR-438 (21.8)
Tannin (mg/100 g)	BC-1 (490), LRB-470 (510), BC-1 (510.50), LRB-160 (513), LRB-470 (517)
Cooking time (Min)	LRB-10(43), EC098453 (43),
Antioxidant activity (%)	IC63980 (69), IC141077 (68), PRR-2011-1 (67), IC563980 (66), PRR-2011-1 (65)
Fe (mg/100 g)	LRB-452 (8.95), BC-1 (7.65) BC-1 (7.4)
Zn (mg/100 g)	LRB-452 (4.30), PRR-2007-2 (4.2)
Ca (mg/100 g)	LRB-160 (336), LRB-470 (332)
Cu (mg/100 g)	RL-3 (0.62), RRB-10 (0.67)
Crude fibre (%)	PRR-2008-2 (6.7)
Methionine (%)	LR-37B0 (0.96), LRB-396 (0.95), LRB-427 (0.94), LRB-363 (0.94)
Tryptophan (%)	LRB-365 (0.94), LRB-364 (0.92), LRB-367 (0.91)
Polyphenols (%)	LRB-312 (0.15), LRB-433 (0.15), PRR-9402 (0.16)
Ash (%)	HRB-11 (1.09), HRB-2 (0.99), HRB-6 (0.99), LRB-355 (0.95), LRB-367 (0.94)

(v) **Disease and pest management:** For root rot of moth bean**,** combination of *Trichoderma harzianum* + *Pseudomonas fluorescens* (4 + 4 g/kg seed) + soil application of *T. harzianum* + *P. florescence* (1.25 + 125 kg in 50 kg FYM for one hectare) for controlling root rot of moth bean. White fly is the major sucking pest. Seed treatment with Imidacloprid 600 FS @ 5 ml/kg seed + foliar spray of Thiomethoxam 25 WG @ 0.3 g/litre controls white fly and other sucking pests. It also helps in controlling YMV (*Yellow Vein Mosaic Virus*). For horse gram powdery mildew, spray of 0.5 ml/l calaxyn at the time of early stage controls the disease. For sucking pest, seed treatment with Imidacloprid 600 FS @ 4 g/kg seed is effective.

Challenges and Opportunities

Challenges: Most varieties of grain legumes are photoperiod sensitive, having low harvest index, and susceptible to diseases like powdery mildew, YMV and sucking pests. There is limited genetic variability in germplasm accessions and landraces. The anti-nutritional factors such as trypsin inhibitor are also present. Hybridization is difficult and severe flower drop after artificial crossing impede backcrossing and alien introgressions.

Opportunities: There is scope to develop high yielding varieties having semi-erect to upright branching behaviour and early maturity. Rice bean is known to be resistant to YMV as well as some sucking pests, hence incorporation of YMV resistance in high yielding varieties is possible through interspecific crosses. Varieties with low or zero growth inhibitors and trypsin inhibitors could be developed after analysing variation in the germplasm.

Marketing, Commercialization and Trade

There is no well-defined system of marketing and trade for most of these crops. Most of the moth bean is utilized in *bhujia, papad, mogar* and nugget industry. Horse gram is consumed by tribal people as sprouted and boiled preparation. It is a major constituent of Ayurvedic medicine cystone. Likewise, for rice bean, moth bean and winged bean, no well-defined marketing systems are available.

Strategies Adopted to Harness their Potential

- Supply of quality seed of newly released varieties to farmers can lead to increase in productivity as well as production.

- Inter cropping, rather than traditional mixed cropping results in better yield, quality and higher returns to the farmers.
- Adoption of minimum plant protection measures like seed treatment with insecticide and fungicide improves plant stand for most of these crops.
- Use of rhizobium strains in combination with minimum dozes of organic fertilizers has resulted in significant increase in production at farmers' field.

Major Focus Areas

- To initiate large scale hybridization programme.
- To identify genetic stocks resistant to major diseases like YMV and powdery mildew.
- To identify the genes/QTL conferring resistance and mapping these with molecular markers.
- To develop high yielding varieties with resistance to YMV and powdery mildew that fit well in intercropping systems.

Infrastructure, Capacity Building and Financial Investment

A major limitation in improving productivity of legumes, in general, is limitation in producing large number of crossed seeds, because of: i) small flower size and ii) severe flower drop (>90%) after artificial crossing. A high-end screen house with temperature and humidity control can improve success rate of crossing. This can help in undertaking interspecific crosses as well. Secondly, no infrastructure is available for screening germplasm and the breeding lines for resistance to YMV and powdery mildew. Well-equipped glass/poly houses are required for undertaking screening of germplasm under artificial conditions. The present level financial support given to these crops is not sufficient to undertake large scale breeding programmes.

Future Thrust

- Development of high yielding and short duration genotypes that can fit in intercropping or as a sandwich crop to increase their production.
- Development of dual purpose genotypes having high seed as well as fodder yield.
- Development of genotypes for low input situations.
- Germplasm enhancement to identify germplasm with determinate growth habit, thermo-sensitive and resistant to important diseases.
- Management of stored grain pest bruchid, *Callosobruchus* spp.

Small Millets

Small millets including finger millet (*Eleusine coracana*), foxtail or Italian millet (*Setaria italica*), proso millet (*Panicum miliaceum*), little millet (*Panicum sumatrense*), barnyard millet (*Echinocloa frumentacea*), kodo millet (*Paspalum scrobiculatum*) and brown top millet (*Brachiaria ramosa*) are underutilized for food and nutritional security in India. Though grown on small acreage and with low productivity (Table 6), but are of local importance as staples and as reserve crops in marginal areas. These are grown from sea level to mid hills right from Tamil Nadu in the South to Uttarakhand in the North, and Gujarat in the West to Arunachal Pradesh in the North-East and show wide variation in thermo and photoperiods (Table 6).

These crops shows exceptional diversity associated for phenology, tolerance to abiotic stresses, resistance to biotic stresses, seed storability and shelf life, and specific grain characteristics associated with end user preferences, hence are indispensable in tribal and hill agriculture. In the climate change scenario, small millet will be harbingers of ever green revolution (Seetharama *et al.*, 2007). These small millets

Table 6. Adaptation and productivity of small millets in India

Crop name	Climate adaptation	Crop duration (days)	Av. yield (kg/ha)	Adaptation for impacts of climate change
Finger millet	Wide adaptation up to 2,300 m	90-130	1,226	Moderately resistant to heat, drought and humidity, adapted to wide altitude range
Foxtail millet	Wide adaptation up to 2,000 m	70-120	565	Adapted to low rainfall, high altitude
Kodo millet	Tropic/ sub-tropic up to 1,800 m	120-180	312	Long duration, but very hardy, needs little rainfall, comes up in very poor soils, good response to improved management
Barnyard millet	Wide adaptation up to 2,000 m	45-60	857	Very short duration, not limited by moisture, high altitude adapted
Little millet	Tropic/ sub-tropic up to 2,100 m	70-110	349	Adapted to low rainfall and poor soils; used as famine food; can withstand water logging to some extent
Proso millet	Wide adaptation up to 3,500 m	60-90	323	Short duration, low rainfall, high altitude adapted

possess unique nutritional characteristics, having complex carbohydrates and are rich source of iron, zinc, calcium and other nutrients (Table 7) that are essential for curbing the problem of malnutrition in India. Finger millet is the richest source of calcium (300-350 mg/100 g) and other small millets are good source of phosphorous and iron. In addition, these are gluten-free and good for people having gluten intolerance. Millet crops have food, feed, fodder and bio-fuel values and their dried vegetative parts are also used in making shelters.

Table 7. Mineral composition of small millet (processed) grains (in 100g)

Crop	Ca (mg)	P (mg)	Mg (mg)	Zn (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Folic acid (µg)
Finger millet	364.0	210	146	2.5	4.6	0.37	0.17	1.3	34.7
Kodo millet	15.3	101	122	1.6	2.3	0.29	0.20	1.5	39.5
Proso millet	14.0	206	153	1.4	0.8	0.41	0.28	4.5	-
Foxtail millet	31.0	188	81	2.4	2.8	0.59	0.11	3.2	15.0
Little mille	16.1	130	91	1.8	1.2	0.26	0.05	1.3	36.2
Barnyard millet	20.0	280	82	3.0	5.0	0.33	0.10	4.2	-

Source: Indian Food Composition Tables, NIN (2017); Nutritive Value of Indian Foods, NIN (2007); USDA (2016) http://ndb.nal.usda.gov

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

In the past small millets scientists hardly had access to germplasm and worked with a handful of local collections which lacked diversity. This blunted the opportunities for of yield improvement through breeding. This situation was to some extent rectified in the 1960 when first attempts were made by ICAR to pool the collections under PL 480 project. The conservation activities further gained momentum with NBPGR, New Delhi, playing a key role in augmenting the small millets collection. Recognizing the importance and conservation and easy access to germplasm, All India Coordinated Research Project on Small Millets (formerly called All India Coordinated Small Millets Improvement Project/AICSMIP) established a separate germplasm unit at Bangalore in 1979 (Seetharam, 2006). It maintains one of the largest collections of germplasm (15,064 accessions) including 7,122 accessions of finger millet, 2,821 of foxtail millet, 1,537 in kodo millet, 939 in proso millet, 1,657 in little millet and 988 in barnyard millet.

Majority of the germplasm accessions have been screened for agronomic, physiological, pathological and even important grain quality parameters. The breeding value of many accessions has been judged by growing in field trials more than once. There is good database available for most accessions and germplasm catalogues have been brought out (Seetharam, 2006). Three germplasm catalogues were published, *viz.* core set of finger millet for 551 accessions, little millet for 902 accessions and barnyard millet for 729 accessions. In order to improve the efficiency for utilization of germplasm, core subsets have been formed and made available to breeders working at different centres. Core sets of germplasm have been formulated in finger millet, foxtail millet, kodo millet, barnyard millet, little millet and proso millet. Selected germplasm has also been evaluated in the all India testing network and a number of superior accessions were identified and a couple of them have been released for general cultivation in different parts of the country. The exotic collections especially from Africa in finger millet have been largely used in recombination breeding resulting in release of many superior high yielding varieties in many states. The African finger millet germplasm have thick stem, dark leaves, robust growth, large ears, and high grain density and source of resistance to blast disease. Hybridization between African and Indian elite varieties has been highly rewarding and has resulted in the release of many high yielding varieties in the country (Seetharam, 1998).

Several useful genetic stocks have been identified in all small millets accessions possessing higher protein, desirable agronomic attributes with high carbon dioxide fixation and low leaf area suitable for rain fed situations, and genotypes which can germinate under limited moisture under hard soil crust have been identified (Sashidar *et al*.,1983,1986; Seetharam *et al*.,1984; Gowda *et al.*,1986). Long glume types with higher ear photosynthesis reflecting in higher seed size and weight will be of interest in improving yield of finger millet in the coming years (Sashidar *et al*., 1983). Accessions capable of producing higher biomass, dual purpose types with superior stover quality are available for improving grain and stover yield of cultivars. Identification of several sources of stable resistance to blast disease of finger millet and their deployment in breeding research has been highly rewarding in evolution of high yielding blast resistant cultivars in finger millet in the country (Gowda *et al*.,1986; Ravikumar *et al*.,1990,1991; Seetharam and Ravikumar,1993; Gowda *et al*.,1998,1999). There is finger millet germplasm with significantly higher grain calcium and protein and useful in breeding for improving quality parameters. In the secondary genepool, *Eleusine coracana* subsp. *africana* will be of interest from the breeding point of view. This could be a useful gene source for improving tillering ability, fodder yield and quality, drought tolerance and even finger number and length. A carefully planned pre-breeding is required for interrogation of characters from *E. africana* to *E. coracana* for deriving lines useful in regular breeding programmes.

In foxtail millet, new sources of dwarfing controlled by oligo genes have been identified (Dinesh Kumar *et al*., 1992). These accessions are useful in breeding dwarf foxtail millet similar to the ones available in wheat. The variability available for protein content (7.176-15.73) and seed fat content (4.0-7.1) in foxtail millet was enormous which can be exploited directly to use in breeding.

The optimum use of germplasm in small millets is most important in future breeding activities for making notable advances in the productivity of these crops and also to make small millets competitive *vis-a-vis* other crop options. Based on the evaluation and geographical origin, core set of germplasm have been formulated in finger, foxtail and proso millets for improving their utilization in the crop improvement. There is variability available for stover quality parameters as well as quantity in the germplasm of various small millets offering scope for the improvement of feed value of crop residues (Schiere *et al*., 2004; Subba Rao *et al.,* 1995)

Area, Production and Productivity

Area under small millets during the last six decades has significantly shrunk from 8 million ha in 1949-50 to around 1.8 million ha in 2011-15. The loss of area is very severe in all small millets other than finger millet. However, in the last 15 years, the finger millet also has lost ground and area has come down from 2.4 million ha to 1.2 million ha. Productivity-wise, finger millet has kept pace with most other major dry land crops in compound growth rates (CGR) for yield while the other small millets have shown little progress (Table 8). By and large, the low productivity of these crops is largely due to less attention received in terms of inputs, water and technology back up which is further compounded by low value status of grain.

Table 8. Decade wise compound growth rates for area, production and yield of finger millet and small millets during 1951-2010

Year	Compound growth rate (CGR)					
	Finger millet			Other small millets		
	Area	Production	Yield	Area	Production	Yield
1951-1960	1.57	4.48	2.85	0.57	0.32	-0.12
1961-1970	-0.28	-1.00	-0.72	-0.32	-1.68	-1.35
1971-1980	1.25	4.28	2.99	-0.76	-0.51	0.25
1981-1990	-1.21	-0.10	1.13	-4.35	-3.26	1.36
1991-2000	-1.80	0.93	2.78	- 5.36	- 5.38	- 0.09
2001-2010	-3.17	-1.73	1.70	- 4.92	-2.93	2.08

Average grain yields for finger millet show a wider variation in different states of India, ranging from as low as 339 kg/ha to as high as 2,771 kg/ha with country average of 1,600 kg/ha for the period 2011-12 to 2014-15. Similarly, for other small millets, the average yield in different states ranged from 413 kg/ha to 1,250 kg/ha and national average of 603 kg/ha. The major reasons for loss of area and production are highly subsidized rice schemes in certain southern states which has resulted in a shift towards rice both in terms of cultivation and consumption. Other factors like convenience of cooking, difficulties in processing of millets on a large scale and relatively lower productivity giving economic advantage to the cultivation of fine cereals are also responsible for the shift from millets to cereals. Thus, both supply led factor such as subsidized input supply and demand led factors such as government policy to supply fine cereals at subsidized prices, output incentives, etc., have resulted in lowering of consumption demand and in turn decline in acreage under millets. Apart from nutritional disadvantage of losing millets from the diet, extensive cultivation of cereals using ground water in arid areas is threatening water security in the country.

Significant Achievements

Variety development: Millets, in general, started receiving with attention with the launching of All India Coordinated Millets Improvement Project (AICMIP) in 1969. All India Coordinated Small Millets Improvement Project (AICSMIP) was established in the year 1986 and research on small millets has been getting focused attention for developing varieties and other agro production and protection technologies suitable to different regions. There were 14 centres functioning all over the country to address to the research needs of small millets. Crop improvement is mainly aimed at developing high yielding varieties with resistance to blast disease quality fodder, early and medium maturity and white seed in finger millet, resistance to head smut in kodo millet and resistance to shoot fly in both proso and little millets. So far, a total of 236 varieties in six small millets have been released in the country. State wise variety release until 2014 is presented in Table 9.

Cultivation practices: The package of practices for cultivation different small millets such as time of sowing, planting, choice of varieties, time and method of application of fertilizers have been developed for different regions of the country. Plant protection measures to control economically important diseases and pests have been evolved. Small millets are mainly grown under rain fed conditions during *kharif*. Line sowing is beneficial in inter-culturing and control of weeds effectively.

Table 9. Number of varieties released in various small millets

State	Finger millet	Foxtail millet	Kodo millet	Little millet	Proso millet	Barnyard millet	Total
Andhra Pradesh	18	9	-	-	4	-	31
Karnataka	37	5	1	-	2	-	45
Tamil Nadu	20	9	7	8	11	4	59
Odisha	6	-	-	5	-	-	11
Madhya Pradesh	-	-	17	4	-	-	21
Chhattisgarh	1	-	1	-	-	-	2
Uttar Pradesh	4	1	2	-	1	3	11
Bihar	1	-	-	-	3	2	6
Jharkhand	4	-	-	1	-	-	5
Rajasthan	-	5	-	-	1	1	7
Total	91	29	28	18	22	10	198

Source: Seetharam (2015)

Maintenance of optimum plant population is essential for realizing higher yields. Two to three inter-cultivations followed by one hand weeding minimizes weed problem. These crops respond well to added fertilizers. Judicious blending of organic manure with 20-40 kg N, 20-40 kg P_2O_5 and 20-25 kg K_2O kg/ha gives higher yield. Nitrogen in two splits helps in efficient use of applied fertilizers. Profitable small millets based intercropping systems have been identified for different regions (Seetharam, 2015).

Processing, value addition and product development: The variation in the size and shape of grains in small millets makes their processing difficult. They have more layers in the epicarp (which can be 1-4 layers thick and may contain pigments which give colour to the small millet grains) region. Hence, pre-processing interventions (like dry treatment, roasting, dehusking, blanching, parboiling etc.) have to be further addressed in order to make the small millets edible. Processing interventions in post-harvest processing in millets include cleaning, grading, dehulling, etc. (primary processing) and semolina or *suji*, flaking, popping, extrusion, baking etc. (secondary) which lead to value-addition. Milling to remove the outer bran (pericarp) of the grain is the most common way millets are processed, a technique similar to those seen with rice, which serves to lighten the colour and lead to faster cooking of softer products (Malleshi, 2007). To increase the functional aspects of millets processing such as parboiling (Kimata *et al.*, 1999), malting, flaking (Dayakar *et al.*, 2014), popping, boiling for food, extrusion (hot and cold) (Dayakar *et al.*, 2014; Gull *et al.*, 2015) are done. This results in the diversification and shift towards more convenient/ processed products of fine cereals like rice and wheat from the millets.

Various processing technologies developed at ICAR-Indian Institute of Millets Research (IIMR) include:

- Convenient/ ready-to-eat and ready-to-cook millet-based products.
- Increased nutrient digestibility through pre-processing and diversification of processing technologies (baking, extrusion, parboiling, milling, flaking etc.).
- Development of healthy and convenient RTC/E foods (30 products across millets).
- Nutritional labelling of *eatrite* products for highlighting the nutritional benefits *vis-à-vis* over existing products.

Disease and pest management: Though small millets do not have serious biotic stresses, some insect pests such as shoot fly, diseases such as blast, smut, etc. may be endemic in some regions during certain years. Research activities in plant protection aspects are concerned with identifying resistant sources, forecasting, loss estimation, epidemiological studies and chemical control measures for major diseases and pests. Some of salient findings (Seetharam, 2015) are:

- Finger millet genotypes, highly resistant to both neck and finger blast, have been identified.
- Spraying of SAAF @ 0.2 per cent at 50 per cent flowering and one more need based spray after 10 days are effective in controlling neck and finger blast.
- Seed treatment with carbendazim @ 2 g/kg seed effectively controls the blast incidence and resulted in higher yield of finger millet.
- Seed treatment with chlorpyriphos @ 12 ml/kg seed was effective in warding off shoot fly damage up to 25-30 days.
- Intercropping/sprinkling of niger or mustard help in enhancing the population of parasites and predators in various small millets and thus help in effective bio control of major pests.
- Early sowing with the onset of monsoon helps in escaping the spray schedules for the control of shoot fly in little, kodo and proso millets.

Challenges and Opportunities

Major challenges include the need to address the gaps in millet production, utilization and marketing, which are as below:

- Millet crops are predominantly grown in marginal lands with low water holding capacity of soil under rain fed conditions leading to low productivity.
- Change in the consumption habits among the urban households coupled with time consuming and tedious procedures of food preparations making utilization difficult.
- Lack of advanced and cost-effective processing technologies for entrepreneurship development.
- Comparatively poor shelf life of the millet-based products.
- Non-adoption of improved crop production practices due to socio-economic constraints.
- Research on genetic improvement in small millets was not given utmost importance.
- Lack of organized seed production and supply of seeds of improved varieties.
- Lack of remunerative and assured price for the produce and marketing facilities.
- Unhusked millet grains are known to store good for a few years without loss of quality, but once milled, they deteriorate faster, and hence genotypes free from rancidity problem need to be developed.

Marketing, Commercialization and Trade

Commercialization of millets as processed products has the inherent problem of: (i) continuous supply of raw material throughout the year (millets being seasonal crops, and grown in lesser area); and (ii) requirement of identity-preserved grain, free from adulteration (the crop often being a mix of farmers' varieties with the prescribed cultivar). Thus, quality and quantity are important determinants. However, tested models are available some low volume crops and are being used by some companies to test the model feasibility in millets on a pilot scale (Dayakar *et al*., 2014). The contractual arrangements between farmers and processors will ensure such uniform quality for an unhindered, reliable and efficient production system. Due to growing urban demand, several small and medium sized enterprises (SMEs) have taken to value addition of millets and marketing in urban clusters and online kiosks. This is expected to reach a critical mass in a couple of years beyond which farmers would be able to realize the benefits of accruing demand. Export of value added products of millet based products has been in place and growing. Adoption of technologies developed through MoU by the stakeholders/ farmers/ entrepreneurs is a key component in agricultural development. ICAR-IIMR has so far signed 22 MoUs and 4 MoAs with various stakeholders for popularization of millets for as nutri-rich foods. Further, the export opportunities of millets can be enhanced by taking several measures:

- Most important factor that reduces the competitiveness of the millets grains in the international market is its quality. Release of pest and disease resistant varieties could effectively address this problem.
- Co-operative or collective cultivation of the millets will also help in the reducing the cost of cultivation and improve the bargaining power of the farmers.
- Value addition to the millet grains is the most effective way to improve the export competitiveness.
- Providing incentives to millet growers, processing and value addition enterprises thereby developing domestic markets for exports will be facilitated.
- Provide tax benefits to value added products to generate demand and area expansion.

Strategies Adopted to Harness their Potential

Increasing yield levels through bridging of yield gaps

It was estimated that in a period of 3-4 years an additional 0.788 million tons of millets could be produced in India only through reduction in yield gaps. Various measures to bridge the yield gaps in millets cultivation would include:

- Availability of location specific technologies.
- Weed infestation often lead to larger yield gaps for millets cultivation. Farmers should be made well aware about the extent of yield reduction due to weed infestation and should be made equipped for proper weed management.
- Soil health condition of these millets growing regions should be recorded in Soil Health Cards and farming practices should be provided based on the nutritional status of the soil.
- The non-government organizations (NGOs) working on millets development programmes in various states have to be made more involved in the grassroots level policy development.
- The focus should, therefore, be on improving the resource use efficiency and adoption of recommended farm management practices so that the farmers are able to realize the full genetic potential of the variety or at least to the minimum level of production of Front Line Demonstrations (FLDs).
- The emphasis needed is on reaching out all the available technologies and recommended practices to the farmers, especially in small holdings of dryland farmers where millets are to be cultivated throughout the year.

Productivity enhancement of millets through seed management

Production and distribution of quality seed of high yielding varieties (HYV): quality seeds of HYV of millets are available in ICAR institutes and agricultural universities of different states. Spread of HYV of small millets cultivars needs lot of improvement. Seed supply of small millets varieties is an area which needs focused attention for enhancement of farmers' income in tribal, hilly and other disadvantageous regions.

Development of millets seed villages: seed village concept should be promoted in order to maintain steady supply of location specific quality millets seeds at a minimum cost. Since cost of seeds is one of the major contributors of the cost of cultivation, availability of seeds from seed villages will help in increased farm income due to cost reduction. This will also help the farmers to maintain their own seeds and thereby purchasing seeds every year from the open market.

Contract farming

Contract farming is much explored in the field of vegetable cultivation which has proven to be effective in connecting steady prices for produce and their procurement. Contract farming, when explored with all necessary measures ensures steady flow of income for the farmers. This farming model also provides price security of their produces as the price is predetermined in the terms of contract. The field of contract farming must be explored with regards to millets (with particular emphasis on small millets). Small millets are not covered under MSP (Minimum Support Price) and hence farmers suffer from price insecurity. These models will provide the price security to the millet farmers and will also ensure steady market.

Farmer producer organizations (FPOs) for better supply chain management

FPOs will help the millets farmers to organize and enhance productivity through efficient, cost-effective and sustainable resource use and fetch higher returns. Supply of location specific inputs, providing timely training programmes and direct procurement of the produce can be effectively managed through these organizations. Farm gate value addition can be initiated with respect primary processing in millets by providing subsidy to farmers directly or through custom hiring centre in each village that would result an increase in gross revenues ranging from 110 per cent to 225 per cent across millets and resulting in additional net revenue ranging from Rs 8,370-37,800/acre at the cost of Rs 5-6 lakhs/unit.

Price and procurement policy

The price realized for millets has been a major driver of growth of value of output of millets along with growth in area and yield. This points out the significance of steady price supports in enhancing the farmers' income in the coming years. Finger millet is the only small millet covered under the Minimum Support Price (MSP) of Government of India. MSP fixed for 2016-17 for finger millet witnessed an increase of 64 per cent over the year 2011-12. There is no provision of MSP for other small millets from the government. Millets are categorized along with maize in the group of coarse cereals in national food security mission (NFSM). The procurement policy of the government of coarse cereals has revolved around maize, ignoring the millets significantly. Thus, there is a need to form a separate group only for the millets to confer more importance to these "nutri-cereals" in the National Food Security Act, 2013, for procurement. This will increase both the procurement and distribution of millets through PDS which will have a direct impact on nutritional security of the country.

Introduction of millets in public distribution system

Still the country lags far behind in terms of achieving the nutritional security, although the foods security has been achieved. Millets are the naturally available nutritional powerhouse in the country, which performs well in the dryland conditions. Some benefits of introduction of millets in the public distribution system are: i) increased local consumption of millets in rural areas; ii) achieving the nutritional security to address malnourishment and mineral deficiency and the problem of hidden hunger; and iii) making nutrients available at cheaper prices through nutri-cereals. Supply of millets through public distribution system (PDS) will lead to overall development of the dryland agriculture and farmers through assured procurement and steady market price.

Major Focus Areas

Presently the seed replacement rate (SRR) in millets is less than 10 per cent, with the exception of finger millet. The farmers and tribals are inevitably sourcing seed from the informal sector, mostly through own-saved seed or from local markets where grain is sold as seed during sowing time leading to low productivity and yields are stagnant for decades. This is coupled with recognition of production constraints and access and availability of improved cultivars seed, are also of critical importance. By making improved varieties and good quality seed of rainfed crops availability to farming communities can straight away increase yield by 15-20 per cent. Major interventions in the area of research, production, and marketing are required to make available good varieties and machines, generate knowledge on benefits of millets and their efficient cultivation, economical processing, remunerative value-addition and seamless marketing. Some of the crop-wise interventions required as summarized in Table 10.

Table 10. Crop-wise interventions proposed to promote production and utilization of small millets

Intervention\millet	Finger	Foxtail	Kodo	Barnyard	Proso	Little
Genetic enhancement to augment yield potential of cultivars	Y	Y	Y	Y	Y	Y
Identification of suitable cultivars for end products	Y	Y	Y	Y	Y	Y
Nutritional profiling of improved cultivars and millet products	Y	Y	Y	Y	Y	Y
Processing interventions	-	Y	Y	Y	Y	Y
Scaling up of technologies	Y	-	-	-	-	Y
Bioavailability studies	Y	Y	-	-	-	-
Commercialization	Y	Y	Y	Y	Y	Y
Promotion	Y	Y	Y	Y	Y	Y
Policy advocacy	Y	Y	Y	Y	Y	Y

Infrastructure, Capacity Building and Financial Investment

The major bottleneck for popularization of small millets is the lack of processing centres in nearby areas thus leaving farmers with little room for price negotiation with middlemen. Processing clusters need to be established in major millet growing districts to enable farmers realize best price for their produce. Capacity building is a requirement for value addition in millets which can be strategically done at FPO and SHG (self-help groups) levels to make best use of integration with farmers and market access. Newer value addition technologies need to be imparted to these groups based on the target market requirement, through appropriate agencies. At IIMR, such groups and farmers are routinely trained and more than 10 batches from six states have been trained till date.

Case Studies/Success Stories for Improvement of Health and Livelihoods

Bioversity International's programme on minor millets in India

An R&D project of Bioversity International, sponsored by International Fund for Agricultural Development (IFAD), worked to develop the value chains of small millets by contributing to the livelihoods of the rural population through the introduction of a new avenue of economic development, and by augmenting diets with the nutritional grain (Bergamini *et al*., 2013). Additionally, the programme sought to strengthen the conservation of the millets' genetic diversity. The project showed that school children eating millets for lunch had up to 37 per cent higher levels of haemoglobin over students eating white rice. The project put in place the means to access to improved varieties of millet account for improved production, with community seed banks established and growing, in their target rural regions. The project also worked upon providing increased markets for small-scale producers have seen restaurants adding millet-based dishes, and women producing millet-based snacks, which have led to increased consumption and demand. An important recommendation was to add millets in the public distribution system, and initiate a farm diversity programme promoting millet cultivation specifically targeted states with malnutrition.

Reviving millets-based bio-diverse farming system in Kandhamal, Odisha, India

Nirman is an Odisha based NGO, which focuses on restoring the ecosystems with rich biodiversity and has specific intervention in agriculture, natural resource management and governance. In 2011, Nirman undertook a study of millets in the Kandhamal district of Odisha and noted declining trend of millets diversity and areas (Nirman, 2012). Variety of millets and its types declined and some millets such as barnyard millets were lost from the areas. Younger generation did not take interest due to drudgery involved in manual dehusking. Besides, millets prices were not remunerative and millets were not available in the government food schemes such as PDS, Integrated Child Development Services (ICDS) and Mid-day meal (MDM). Therefore, Nirman, aiming at reviving millet cultivation and consumption, tried to develop seed system by development of community seed banks, formed village development committees, conducted village level training programmes for farmers on millet-based mixed farming, SRI and preparation of organic farm inputs, covering 1,383 households in 48 villages, encompassing 2,895 acres farms. Demonstration of millet-based mixed farming through creation of an agro-diversity block, and encouraging heirloom seed conservation through workshops and training programmes for farmers ensured efficient farming of millets and sustainable mechanism to carry on the good job (Mohanty, 2014). The final outcomes were: (i) revival of indigenous tradition of community-based seed banks, (iii) 252 acres of land supplied with indigenous heirloom seeds, and (iii) 552 households from 20 villages have become self-sufficient, without depending on markets for seed inputs.

Future Thrust

Thrust areas for research in small millets are as follows:

- Enhancing the efficiency of hybridization techniques in small millets
- Development of male sterility systems for evolving hybrids in small millets
- Evolving varieties for specific end-uses and increased health benefits
- Optimization of production technology for rainfed and low input situations
- Development of cost-effective processing technology
- Development of technologies to manage important pests and diseases during production and storage
- Basic and strategic research on storage pest problem in finger millet (blast and grain mold).

Conclusions

Pseudocereals are rich sources of protein (12-16%) as compared to cereals (6-13%) with balanced amino acid composition. Lysine content in pseudocereals (~ 6%) is comparable to milk and eggs. Thus, pseudocereals can be of great help in providing balanced nutrition to the malnourished population of the country. While grain amaranth should be incorporated in the PDS and MDM schemes for the benefit of the poor people, cultivation of buckwheat and *Chenopodium quinoa* should be promoted for export to the East Asian countries like Japan and Korea as these crops have a special niche in the diets of East Asian population.

Similarly, cultivation of drought hardy and high temperature tolerant minor legumes moth bean (V*igna aconitifolia)* and horse gram (*Macrotyloma uniflorum*) should be promoted in the arid and semi-arid regions, respectively. While rice bean (*Vigna umbellata*), which is immune to YMV and powdery mildew, can serve as source of resistance for other pulse crops but along with winged bean, it also has the potential to supplement the pulse production in the country, particularly in the Eastern and North-eastern regions.

After years of neglect, small millets are receiving some attention in the country. They are viewed as important for health and wellness of people and can help in preventing many kinds of diseases related to modern life style including obesity and diabetes. The productivity could be increased by more than 50 per cent by developing and adopting improved production practices as demonstrated by the results of frontline demonstrations. Since the seed rate is low for these crops (10-12 kg/ ha) the extra expenditure incurred on seeds of high yielding varieties is not high and could be considered as low-cost technology. In lieu of climate change contingency planning is required in case of excessive, scanty or delayed rains, wherein the versatile small millets would fit in more eminently. The rich diversity of small millet crops has made these crops well suited for contingency crop planning and also to address the issues of climate change. The plasticity exhibited has made them flexible for apparent early as well as delayed planting, cultivation in very low and high rainfall areas, diverse elevations and soil regimes. Intensification of research for genetic improvements and improved farming practices are important to increase and stabilize farm yields and make these crops remunerative.

Intensification of efforts to secure the millet growing areas by offering improved germplasm, more assured market through social, industrial and marketing back up is very much needed now. The farmers who had shifted from millets to other crops are keen to go back to millets cultivation in view of the stable harvests ensured, easy crop production, drought resistance, and eco-friendly production. The higher prices being offered in some parts of the country to small millets duly recognizing their unique nutritional features is making small millets a remunerative proposition *vis-a-vis* with other crop options in the region. Most of the small millet traded internationally is imported by the pet food industry in the developed countries for use as bird feed, which needs to be explored. There is a greater demand for organically produced small millets which can be further stepped up so that the demand for these crops is increased for the benefit of millet farmers.

There is need for the R&D to address to whole range of activities from conservation to final consumption. The interventions made in the area of grain processing and value addition through the development of novel diversified foods especially in finger millet and other small millets are opening new avenues for expanding consumer base, enhanced absorption for food use. However, several challenges specific to region are being faced in many key areas of production to consumption system which need close attention. Rising awareness on the nutrient richness of small millet grains and identifying technology and policy options should receive attention.

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Country Status Report - Iran

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Introduction

Increase of world's population and the limitation in land and water resources, show that more attention should be devoted to find new potentials to secure food and nutrition. Climate changes, in the recent decades are a great threat to world agriculture. The negative effect of increasing temperatures together with the change in precipitation, heat and drought stress causes a significant effect in agricultural systems. Certainly, climate change also negatively affects the diversity and geographical distribution of plants, and consequently the agricultural policy. Of course, the right use of plant genetic resources could alleviate the crisis and ensure more food security.

So, increasing the diversity of high potential plants in the agricultural systems could guarantee the access to more secure sources for food and decrease the risk for hunger. The other motivation is to find and use new food sources for world's increasing population. The limitation in resources shows that attention should be devoted to all aspects including the potential of new species.

Area, Production and Productivity

Iran has various climatological conditions (cold, temperate, subtropical and tropical) that permits to have different crop species commercially. The variation in climatological condition is such that there is a 20°C range in monthly average temperature and a difference from 50 mm to above 1000 mm in precipitation in different locations.

The area under cultivation and production of agricultural crops is around 13 million ha and 94 million tons, respectively. Cereals, pulses, forages and industrial crops are the main agronomic commodities with 79 per cent of area and 55 per cent of production. Horticultural crops (fruits and vegetables) with 21 per cent of area and 45 per cent of production are also important (Table 1).

Many horticultural and agronomic crops could be considered as underutilized. Species like *Berberis vulgaris, Crataegus aronia*, *Eleagnus angustifolius, Rubus idaeus, Allium hirtifolium, A. ampeloprasum* var. *iranicum*, *Rheum ribes, Tragopogon collinus, Falcaria vulgaris, Gundelia tourneforti, Carthamus tinctorius*, *Vigna radiata* and *V. mungo* are native with good diversity, rich germplasm and long history of traditional uses in Iran. Another group of crops like *Ziziphus jujube, Mespilus germanica, Eriobotrya japonica, Cornus mas, Ziziphus mauritiana, Psidium guajava, Manilkara zapotilla, Ribes* sp. and *Carya illinoensis* are introduced crops, but have the potential of being used in higher scale. So, inspite of having low area and production, these crops have potential of being used more extensively in the future for both food security and nutritional value.

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Table 1. Area and production of agricultural crops in Iran

Crop	Crop group	Area (1,000 ha)	Area (%)	Production (1000 ton)	Production (%)
Agronomic Crops	Cereals	8,175	61.19	18,241	19.35
	Pulses	712	5.33	518	0.55
	Industrial crops	432	3.23	13,460	14.28
	Forages	1,076	8.05	19,695	20.89
	Other agronomic crops	157	1.18	180	0.19
Total agronomic crops		10,552	78.98	52,094	55.27
Horticultural (fruits)	Temperate fruits	1,315	9.84	9,928	10.53
	Subtropical fruits	661	4.95	7,106	7.54
	Tropical fruits	10	0.07	188	0.20
Horticultural (vegetables)	Cucurbits	305	2.28	7,607	8.07
	Fruit, salad and tuber crops	518	3.88	17,335	18.39
Total Horticultural crops		2,809	21.02	42,164	44.73
Total		**13,361**	**100.00**	**94258**	**100.00**

Significant Achievements

As mentioned previously many horticultural and agronomic crops are underutilized in Iran now. Among these crops some are especially native with rich germplasm and natural diversity and so, good there exists opportunity for improvement of new cultivars and expansion of their cultivation. Evaluation of the plant materials from some exotic species have been undertaken, with the aim of determining their adaptability too. Therefore, more attention had been given recently to some underutilized crops (UUC) especially in research projects.

Germplasm collection, characterization, evaluation, conservation and documentation: Research activities on UUC are concentrated more on germplasm collection, characterization, evaluation, conservation and documentation. In barbery (*Berberis vulgaris*), there is a rich germplasm both in commercial orchards and as a wild species. Evaluation of the germplasm has been completed in different provinces and superior genotypes are planted for further evaluation in a collection in Birjand, Iran. Among the selected genotypes, some seedless genotypes showed the potential of being released as new cultivars (Zeraatgar, 2014a). In jujube (*Ziziphus jujube*), selection of genotypes and establishment of a collection has been done in Birjand too. The evaluation showed that there are some superior genotypes with good characteristics comparable with commercial cultivars (Zeraatgar, 2014b) (Fig. 1).

For medlar (*Mespilus germanica*) (Padasht, 2018a) and loquat (*Eribotria japonica*) (Padasht, 2018b), selections have been made and superior genotypes are propagated and planted in the collections in Lahijan, Iran. Evaluation are running for characterization and documentation on the both collection (Fig. 2).

The cornelian cherry (*Cornus mas*) is another underutilized species. The selection has been done among the chance seedlings in the traditional orchards and some genotypes were selected, propagated and planted in a collection in Qazvin, Iran (Golmohammadi, 2013).

The Indian ber (*Ziziphus mauritiana*) is also an important species suitable for growing in the topical conditions of Iran. A collection of superior genotypes has been established and evaluations are being undertaken in Balochistan, Minab and Ahvaz. Some other horticultural species such as *Eleagnus angustifolius, Rubus idaeus, Allium haemanthoides, A. hirtifolium, A. ampeloprasum* var. *iranicum*, *Rheum ribes, Tragopogon collinus, Falcaria vulgaris* and *Gundelia tourneforti* are native with very good diversity, rich germplasm, long history of traditional uses and high nutritional value in Iran (Fig.

Fig. 1. *Jujube (left) and barbery (right) selected genotypes in Birjand, Iran (Photos from H Zeraatgar, South Khorasan Agricultural and Natural Resources Research and Education Center, Birjand, Iran)*

Fig. 2. *The young medlar collection in early season (right) and in the stage of fruits ripening in Lahijan, Iran (Photos from MN Padasht, Gilan Agricultural and Natural Resources Research and Education Center, Rasht, Iran)*

3). Meanwhile, some introduced horticultural species like *Psidium guajava, Manilkara zapotilla, Ribes* and *Carya illinoensis* seems to be important for the future too.

Among agronomic crops the species like safflower (*Carthamus tinctorius*), mung bean (*Vigna radiata* and *V. mungo*) and quinoa (*Chenopodium quinoa*) are more important species. The FAO and Iranian quinoa accessions were evaluated in Iranshahr, and some other regions in Iran (Sepahvand and Miri, 2014).

Variety development: In almost all UUC, development of new cultivars is main goal in the programme. So, it is expected that in UUC like barberry, medlar, loquat, cornealian cherry, and Indian ber the research could result to new cultivars in near future.

In agronomic crops like safflower (*Carthamus tinctorius*), there are new released commercial cultivars available. Cultivars like 'Goldasht' and 'Golsefid' are released for warm climates while, 'Padideh', 'Golmehr', 'Soffeh' and 'Isfahan' (Fig. 4) are released for cold and temperate regions (Omidi *et.al.* 2010).

Cultivation practices: The potential UUC in Iran include perennial trees and annual vegetables or agronomic crops. Obviously, the cultivation practices for each group of crops are specific but because of long history of cultivation of these crops on local scale, there are no critical problems for cultivation practices.

Fig. 3. *(a) Allium haemanthoides, (b) A. ampeloprasum* var. *iranicum; (c) Rheum ribes, (d) Tragopogon collinus, (e) Falcaria vulgaris and (f) Gundelia tourneforti (Photos from MR Imani, Vegetable Research Center, HSRI, Iran)*

Processing, value addition and product development: The UUC could be consumed directly, but processing, value addition and product development has the same importance or maybe more in several crops. For example, in agronomic crops, they are used directly as food, while in horticultural crops, that are more numerous as UUC, they are more important for health benefits and to be used as processed and value-added products.

Disease and pest management: The UUC are mainly traditional and local crops and compatible with the conditions of the Iran. But, there are no complications regarding their disease and pest management.

Fig. 4. *Safflower new cultivars Golsefid (left) and Goldasht (right) (Photos from AH Omidi,Oil seed Research Department. Seed and Plant Improvement Institute, Karaj, Iran)*

Challenges and Opportunities

Limitation in funding is the main challenges for UUC. The government supports usually a limited numbers of plants called strategic crops; the same needs to be provided to important UUC. The opportunities for UUC are their nutritional value for enriching the food basket.

Marketing, Commercialization and Trade

Some of the UUC have a good local market in Iran and the consumer know the products well. It is, therefore, expected that by increasing their production, the market will be available in national level too.

Strategies Adopted to Harness their Potential

Unfortunately, there is no adopted appropriate strategy yet and the Ministry of Agriculture and other public institutions have to consider and support the important UUC in the national programmes.

Major Focus Areas

- Research and development (R&D) for germplasm collection or introduction, germplasm evaluation and characterization and improvement of new cultivars
- Development of practical methods for increasing the production
- Focusing on processing, value addition and product development
- Using the public media for extension of the potential of UUC

Infrastructure, Capacity Building and Financial Investment

- Development of new and efficient infrastructure using public funds, especially for processing, value addition and product development for UUC
- Encouraging the private sector for financial investments
- Providing the technical assistance and training to improve the capacity

Future Thrust

Entry of UUC as new crops with considerable production that covers part of agricultural products and affects significantly the population, nutrition and health.

Conclusions

- Supporting the R&D in breeding, production management and post-harvest and processing of UUC
- Including the important UUC in national agricultural development programmes
- Development of new and efficient infrastructure for UUC
- Focusing more on processing, value addition and product development
- Providing the technical assistance and training
- Use of pubic media for extension of UUC

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Country Status Report - Sri Lanka

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Introduction

Sri Lanka is an island, which is situated in the Indian Ocean to the South East of India and lies between 5° 55′ and 9° 51′ North longitute and 79° 41′ and 81° 53′ East latitude. The total land area of the island is 6.5 million ha. Population is estimated to be 21.2 million with an annual growth rate of 1.1 per cent (CBSL, 2016). The contribution to the gross domestic product (GDP) by agriculture is estimated to be 7.1 per cent and employment in the agriculture sector is 27.1 per cent (CBSL, 2016). Of 6.5 million ha total land area of the island, 2.7 million ha are cultivable.

Sri Lanka is divided into three major zones on the basis of annual rainfall *viz.* wet - 1.54 million ha (>2,000 mm), intermediate - 0.85 million ha (1,000-2,000 mm) and dry- 4.17 million ha (<1,000 mm) zones (Fig. 1). The wet and intermediate zones are further categorized into low, mid and up-country regions based on the elevation. The low country is situated at elevation between 0-300 m above mean sea level (msl), while mid country is considered as the area between 300 m and 900 m elevation. The upcountry region of Sri Lanka is the area above 900 m elevation. Based on rainfall, elevation and soils, three major agro-climatic regions (wet, intermediate and dry zone) are further subdivided into 24 agro-ecological regions.

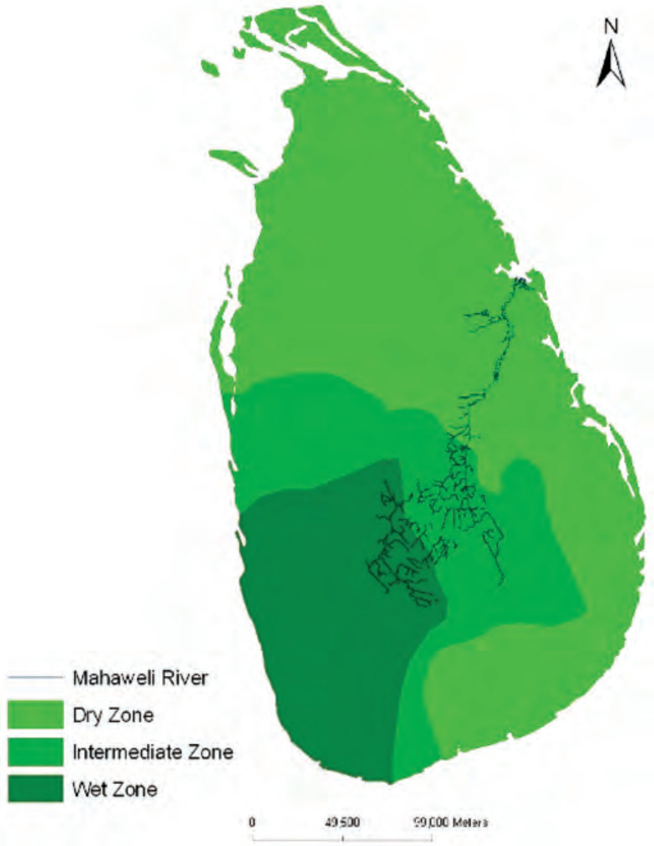

Fig. 1. *Major zones in Sri Lanka*

There are two main cropping seasons namely *maha* (North-East monsoon; wet season from September to February) and *yala* (South-West monsoon; dry season from March to August). Due to availability of water the *maha* is considered as the major cropping season of the country. The mean annual rainfall in Sri Lanka varies from 2,500-5,000 mm in the

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South-West of the island, while in the North-West and South-East annual rainfall is less than 1,250 mm. Rainfall over most parts of the country follows a bimodal, seasonal pattern. The minimum and maximum air temperature varies from 18.6-27.0°C in the hill upcountry wet zone (UCWZ) from 24.4-31.9°C in low country dry zone (LCDZ). Sri Lanka is an agricultural country with a plantation and domestic agriculture sub-sectors. Plantation agriculture involves the large-scale cultivation of tea, rubber and coconut which are located mainly in the wet zone, and the intermediate zone of the country covering an area of around 0.8 million ha. Non-plantation domestic agriculture sector represents nearly 1.8 million rural farmers cultivating around 0.9 million ha. Paddy is the main crop cultivated in around 0.75 million ha in the lowlands whereas other field crops, fruits, vegetables etc. are grown in the uplands.

Soils in Sri Lanka

Depending on morphological, physical and chemical features, various types of soils can be recognized in Sri Lanka. The major ones are lateritic soils, red earths, and alluviums covering over 90 per cent of Sri Lanka. The rest consisting only of saline soils and peat, are of limited occurrence. Thirteen great soil groups have been identified in Sri Lanka (Panabokke, 1996).

Major Production Constraints

Water shortage, soil erosion, fertility depletion, decrease of organic matter, acidification, soil compaction, salinization, etc. have been identified on the main production constraints in Sri Lanka (Wijewardena *et al.,* 1999). Some of these constraints are aggravated with accelerated soil erosion taking place in rainfed upland farming. Due to the soil erosion soils have shallow depth and significantly low organic matter as well as low plant nutrient contents (Nayakekorala and Prasantha, 1996). Land resource in the dry zone of Sri Lanka utilized for agriculture tends to deteriorate and declining its production potential. In addition, due to the low rainfall in the dry zone of Sri Lanka adopting moisture conservation methods are also important particularly in upland cropping systems. Since, other field crops (OFC) are mainly grown in the dry zone of Sri Lanka, improvement of soil fertility and moisture conservation measures should have to be adopted to increase the production of these crops.

Area, Production and Productivity

During the ancient period every village was self-sufficient in food, thus the entire country was self-sufficient in the food crop sector. However, a drastic change in this position occurred with the influx of Western nations to Sri Lanka and with the introduction of the plantation crops. As a result, many local, indigenous and underutilized crops (UUC) were neglected. Extent, production and average yield of some UUC are shown in Table 1.

The UUC are the plant species that are traditionally used for their food, fiber, oil or medicinal properties. However, those species have under-exploited potential to ensure food security, nutrition, health, income generation and environmental services. They have local or regional importance, but generally lack national recognition and appreciation. The potential role of UUC species are (i) contribution to local food security and nutrition and (ii) buffering against the consequences of climate change and reductions in agricultural biodiversity. Table 2 lists some of the important UUC in Sri Lanka.

There are a large number of underutilized fruit species growing naturally in various parts of the country, which have potential for contribution to food security, health and nutrition, income generation and environmental services. Many other species that grow in home gardens, wastelands and in the wild, could be a good source for a number of benefits, particularly to the rural communities.

Table 1. Extent, production and average yield of UUC in 2015

Crop	Extent (ha)	Production (mt)	Average yield (mt/ha)
Underutilized other field crops			
Kurakkan	6,950	8,916	1.28
Sorghum	72	101	1.40
Soybean	6,383	11,254	1.76
Gingelly	17,841	13,285	0.74
Underutilized vegetable crops			
Ash plantain	7,654	85,085	11.12
Ash pumpkin	923	8,721	9.44
Bitter gourd	4,259	43,507	10.21
Brinjal	10,832	123,632	11.41
Snake gourd	2,718	44,055	16.21
Luffa	4,464	46,681	10.46

Source: AgStat (2016)

Table 2. List of important UUC in Sri Lanka

Crop category	Name
Cereals	Finger millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*) and proso millet (*Panicum miliaceum*)
Pulses	Black gram (*Vigna mungo*), cowpea (*Vigna unguiculata*) and horse gram (*Macrotyloma uniflorum*)
Oilseeds	Groundnut (*Arachis hypogaea*), soybean (*Glycine max*) and sesame (*Sesamum indicum*)
Vegetables	Long bean (*Vigna unguiculata*), pumpkin (*Cucurbita maxima*), ridge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantica*), snake gourd (*Trichosathes anguina*), Ceylon spinach (*Basella alba*), *gotukola* (*Centella asiatica*), *mukunuwanna* (*Alternanthera sessilis*), *kankung* (*Ipomoea aquatica*), *kathurumurunga* (*Sesbania grandiflora*), *thampala* (*Amaranthus* spp.), drumstick (*Moringa oleifera*), kohila (*Lasia spinosa*) and okra (*Abelmoschus esculentus*)
Fruits	Durian (*Durio zibethinus*), *nelli* (*Phyllanthus emblica*), wood apple (*Limonia*), *beli* (*Aegle marmelos*), *lovi* (*Flacourtia inermis*), *veralu* (*Elaeocarpus serratus*), jackfruit (*Artocarpus heterophyllus*), tamarind (*Tamarindus indica*), *goraka* (*Garcinia quaesita*), guava (*Psidium guajava*), annonas (*Anona* spp.), *Citrus* spp., mangosteen (*Garcinia mangostana*), *biling* (*Averrhoa bilimbi*), *gaduguda* (*Baccaurea motleyana*), *rata nelli* (*Phyllanthus acidus*), *uguressa* (*Flacourtia indica*), *lovi* (*Flacourtia inermis*) and sapodilla (*Manilkara zapota*)
Tubers	Sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), *innala* (*Plectranthus rotundifolius*) and dioscorea yams (*Colocasia esculenta* and *Xanthosoma* spp.)

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Biodiversity of Sri Lanka is particularly blessed with a wide range of ecosystem diversity, which is ideal for growing several crops. In Sri Lanka, the Horticultural Crop Research and Development Institute (HORDI), Field Crop Research and Development Institute (FCRDI) and the Plant Genetic Resources Centre (PGRC) of the Department of Agriculture (DOA) promote plant genetic resources (PGR) of underutilized crops and work on germplasm collection, and development of production and processing technologies with several local and international organizations. Community Development Centre has conducted a successful programme on enhancement of conservation and use of underutilized tuber crops through community participation.

Sri Lanka has been identified as one of the countries in Asia with a very high degree of biodiversity. Genetic erosion of cultivated indigenous varieties and wild relatives of crops has been occurring rapidly in natural habitants during the last century. Several programmes have been implemented towards *in situ* conservation of PGR. An atlas of 35 maps of collection sites of 46 crop species has been published, based on the information collected by PGRC, which is the focal point of national programme on *ex situ* conservation. Field gene banks of a number of organizations also have effective *ex situ* conservation programmes.

A large number of new crop varieties have been developed by the DOA working as nodal organization for UUC in Sri Lanka. There are various projects and strategies, multilateral agreements and mechanisms for institutional integration/coordination constituting main instruments that addresses various aspects of PGR conservation and use in the country. There are substantial amount of laws enacted to conserve under-utilized food crops in Sri Lanka. Many of these are directly or indirectly relevant to the conservation and substantial use of biological diversity. In Sri Lanka, PGRC has developed bi-lateral material transfer agreements (MTA) for exchange of PGR with any interested parties on mutually agreed terms and conditions. In the recent past compiling directory with species, varietal and clonal collection and establishing a set of guidelines were prepared by government organizations, private sector organizations, and NGOs.

Variety development

Minor cereals and millets: With the rapid advances that have been made in rice production, more attention is now being concentrated on the improvement of finger millet, sorghum, little millet, kodo millet, foxtail millet and proso millet. Promising short aged varieties of finger millet (2.5 - 3 months), higher yielding and more adapted to the short rainfall periods and poorly irrigated areas of the dry zone are in the final stages of testing prior to release.

Grain legumes: Pulse improvement has figured prominently in the research programme because this class of crops in the main source of low-cost protein in the national diet. First objectives were directed at improving the production potential of local varieties and developing determinate to semi-determinate short-aged types (2.5 - 3 months) to suit the weather conditions obtaining in the dry zone. Outstanding varieties which have stood the test of time are Arlington and MI 35 in cowpea and MI-1 black gram.

Oilseed crops: The two most important oilseed crops are groundnut (peanut) and sesame (gingelly). Several improved bush varieties of groundnut of three month duration have been recommended over the last three decades. Experiments are in progress to identify large-seeded and three-seed types which have export potential. MI 1 (black seed) and MI 3 (white seed) are the two recommended sesame varieties.

Root and tuber crops: Improved varieties of cassava (MU 51 and CMC 84) and sweet potato (Cinchi, B1 and C26) have been released for cultivation.

Fruit crops: Sri Lanka has over 60 varieties of underutilized fruit crops. The DOA has collected various types of underutilized fruit crops and initiated seed and planting material production programme. In recent past, Sri Lanka has given much attention to the underutilized fruit crops than any other crop in this group.

Cultivation Practices

The DOA as a main responsible institution for almost all UUC for food, has developed technologies in relation to them. Agronomic practices on these crops are well-documented in a "Techno

Guide" published by the DOA. In addition, leaflets were also prepared and distributed among farming community to disseminate the correct cultural practices including pest and disease control of UUC.

Processing, Value Addition and Product Development

In Sri Lanka, the DOA, Institute of Postharvest Technology (IPHT), and the private sector have involved in product development and processing technologies. Some supermarkets have established forward contracts with small growers of underutilized vegetables, mainly for leafy vegetables. This has facilitated their marketing and making them available for the consumers in the cities. Similarly, such activities will promote sustainable production to meet the increasing demand for direct consumption and industrial uses. The DOA, IPHT and the private sector have also initiated many programmes for value addition in UUC. The production of some species such as *gotukola* and bitter gourd into tablet form are the other examples. In addition, private sector has produced moringa capsules and dried leaf powder and released to the local and international markets. Many of these underutilized vegetables are traded in the rural markets, and presently in the supermarkets in urban areas.

Some recent trends in underutilized fruit and vegetable processing :

- By using new heating (e.g. UHT, microwave) and freezing techniques combined with new packaging materials and technologies
- Canned fruits and vegetables, fruits, crisps
- Packed fruits and vegetables

Due to the commercialization of few crops the entire country is mainly depend on handful of crop species neglecting large number of vegetables, fruits and other crop species with high nutritional and medicinal values which were traditionally in the past. The processing of underutilized fruits is also a neglected area, which needs attention. As these are not grown extensively, the yields are inadequate; hence manufacturers are reluctant to invest on processing industries. In other words, fruit production is too low and inconsistent to operate and sustain the commercial level processing industries. As the production is not spread throughout the year, facilities are needed to store the produce for regular supply of produce for processing. In this scenario, it would entail the development of low-cost processing technologies for the underutilized fruit crops. Sometimes the demand for possessed products is less in the local market, and in such situations, the marketing of fresh products has to be encouraged.

Nutrition Value and Health Benefits

The underutilized vegetable species are important for food and nutritional security, healthy and productive lifestyle, income generation and poverty alleviation (Kalb and Lumpkin, 2006). One of the sustainable strategies would be to promote underutilized vegetables and fruits to overcome micronutrient deficiencies aiming at the poor segments of society to diversity diets using their own resources. It is suggested that vegetables are the most sustainable and affordable dietary sources of micronutrients and fiber. This will also empower the households to access variety of fresh foods rich in nutrients and diversify the food basket. The main argument for the promotion of underutilized vegetables is the supply of dietary fiber, essential vitamins and minerals which are deficient in the commonly consumed commercial types of vegetables. There is an array of evidence in this regard that underutilized vegetables contain minerals and vitamins (Table 3) required for a balanced diet. The use of these vegetables could diversify the diets, improve nutrition, increase income and improve the wellbeing of the people.

The food base of the rural populations in Sri Lanka, especially those living in the marginal areas has become narrower leaving them to food shortages and nutrient deficiencies. The regions most affected are the poverty prevalent areas such as Moneragala, Badulla and Hambantota districts

Table 3. Vitamins and minerals in different underutilized crops

Micronutrient	Quantity	Crop
Vitamin A	> 2,000 IU	Amaranth (*thampala*), spinach, kale, kangkung
B vitamins	> 17 mg	Legumes, taro, horse radish leaves
Vitamin C	> 20 mg	Amaranth, squash, kangkung, bitter gourd
Calcium	> 20 mg	Amaranth, kangkung, spinach, soybean
Iron	> 3 mg	Amaranth, kangkung
Phosphorus		Spinach
Iodine		Okra, asparagus (*hathawariya*)
Protein		Soybean, cowpea

Source: Chadha and Oluoch (2002)

which record poverty levels as high as 30 per cent. The wild and weedy species which were used in the past has disappeared due to the changes to land use systems, use of improved hybrid seeds and rapidly changing food habits. The lack of knowledge on food values and cooking methods to minimize nutrient losses during cooking is also rapidly disappearing. Currently, some of the underutilized vegetable are becoming popular both among the rural and urban populations due to their therapeutic and food values. There is a growing public awareness regarding the value of these green leaves as providers of dietary fiber, vitamins and minerals essential for maintaining human health. Some specific examples of these are the use of *gotukola* (*Centella asiatica*to) retain memory and bitter gourd (*Momordica charantica)* as cure for diabetes. Chadha and Oluoch (2002) reported several examples of vegetables rich in vitamins and minerals in Asian countries (Table 3). Therefore, these crops are important sources of nutrients for overcoming vitamin and micronutrient deficiencies of rural populations in Sri Lanka and elsewhere. In general, UUC are recognized for their health beneficial effects such as anti-diabetic, anti-tumerogenic, atherosclerogenic effects, anti-oxidant and anti-microbial properties due to low glicimic index. Crop like bitter gourd is considered to have hypoglycemic effect (Fonseka *et al.,* 2006). Many of the underutilized fruits have known medicinal properties (Dahanayake, 2015) and have been used by the villagers in traditional medicine. In addition, when absorbed by the body the beta-carotene in sweet potatoes is converted into vitamin A, a powerful antioxidant.

Challenges and Opportunities

The major challenges to popularize UUC are low economic value, low adoptability/ acceptability by farmers, poor consumption by young generation, lack of value addition, low soil fertility management practices adopted by farmers, lack of information available on nutritional value of underutilized crops, lack of improved varieties, quality seed and planting materials. Major opportunities of underutilized crops are adoption to adverse environmental conditions, low response to chemical fertilizers, high nutritional value and medicinal and cultural values.

Marketing, Commercialization and Trade

Much effort has been made by policy makers, government organizations, private sector and growers for value chain development in UUC. Mostly fresh green leaves of UUC are traded as commercial products even in supermarkets. The prices of some green vegetables are equal or sometimes higher than that of exotic greens such as lettuce. Most of underutilized fruits are unattended but produce a large quantity of fruits in the season. The villagers often collect and sell them in the village fairs or supply them to the collectors. Some of these are processed by small entrepreneurs into jam, jelly and ready-to-drink products and sold in groceries and supermarkets. As they are novel products with herbal properties, they fetch high prices in the local markets, and the demand for these is increasing in the export markets. Some of these have become domesticated to some extent, but many remain underutilized

Strategies Adopted to Harness their Potential

Strategies adopted are establishment of demonstrations and model gardens, ensure the quality seed and planting materials production, women entrepreneurship development, promoting the consumption of product developed, promoting new technologies and undertaking research, value addition, undertaking private sector involvement, encourage self-seed production, establishment of production villages, establishment of sales and food preparation outlets in urban areas where customers have easy access for a healthy meal, promote home gardens with underutilized crops, use effective extension methodologies, conducting "Farmer Week Exhibitions" and "Food Festivals".

Introduction of "Hela Bojun" sale centers by DOA in recent past which is set up for preparation of local food using various raw materials of UUC has significantly contributed their popularization. At present, there are several "Hela Bojun" outlets established throughout the country. Under this concept people get a chance to taste and familiarize food prepared with UUC (DOA, 2016). The women of Female Farm Organizations (FFO) are handling the 'Hela Bojun' sale centers. "Hela Bojun" concept which was recently started could be considered as a success story for improvement of health of public and livelihoods of farmers and members of FFO. In addition, establishment of "Healthy Food Restaurant" by the Food Promotion Board of the MOA has contributed to promote underutilized food crops among the public and promote local food challenging the food culture such as fast food takes away, etc.

Major Focus Areas

Major focus areas are collection and conservation of germplasm, purification and quality seed and planting material production, production of high yielding varieties, establishment of gardens and fruit villages, identification of new areas for cultivation, integrated pest management, organic crop production systems, value addition and post-harvest technologies, marketing, nutritional and wellness, self-employment programme for women to popularize use of nutritious herbal food and beverages.

Infrastructure, Capacity Building and Financial Investment

The DOA is well equipped with necessary infrastructure facilities to develop even UUC. It has PGRC, HORDI, FCRDI, Fruit Research and Development Institute, Seed Certification and Plant Protection Centre (SCPPC), Seed and Planting Material Development Centre (SPMDC), Extension and Training Centre, and publication unit to cater for research and development activities of the agriculture sector. In addition, DOA has appointed officers for major crops including underutilized crops to look after research and development activities as "Crop Leaders". Similarly, IPHT is responsible for value addition and post-harvest technologies and Food Promotion Board established under the MOA is catering for marketing, promoting local, traditional and underutilized food production and use.

The Extension and Training Centre of the DOA is regularly conducting capacity development programmes through In-Service Training Institutes (ISTI) situated throughout the country. In addition, extension officers attached to 554 "Agrarian Service Centers" are also conducting various capacity building programmes in relation to all food crops including underutilized crops. Annually, funds are allocated by the treasury for respective institutions as capital, recurrent and special projects to conduct research and development activities in the agriculture sector. Similarly, the Ministry of Agriculture provided funds to increase the production of fruits over the years and also increase value addition by establishing fruit processing units.

Future Thrust

There is dearth of information on the UUC in Sri Lanka. Due to their emerging importance, well organized research is needed and should be included in the national research agenda. Some of research needs are policy research, management of genetic resources, production of high yielding varieties, agronomic studies, post-harvest studies, product diversification, value addition, marketing, evaluation for nutrition value and health benefits and baseline surveys. In this regard, networking could be considered as an immense value in promoting underutilized crop commodities. It will be ideal for networking to utilize the available resources for the domestication and development of UUC.

Priority UUC Requiring R&D

- Cereal crops: finger millet (*Eleusine coracana*) and sorghum (*Sorghum bicolor*).
- Pulse crops: Cowpea (*Vigna unguiculata*) and black gram *(Vigna mungo).*
- Oilseed crops: groundnut (*Arachis hypogaea*), soybean (*Glycine max)* and sesame (*Sesamum indicum*).
- Vegetables: drumstick (*Moringa oleifera*), Ceylon spinach (*Basella alba*), *thampala* (*Amaranthus* spp.) and *kohila* (*Lasia spinosa*).
- Fruits: wood apple (*Limonia*), *beli* (*Aegle marmelos*), *veralu* (*Elaeocarpus serratus*), tamarind (*Tamarindus indica*), *goraka* (*Gracinia quaesita*) and *uguressa* (*Flacourtia indica*).
- Tuber crops: *innala* (*Plectranthus rotundifolius*) and dioscorea yams (*Colocasia esculenta* and *Xanthosoma* spp.)

Conclusions

In Sri Lanka there is a high potential for cultivating underutilized crops for the domestic and export markets. The DOA, the main organization responsible for R&D activities in relation to UUC, has initiated a number of activities to develop this crop category. It has collected germplasm of various UUC and initiated characterization, evaluation, conservation of PGR at PGRC. In addition, a large number of crop varieties and various technologies have also been developed by the DOA. There are several challenges that are limiting the development of this crop sector. However, consumption of wide range of UUC is getting prominence in Sri Lanka over the years due to nutritional and health benefit of these crops when compared to improved crop varieties. However, more research and scientific investigation is needed to explore their properties. As a result, the MoA has released sufficient funds in recent past to develop the UUC sector in Sri Lanka. "Hela Bojun" concept, initiated by the DOA has shown tremendous impact on popularization of food preparations of underutilized crops among the general public. In Sri Lanka, government and private sector are involved in product development and processing technologies. However, the processing of these crops is also a neglected area, which needs attention.

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Country Status Report - Nepal

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Introduction

Nepal is a land locked country located between 26°22´ to 30°27´North latitude and 84°12´East longitude in South Asia. The country extends over a length of 885 km from East to West and width 193 km from North to South. The total land area is 147,181 km^2. Nepal is predominantly mountainous country with elevation ranging from 64 to 8,848 m, and has the highest peak in the world. The physiographic zone is mainly divided into mountain, hill and *terai* (flat land). Nepal is safe heaven on earth for many plants and crop species. The major cereal crops grown in the country are rice, maize and wheat followed by barley, finger millet and buckwheat. Other minor crops are grain amaranth, foxtail millet, proso millet. Crops like barley, finger millet, buckwheat, grain amaranth, foxtail millet and proso millet, sorghum, beans, gram, taro, yam, many genetic resources (wild vegetables, fruits and medicinal plants) native to mountain agro-ecology (Sah, 2002 and Padulosi *et al.,* 2011) are set into the category of neglected underutilized species (NUS) despite its huge nutritional value (Gopalan *et al.,* 1989). In Nepal, underutilized crop (UUC) species are traditionally used for food, fibre, fodder,medicinal values etc., have local or regional importance but generally lack national recognition and appreciation. However, these crop species serve to ensure food security, nutrition, health, income generation and environmental services in Nepali mountain agro-ecosystem.

Area, Production and Productivity

Finger millet (*Eleusine coracana*): It is the fourth most important food crop in Nepal. The total cultivated area of the crop is 266,799 ha, of which more than 77 per cent area lies under mid-hills followed by 20 per cent in mountains and 3 per cent in *terai*. Total grain production has been 302,397 million tons with productivity of 1.133 t/ha. It is dominantly grown under maize-millet relay system in mid-hills of western, central and eastern regions where as in the hilly areas of mid and far western region, it is grown as mono crop.

Barley (*Hordeum vulgare*): It is an old, winter crop in mountain regions of Nepal. There is large amount of diversity, and is considered to be the center of diversity of barley (Witcombe and Gilani, 1979). It is the fifth crop among the cereals in Nepal. The total area of barley cultivation in Nepal was 28,361 ha, with production and productivity of 32,801 million tons and 1.157 t/ha respectively (MOAD, 2016).

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Recent data shows that area and production of barley is decreasing in *terai* and stagnant in hills and mountains. It is the staple food mainly in the hills and high land regions in the western part of the country. It is an important crop in these regions because it is grown during winter season and matures approximately one month earlier than wheat which can allow growing next crop in time. In alpine region, barley is grown as spring crop taking up to ten months. It is grown from *terai* up to an elevation of 4,000 m. It is grown in marginal land by marginalised farmers. It provides nutritional and food security under the harsh environmental conditions in high-hills of Nepal (Aase *et al.,* 2009).

Buckwheat (*Fagopyrum* spp.): The total area of buckwheat cultivation is 10,842 ha of land with production and productivity of 11,641 million tons and 1.07 t/ha, respectively. It is one of the important food crops for the people living in the hills and mountains of Nepal. Sweet/common (*Fagopyrum esculentum* Moench) and bitter/tartary types (*Fagopyrum tataricum* Gaertn) buckwheat are under cultivation in Nepal. It is grown as early maturing (2-3 months) catch crops all over Nepal except high mountains for grain and vegetable purpose. Common/sweet type buckwheat is a cross pollinated crop and can be grown during winter season in *terai* and autumn season in hills (2,200 masl). Tartary type is grown as summer season crop in high hills, autumn and spring season crop in mid hills. Tartary/bitter buckwheat is self-pollinated crop with large seeds. In general, tartary types are more predominantly cultivating mainly in the high hills (2,000-3,000 masl) than sweet/common type.

Grain amaranth (*Amaranthus* spp.): It is a multipurpose crop with good potential for exploitation as grain, vegetable and fodder. Considerable variations have been observed in nutritional constituents. Seed protein content varied from 8.86-19.6 per cent (Mishra *et al.,* 1985). It is a good source of high protein with high lysine and a good balance of other amino acids. It is cultivated in Nepal as a vegetable and grain purpose. However, area, production and productivity have not been documented yet.

Other millets (proso millet, foxtail millet, sorghum): Area, production and productivity of proso millet, foxtail millet and sorghum are poorly documented. These crops are mostly grown in mountain, mid and far western regions of the country.

Significant Achievements

Germplasm Collection, Characterization, Evaluation and Documentation

Systematic collection, characterization, evaluation and documentation of germplasm enhance the use of genetic resources by plant breeders. Germplasm has been collected particularly from different parts of the country. In the past, exotic germplasm of finger millet and buckwheat were received from India and Japan, respectively. Some of the barley germplasm has been received from ICARDA. Descriptors, normally for agro-morphological characterization, are available. The involvement of multidisciplinary team for characterization and evaluation is limited. National Agriculture Genetic Resource Centre (NAGRC), Khumaltar under Nepal Agricultural Research Council (NARC) has been doing considerable work since several years. Also, Hill Crop Research Program (HCRP), Dolakha under, NARC, partly collected and receive the germplasm from NAGRC for characterization and evaluation for use in breeding programme. Till date, large number of germplasm of different neglected and underutilized species (NUS) are collected and documented in Nepal by NARC which is shown in the Fig. 1.

Variety Development

Crossing and hybridization of elite germplasm is an urgent work to develop new varieties. Hill crops Research Program (HCRP), Dolakha has developed and recommended the varieties through introduction of exotic germplasm and conventional breeding method. Most of the varieties were developed and released through mass or pure line selection of local landraces and very few of them from exotic germplasm. Hybridization (pedigree/selected bulk method) in barley is ongoing. There is hardly any biotechnology and molecular breeding methods used in these crops. Recently mutation breeding in finger millet was initiated. Evaluation of genotypes received from mass or pure

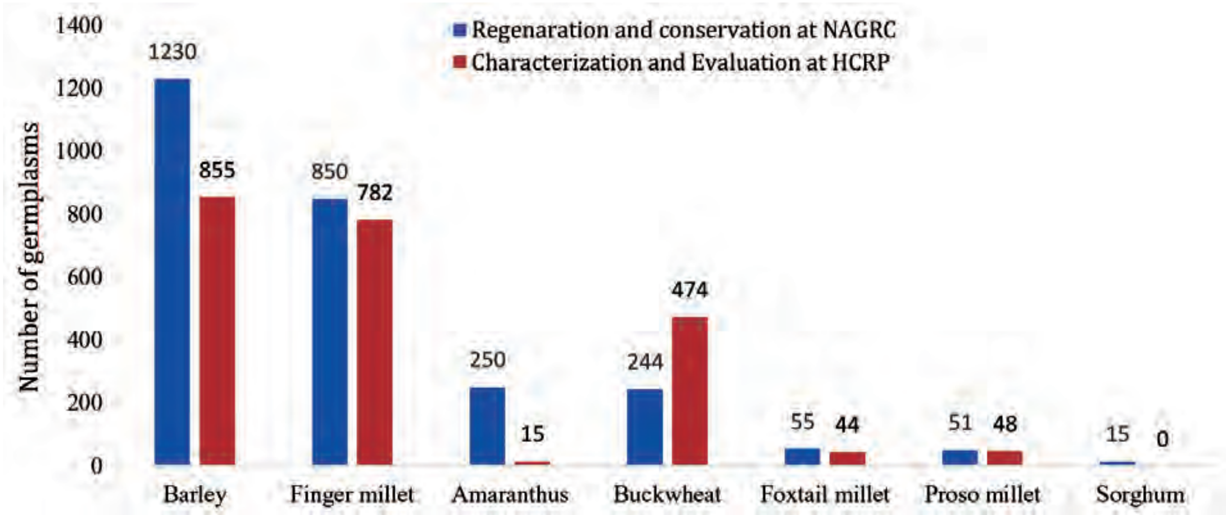

Fig. 1. *Number of germplasm of NUS collected, characterized, evaluated and conserved at NARC*

(Note: Research and varietal development activities on foxtail millet, proso millet and grain amaranths were re-initiated few years back after loss of germplasm)

line selection method and pedigree/bulk method are tested on station and multi-location evaluation (IET, CVT) in the form of replicated yield trials, biotic and abiotic stress evaluation nurseries and on-farm adaptive (FFTs, PVS, FATs, large plot demonstration etc.) studies are commonly used. Nutrient analysis and organoleptic test is done in promising genotypes. Different stakeholders visited on station as well as on-farm trials. Based on the feedback from different stakeholders, promising genotype is recommended for Variety Release Committee of National Seed Board, Nepal. Till date five varieties of finger millet, six varieties of barley and one variety of common/sweet buckwheat have been released for different ecological domains (Table 1).

Table 1. Varietal development status of NUS in Nepal by NARC

Crop	Variety name	Origin	Released year (AD)	Maturity days	Recommended domains	Grain yield (t/ha)
Finger millet	Dalle-1	India	1980	125 151	Inner *terai* to mid-hills	3.3
	Okhle-1	Nepal	1980	154 194	Mid-High-hills	3.3
	Kabre Kodo-1	Nepal	1989	167	Mid-hills	2.3
	Kabre Kodo-2	India	2015	152	Mid-hills	2.5
	Sailung Kodo-1	India	2015	155	High-hills	2.4
Barley	Solu Uwa	Solukhumbu-Nepal	1990	177	High hills	1.9
	Ketch	Introduced varieties and not conserved	1974	112	Terai, Inner terai	2.5
	CI-10448		1973	125	Terai, Inner terai	2.6
	Galt		1973	157	Terai, Inner terai	2.3
	HBL-56		1973	135	Terai, Inner Terai	3
	Bonus	Sweden	1973	162	Kathmandu valley	3.6
	Muktinath (Coll#112-14)	Mustang-Nepal	Proposed	155	Mid-high hills	2.5
Common buckwheat	Mithe Phapar-1	Japan	2015	72	900- 1700 m mid hills	1.2
Tartary buckwheat	Acc#2223-1	Nepal	Proposed	79-86	Mid-high hills	1.2-1.8
	Acc#2227-1	Nepal	Proposed	79-85	Mid-high hills	1.4-1.7

Cultivation Practices

These crops are grown in terraces and small valleys of marginal and low fertile land. Traditional farming system is common in these crops, where farmers cultivate these crops in residual moisture. Farmers save their own seed and repeatedly use these seeds. They don't use chemical fertilizers and pesticides due to poor access to markets, road extension services, etc. HCRP, Dolakha has developed improved cultivation practices. However, due to poor access of extension services and farmer's awareness, improved technologies are less adopted in these crops. Improved cultivation practices of NUS are given below (Table 2).

Table 2. Major cultivation practices of NUS

Crops	Tillage	Fertilizer rate (NPK kg/ha)	Spacing-cm (RR*PP)	Seed rate (kg/ha)	Irrigation	Weeding	Trial average yield (t/ha)
Barley	2 time harrowing and leveling	45:30:30	25*continuous	100	Thrice	Twice	3.13
Finger millet	Mono-2 time harrowing and leveling	30:30:00	10*10	10	Rainfed	Twice	4.31
	Relay- puddling only						
Proso millet	2 time harrowing and leveling	Not standardized	25*10	8-10	Rainfed	30 DAS	2.03
Foxtail millet	2 time harrowing and leveling	Not standardized	25*10	8-10	Rainfed	30 DAS	1.52
Buckwheat	Harrowing and leveling	30:30:0	25*Continuous	50	Rainfed	-	1.5
Amaranths	2 time harrowing and leveling	45:30:20	50*40	1	Rainfed	Twice	Veg.- 10 and Seed- 0.73

Processing, Value Addition and Product Development

There is no large processing industry for product development of these crops. Farmers use most of the production for their home consumption and only some amount goes to local markets. Still, some products are developed from these underutilized crops (UUC) (Fig. 2). Buckwheat and finger millet flour 40 per cent and wheat flour 60 per cent is good combination to develop value added products. Food Research Division (FRD), Khumaltar under NARC developed noodles, cakes, biscuits, namkins from finger millet and buckwheat flour. Similarly, biscuit cakes are developed from proso millet, foxtail millet, amaranths and sorghum (FRD, 2016). These products are preferred by consumers particularly hotels of Pokhara, hospitals, and intellectual persons. Bakeries, small entrepreneurs, cooperatives, progressive farmers are trained regularly to develop value added products and food diversification by HCRP, Dolakha (HCRP, 2016).

Disease and Management

Some of the common pests occurring in major UUC in Nepal are given below:

- Finger millet: Blast (*Pyricularia grisea*), Cercospora leaf spot (*Cercospora eleusine*) and sheath blight (*Rhizoctonia solani*) (Fig. 3).
- Barley: Yellow rust (*Puccinia striiformis f. sp. hordei)*, Powdery mildew (*Blumeria graminis f. sp. hordei)* and Barley stripe (*Helminthosporium gramineum)* (Fig. 4).
- Buckwheat: Damping-off and Root rot *(Rhizoctonia solani, Pythium* spp., *Fusarium* spp.), Powdery mildew (*Erysiphe polygoni*) and Botrytis leaf blight (*Botrytis cinerea*) (Fig. 5).
- Amaranths: Cercospora leaf spot (*Cercospora canescens*) and Anthracnose (*Colletotrichum gloeosporioides*) (Fig. 6).

Fig. 2. Processing, value addition and product development of NUS in Nepal

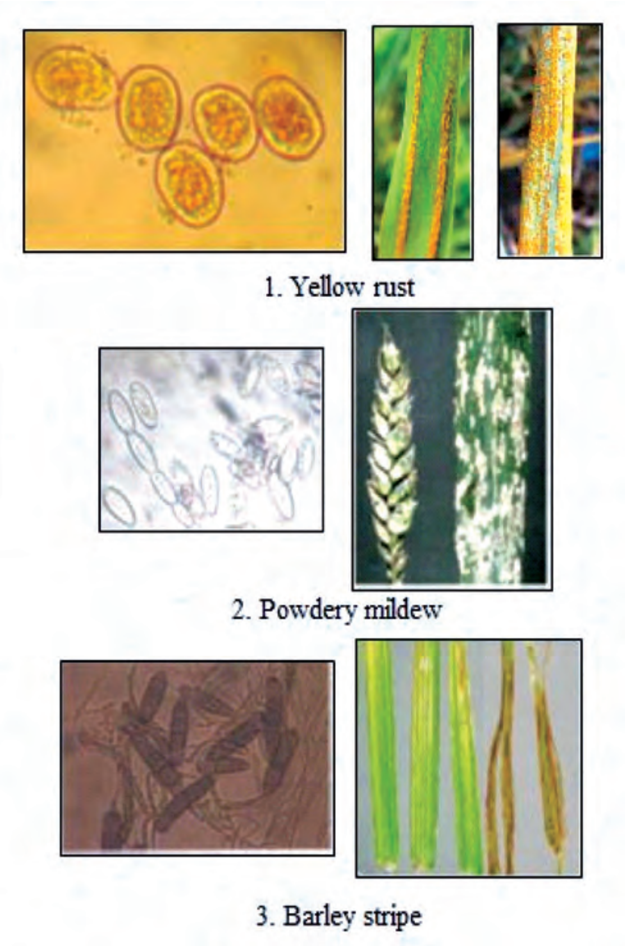

Fig. 3. Finger millet diseases (Manandhar et al., 2016)

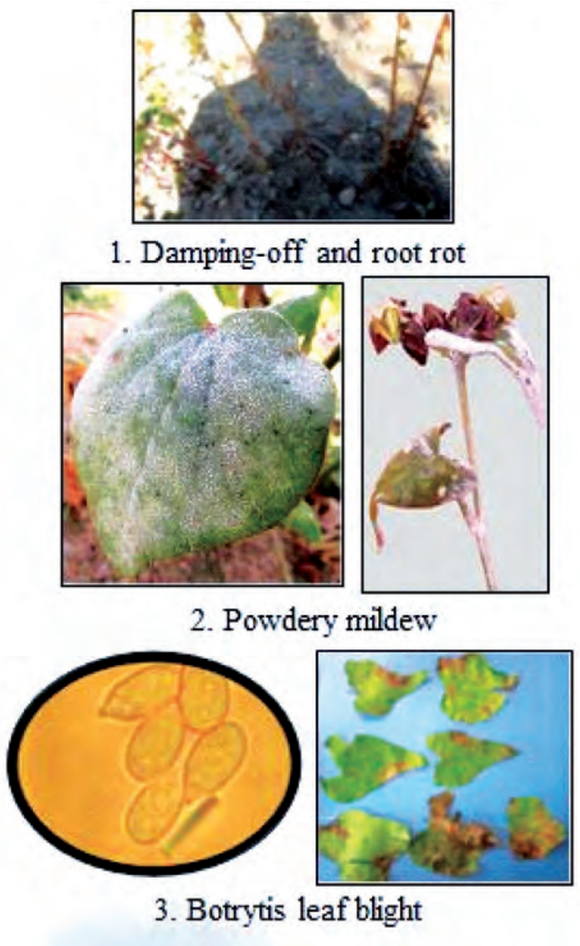

Fig. 4. Barley diseases (Manandhar et al., 2016)

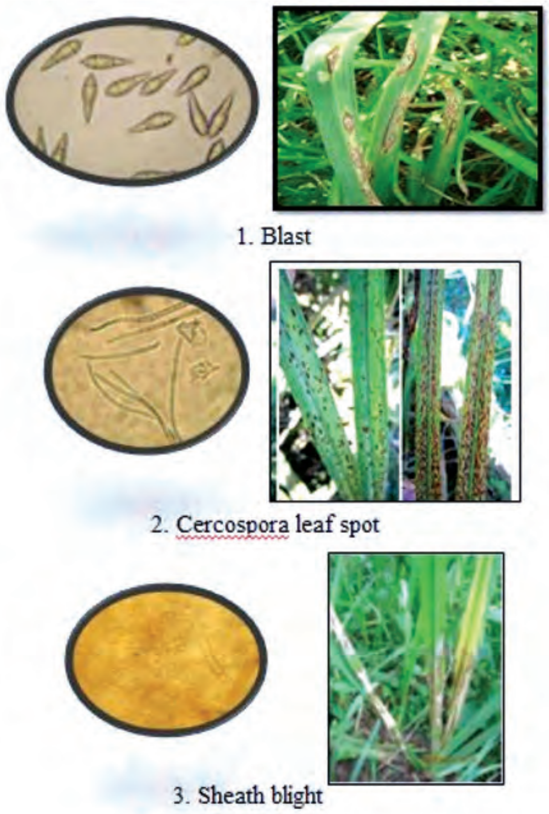

Fig. 5. Buckwheat disease (Manandhar et al., 2016)

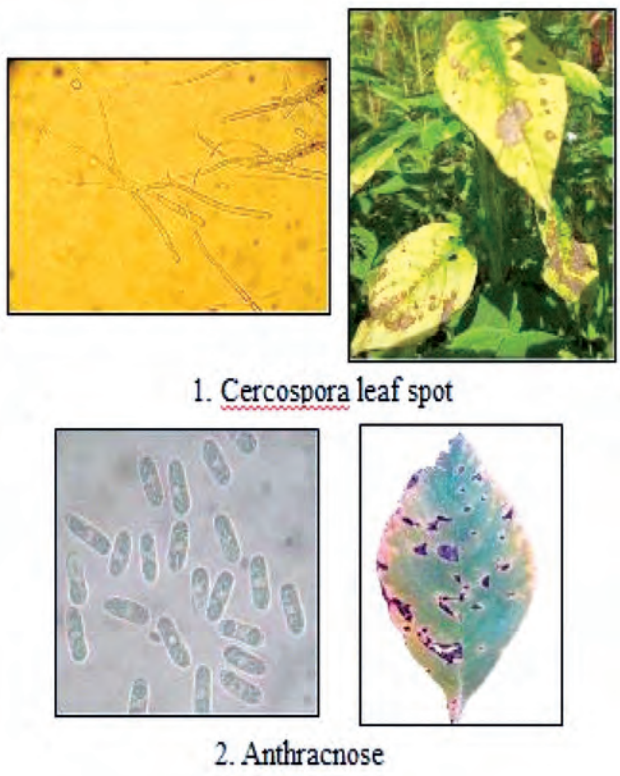

Fig. 6. Amaranth diseases (Manandhar et al., 2016)

Following are the crop management strategies of NUS adopted by HCRP, NARC in Nepal:

Finger millet

- Early sowing
- Optimum fertilization
- Crop density management
- Drainage management
- Varietal mixture
- Cultivation of improved variety

Barley

- Early sowing
- Irrigation management and
- Varietal mixture (naked barley)

Buckwheat

- Crop density management
- Optimum fertilization
- Drainage management and
- Varietal mixture

Amaranths

- Early sowing and crop density management – leaf spot and anthracnose

Challenges and Opportunities

Despite the potential value of these crops for food and nutritional security in hills and mountain, policy makers have given less priority as compared to major cereals. Following are the major challenges that limit the cultivation and consumption of these crops.

Globalization of Trade and Markets

Funding for addressing research and improvement of UUC around the world is limited. Farmer's life changing, includes urbanization, small commercial activities are replaced by large enterprises, homogenization of local culture. As a result of spreading of new models and culture and improved communication, globalization is bringing in favor of few crops that lead to much narrower agricultural basket estimated to hold some widely commercialized crops (Prescott-Allen, 1990) which will enter newer areas and replace local ones.

Deteriorating Local Food System and Local Biodiversity

Hills and mountain people are attracted towards high yielding staple rice and cash crops. They like to eat rice in hills and mountain due to road access to remote hills in Nepal. Population growth and changing food habit, increase the demand of advanced crop varieties of rice and others, but not the NUC that limits their cultivation and consumption. Market demand is ever increasing of major cereals which resulted to abandon cultivation of these crops. Decrease in cultivation and consumption of UUC lead to decline in local agricultural biodiversity and dietary diversities.

Changing Food Habits of the People

Particularly young generation of mountains, hilly regions and people of urban areas are changing their food habits. These people prefer instant/fast food items instead of traditional food items derived from UUC. Inadequate availability of local varieties and diversity rich products in market, systematic effort to promote new markets for local and diversity rich products and inadequate investment in market promotion of local varieties and their products resulted in changing food habits of the people.

Inadequate Awareness of Diversity Rich Products in Human Nutrition and Health

The UUC are very rich sources of nutrition and good for human health. People are less aware about the nutritional and food security from these crops. Indigenous knowledge plays vital role in the conservation, consumption and utilization of these crops. Lack of indigenous knowledge leads to reduced cultivation and consumption of these crops.

Out Migration

Young males of mountains and hills are migrating inside and outside the country in search of job and food security, that lead to abandoned agrarian life and agricultural land. Impact of global warming and climate change is also occurring in mountains that result in heavy and erratic rainfall, landslides, loss of water resources that forced to migration and ultimately lead to loss of agricultural diversity in these regions. On-farm conservation of NUS and UUC is of paramount importance (Padulosi *et al.,* 2012).

Lack of Policy

Protection and promotion of these crops is not among the priorities of the government. Strategies for promotion of these crops is almost missing in existing food and nutrition security policies and programmes of government. The allocated fund from government organizations (GOs), NGOs/INGOs is very low as compared to major cereals. For example, recently implemented Prime Minister Agricultural Modernization Project (PMAMP) has not included these crops.

UUC are important assets for those fragile social groups who may never be able to afford certain commodities in difficult areas often found unsuitable for the cultivation of improved varieties of major cereals. UUC provide more balanced diets, diversified income to farmers as well as related sectors of the society, better maintenance of agro-ecosystems and greater use of marginal lands along with preservation of cultural identity (Padulosi, 1999).

Marketing, Commercialization and Trade

Most of the production of NUS are consumed within household for food (dhido, vegetables, pancakes and pickles) and local beverages (finger millet and barley wine), and few amounts go to market. They also use these crops for medicinal (e.g. tartary buckwheat leaf for diabetic and heart patient, barley sprouts for increasing WBC count in cancer patient) and religious purpose (barley seed in Hindu community, finger millet flour in Tamang community and barley flour in Sherpa community). In Nepal, major market is for location transaction and finger millet is imported from India. Also, some barter system still exists in mountains of Nepal. Now, there is an increasing interest in these crops for export and domestic markets. Interest in NUS seems to be due a variety of factors, including their contribution to agriculture diversification and better use of land. These crops are primary food for home consumption making productive use of marginal land and also provide income to small farmers, entrepreneurs and local market experts. Intensive work has not been done in marketing, commercialization and trade. There is no survey about consumer preferences, risk, prices, marketing strategies, quality control and technical support for processing, packaging, labeling, certification etc. Different private entrepreneurs are encouraging to develop variety of products and test them in the market with the technical support from FRD, Khumaltar. This has been increased the demand of UUC in market which has been an incentive for farmers for continuous production of these crops. Till date, there are hardly any good links among farmers, entrepreneurs, retailers/wholesalers and consumers. Also, no credit and grant schemes to encourage all relevant stake holders.

Strategies Adopted to Harness their Potential

To harness the potentials of NUS; NARC, Nepal has adopted the following strategies:

- Collection, characterization and evaluation of indigenous and exotic germplasm
- On-station varietal development trial
- Multi-locational trials on different agro-ecological regions of Nepal
- Crop management technologies in agronomy, soil fertility and plant protection
- Farmers acceptance test (FAT) through informal R&D (IRD)
- Post-harvest processing equipment's development
- Trainings organized in different locations about the cultivation practices
- Trainings organized for NUS foods product diversification among farmers and bakery entrepreneurs
- Source seed production and distribution to community based seed production (CBSP)
- District seed self-sufficiency programme - Cooperatives, seed companies etc.

Major Focus Areas

Following are the major focus areas of NARC for these NUS in Nepal:

- Policy lobbying
- Collection, characterization and evaluation of germplasm
- Development of location specific, farmers/community preferred varieties
- Development of climate resilient varieties
- Information and documentation

- Crop management technologies in agronomy, soil, plant protection
- Release and promising technologies verification through FFT, PVS, IRD, FAT, Minikit, mass media etc.
- Mechanization in cultivation practices and post-harvest operations
- Value addition and food diversification
- Market development
- Linkage and coordination among stake holders
- Collaborative research and germplasm exchange with national and international organizations

Infrastructure, Capacity Building and Financial Investment

Institutional Involvement

- HCRP: collection, regeneration, characterization, evaluation, selection, breeding and other related tasks.
- NAGRC: collection, regeneration and conservation
- FRD: Nutrient analysis, Value addition and product diversification
- Agriculture Engineering Division (AED): development of machinery equipments.
- Others: Agriculture Research Station (ARS), Regional Agriculture Research Station (RARS) - conduct multi-location trials

Physical Infrastructure Available

- Threshing machine
- De-husking machine
- Grading machine
- Long term storage facility
- Heavy tillage machines
- Light tillage power tillers
- Vehicles
- Refrigerators (short-term storage)
- Store house

Capacity Building Opportunities

- No linkages to international research institutions for capacity building of scientists and technicians and in recent years nobody took the international training course about NUS.

Capacity Building Opportunities Granted

- Several trainings on crops cultivation, seed production, crop protection, processing and storage to farmers groups and seed producer cooperatives/groups.
- Training on product diversification of NUS organized to different bakery entrepreneurs, cooperatives and village youths.

Financial Investment

Low priority in government policy on NUS and low budget and human resource allocation in research as compared to rice, maize and wheat as shown in the Fig. 7 and Fig. 8.

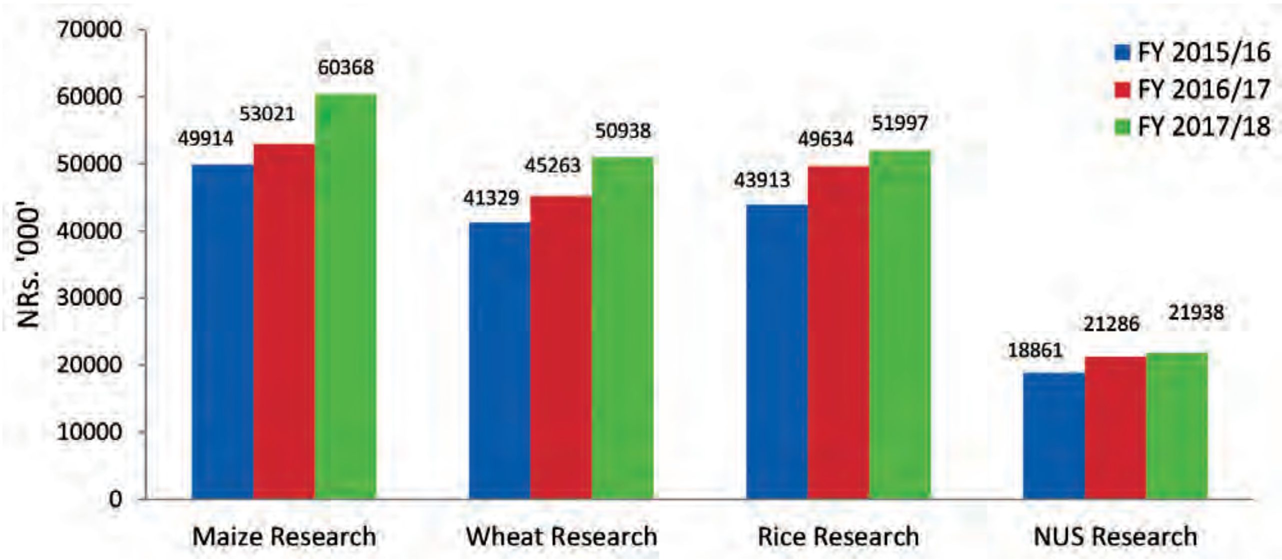

Fig. 7. *Financial investment in rice, wheat and maize in comparison to NUS over the last three fiscal years in Nepal*

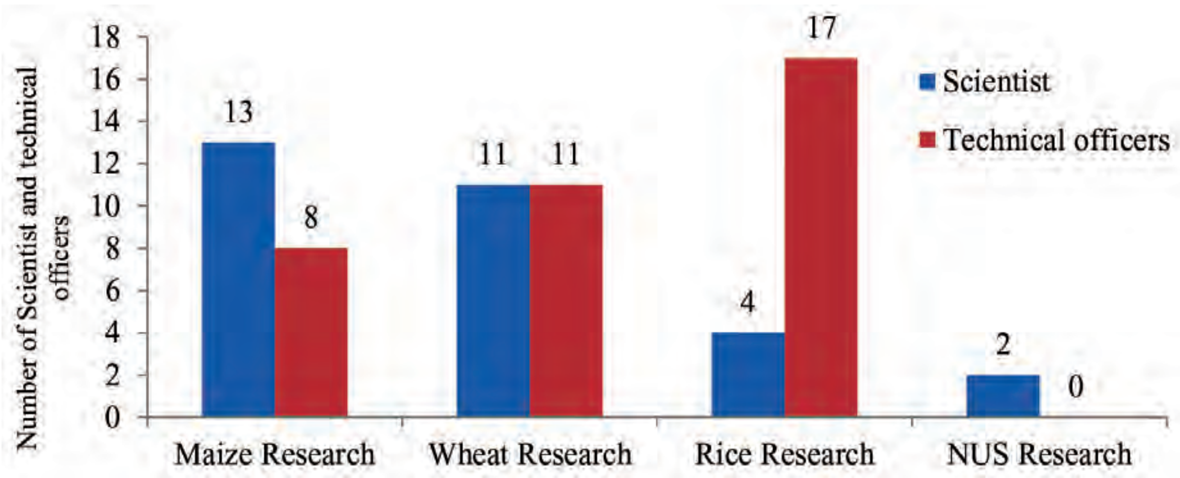

Fig. 8. *Human resource allocation in different commodity programmes in NARC, Nepal in 2017*

Success Story

- **Location**: Kaski
- **Organization:** LI-BIRD, Pokhara led programme
- **Finger millet growers**: Farmer group of Kalabang and Ralamare, Kaski
- **Intervention:** Awareness and dissemination through print, radio, fairs and festivals, workshops and school programmes, about nutritional and other beneficial aspects.
- **Impacts:** Surveillance revealed that there is increased demand of millet products among intellectuals, diabetics, young generations and foreigners. Sale of millet cookies, *namkin*, savory snacks increased almost twenty-fold over a year in Pokhara.

Future Thrust

The future thrusts for NUS in Nepal, recognized by NARC are as follows:

- R&D institutions of UUC to be established at local, regional and central level.
- Depute large number of plant breeders in GOs/NGOs in private R&D agencies.
- Strong support to informal seed supply system.

- Access of farmers in extension services of good improved practices in farmers' field.
- Make strong commodity research programme from R&D perspective.
- Allocate sufficient fund from government and development of collaborative projects at national and international level for germplasm, technical and financial support from related organizations.
- Establishment of conservation facilities at commodity programme, regional stations.
- Capacity building (infrastructure, human resources): exchange visits for scientists and technical officers for enhancing and sharing technical knowledge for capacity development.
- Crop based experts for characterization either by recruitment or by providing training.
- Increase deputation of scientists, technical officers and supporting staffs.
- Use of modern molecular and biotechnology tools for variety development and others.

Conclusions

The UUC have great potential to contribute towards food and nutrition security and to overcome the consequences of climate change not only in Nepal but also globally. It is imperative that agricultural production should be sustained enhanced through the use of alternative crops which are underutilized and underexploited. Breeding, agronomic and quality studies for the development and promotion of improved varieties, capacity building for taxonomic classification and genepool studies of new materials should be promoted. Adequate importance should be given to human resource development and higher studies and training in relevant areas. Linkages should be established for germplasm exchange, knowledge sharing, knowledge management, capacity building, molecular based studies, value chain, value addition and other areas such as product development and marketing to be able to exploit the potential.

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Country Status Report - Pakistan

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Introduction

Generally, plants are a fundamental component of the natural resource available to the poor and the role played by underutilized species (UUS) is indeed central to reducing poverty and empowering the poor so as to allow poor rural communities to pursue resource-based rather than commodity-based development (Burgess, 1994; Blench, 1997). Just three crops - maize, wheat and rice - account for about 50 per cent of the world's consumption of calories and protein. About 95 per cent of the world's food needs are provided by just 30 species of plants in stark contrast, at least 12,650 species names have been compiled as edible. Neglected and underutilized plants are those that could be - and, in many cases, historically have been - used for food and other uses on a larger scale. Such crop species have also been described as "minor", "orphan", "promising" and "little-used".

Underutilized crops (UUC) are defined as the species domesticated and used by human beings, but their genetic potential has not been not realized fully (Padulosi and Hoeschle-Zeledon, 2004). These orphan non-commodity crops are part of a "mega biodiversity portfolio" that remained underused by farmers and consumers for a variety of reasons including awareness, agronomic, genetic, economic and cultural factors. Although Pakistan is a food secured country at present, however diversification of food has been limited to few crop species. Food security can be enhanced through diverse assemblage of crop species particularly the UUC that has recently increased priority and constitute health food (Mayes *et al*., 2012). The UUC species are often adapted to marginal lands. However, they offer viable agricultural alternatives particularly in response to climate change and provide additional options for maximizing land usage for the farming community. These crops provide increasing demand for "natural" and environment friendly products, thus offering sources for diversified income to farmers and agricultural businesses (Thie, 2000).

Establishment of plant genetic resources for food and agriculture (PGRFA), and their characterization is the first step in securing these resources, especially of UUC which constitute an undocumented contribution for humans including food security and traditional healthcare. The germplasm collections include cultivated materials, heirlooms, landraces, closely related types and wild species, and their populations thus represent potentially important source of genetic diversity for ongoing plant breeding efforts (Tanksley and McCouch, 1997). Unimproved landraces and wild germplasm may be particularly valuable sources of undiscovered alleles for the adaptation of crop plants to environmental challenges (McCouch *et al*., 2013). The improvement work on UUC remained stagnant due to multiple reasons, i.e., lack of germplasm information, lack of trained human resources, financial constraints and least priority by the policy makers. Unfortunately,

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little is known about inter- and intra-genetic diversity of UUC, hence their genetic potential remained untapped.

Among large number of PGRFA, few agricultural crops are being used significantly by humans and diversification of food crops can solve world's food requirement at large using potentially important underutilized and neglected crops (Kahane *et al*., 2013). A considerable number of plant species are either ignored, or marginalized by researchers, breeders and policy makers, hence remained unutilized (Padulosi *et al*., 2013). In the past emphases has been given to improve major crops that contribute directly to food security, however UUC are needed to use due to their additional benefits of rich sources for healthy food. Due to emerging awareness for food diversification, these UUC are getting importance for researchers. Discovery of nutritional food, improved culinary ethics, resistance to biotic and abiotic stresses and adaptation to climate change are contributing to the interest of researchers in UUC. There is a need to broaden the utilization of the PGRFA to avoid dependence on few major crops. Since UUC are more adapted to marginal soils and under less favorable environmental conditions than major crops, their use can also make complementary approach to the continued use of major crops (Cheng *et al*., 2017). Pakistan lies in the vicinity of three centers of diversity, hence is endowed with great biodiversity for crop plants and their wild relatives. Significant achievements have been made for major crops on which food security is trusted, however a great potential exists for minor and UUC for nutritional food security. Conservation, characterization, evaluation and use of UUC has become important for crop diversification and food security in future due to untapped potential for this group of crop species.

Neglected and underused crops are domesticated plant species that have been used for centuries or even millennia for their food, fibre, fodder, oil or medicinal properties, but have been reduced in importance over time owing to particular supply and use constraints. These can include, *inter-alia*, poor shelf-life, unrecognized nutritional value, poor consumer awareness and reputational problems (famine food or "poor people's food", sometimes due to the modernization of agricultural practices). Some crops have been so neglected that genetic erosion of their genepools has become so severe that they are often regarded as lost crops.

As the demand for plant and crop attributes changes (reappraisal or discovery of nutritional traits, culinary value, adaptation to climate change, etc.), neglected crops can overcome the constraints to the wider production and use. As a matter of fact, many formerly neglected crops are now globally significant crops (oil palm, soybean, kiwi fruit). Although the options for scaling up neglected crops for large-scale agriculture appear to be increasingly exhausted, many species have the potential to contribute to food security, nutrition, dietary and culinary diversification, health and income generation. They also provide environmental services. It is impossible to define what would constitute "proper" or "correct" levels of use; however, many neglected species evidently are underused relative to their nutritional value and productivity.

Area, Production and Productivity

Country's major natural resources are arable land and water; approximately 25 per cent of Pakistan's agriculture accounts for about 21 per cent of Gross Domestic Product (GDP) and employs about 43 per cent of the labour force. The most agricultural province is Punjab where wheat and cotton are the major crops. Mango orchards are mostly found in Sindh and Punjab provinces that make Pakistan the world's fourth largest producer of mangoes. Archeologically, barley, wheat and lentil are visibly found in Mehrgarh by 8000-6000 BC. Irrigation was developed in the Indus Valley Civilization by around 4500 BC. The farm production is mainly dominated by a few crops that account for almost 60 per cent of GDP from agriculture. Cropping systems vary widely because of variations in agro-climatic and soil conditions. Wheat is the major winter crop in all regions of the country. In summer, rice, cotton, and maize are grown in areas suitable for their production. Crop production takes place both on irrigated and dry land, with irrigated agriculture contributing about 80 per cent of the total production. The five major crops (wheat, rice, cotton, sugarcane and maize) contribute for food security and farmers' income at large.

Coarse grains including sorghum, millet, and barley constitute major feed and fodder source, however remained underutilized in the past due to changes in production patterns. Many pulse and minor-crop areas were shifted to major crops, however that caused negative effect on country's agricultural productivity. The high input crops are being produced in surplus and low input crops are imported that caused a serious breakage in diversification of crops for food security. However, emphasis on the development of improved and disease-resistant varieties of pulses, oilseed and coarse grain crops is urgently required that has got attention for research and development (R&D). Simultaneously, new growing areas particularly in the Baluchistan and Khyber Pakhtunkhwa provinces will have to be explored to exploit these UUC to meet nation's requirements for healthy food security.

Fig. 1 represents the agricultural land use of Pakistan. Major crops are wheat, cotton, rice and maize, whereas oilseeds, pulses and fodder despite their importance are still underutilized. Pakistan has not officially identified UUC; however, based on utilization, production and marketing, the crops with marginal interest in adaptation, uses and research are considered UUC. The major crops of one area could be underutilized at other area. This category can swipe and depending upon farmers' need, the cropping pattern and choice of crop is a focused target for a particular area. The data on production and consumption patterns in the past and present, data of some UUC is given in Table 1. It is obvious that categorization of UUC is not quantifiable. The major crop under one area could be underutilized in other particular area, e.g., historically maize had been a major crop in the province of Khyber Pakhtunkhwa (KP) as a staple food. However, with the introduction of hybrid maize, it has become a major crop in the Punjab province and underutilized in KP.

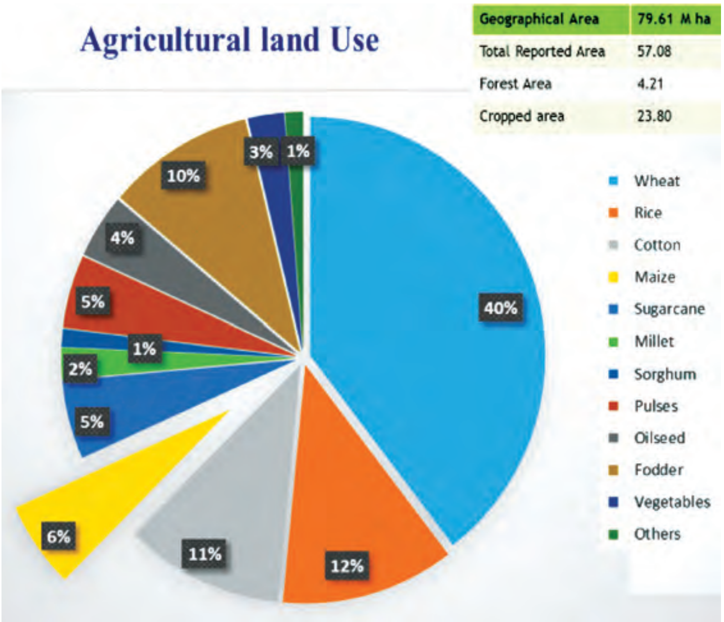

Fig. 1. *Agricultural land area uses for various crops in Pakistan*

Table 1. Area and germplasm status of UUC in Pakistan

Underutilized crop	Area (ha)	Accessions in genebank	Accessions characterized	Traits studied	Selected accessions
Buckwheat	NA	198	160	6	-
Fenugreek	159	302	167	22	2
Guar	175,000	880	400	17	4
Kalonji	NA	125	80	14	1
Linseed	3,800	689	150	16	2
Safflower	73	826	369	21	27
Sesame	75,000	823	184	16	8
Taramira	NA	405	290	20	3
Turmeric	5,600	1	20	21	1
Barley	70,778	1277	700	12	4
Sorghum	194,773	947	541	18	2
Millets	461,901	225	194	20	6
Oats	NA	524	360	15	5
Castor oilseed	2456	106	65	14	5

Underutilized crop	Area (ha)	Accessions in genebank	Accessions characterized	Traits studied	Selected accessions
Cowpea	NA	384	173	27	12
Mash	20,900	649	550	18	25
Common bean	NA	1221	400	3	5
Moth bean	NA	67	51	6	2
Faba bean	NA	60	6	4	
Pigeon pea	NA	9	4	6	
Lathyrus	NA	51	32	8	
Sunhemp	221	113			
Kenat	NA	66			
Roselle	NA	28			
Portulaca	NA	16			

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Plant Genetic Resources Programme, Bio-Resources Conservation Institute (BCI), National Agricultural Research Center, Islamabad is actively involved in the collection, conservation, evaluation and documentation of PGRFA in Pakistan including UUC. Table 2 gives the number of accessions in the National Genebank at Bio-resources Conservation Institute (BCI), NARC, Islamabad, Pakistan. It is the only *ex situ* conservation of crop species that maintain the PGRFA for active and base collection with duplications at respective genebanks along with Seed Vault, Svalbard, Norway. The detail indicates the number of accessions conserved and evaluated for future research and utilization in crop improvement programmes to meet the national requirements. The evaluated and selected accessions are being shared with the National Agricultural Research System (NARS) for crop improvement programmes.

Table 2. Germplasm status in National Genebank of Pakistan

Crop group	Number of accessions in the genebank	Number of accessions evaluated	Number of selected accessions
Cereals	10,160	6,514	246
Oilseeds	7,797	4,525	356
Legumes	6,141	4,598	241
Vegetables	4,967	1,421	102
Fiber crops	2,296	654	54
Fodder crops	2,161	897	98
Medicinal Plants	1,939	1,021	146
Weeds	97		
Others	53		
Total	**35,611**	**19,630**	**1,243**

At present more than 35,000 accessions have been conserved, major being for cereals, oilseeds and legumes. Among these more than half of the germplasm has been characterized and evaluated. Little effort has been done for UUC species. Number of UUC varied significantly and comprised of diverse groups that make R&D more difficult in these crops. In Pakistan generally, among cereals, UUC are minor and pseudocereals (Table 3). The area under barley, sorghum and millet is documented, whereas there is no record for oats and buckwheat. Buckwheat has been traditionally cultivated in Northern areas of KP and Gilgit Baltistan provinces. However, its cultivation has now decreased due to introduction of commercial cultivars of cash crops. Other UUC include sesame, linseed, safflower and castor in the oilseed crop group. These crops need special attention by the policy makers, researchers and farmers to produce more edible oil in the country. Similarly, pulses (cowpea, moth bean, faba bean, blackgram, pigeon pea and *Lathyrus sativus*) are being cultivated at one or the other area of the country and attain the status of underutilized. As far as vegetable crops are concerned, almost all of these are underutilized except, for the crops where hybrid seeds are available along with production technology. Even for major crops where yield plateau has been achieved either through green revolution or gene revolution, the potential has not been fully exploited in Pakistan due to one or the other reasons. On the other hand, UUC were never considered important for R&D, hence lack improved genetic material for general cultivation. All the produce from these crops are either from landraces or local adapted cultivars. The National Genebank maintains a higher level of genetic diversity for these crops due to abundance in landraces occurrence because modern varieties available for UUC. Other medicinal and aromatic plants (MAPs) remained unattended and all the material is collected wild or cultivated on limited area using farmers' own seed of landraces.

Table 3. UUC in National Genebank of Pakistan

Crop group	Name	Area (hectares)	Production (tons)	Accession (no.)	R&D efforts
Cereals	Barley	70,778	66,451	1,277	Fair
	Sorghum	194,773	114,619	947	Fair
	Oats	NA	NA	524	Fair
	Millet	461,601	294,395	225	Little
	Buckwheat	NA	NA	198	Nil
Oilseeds	Sesame	82,698	33,147	825	Little
	Linseed	3,302	2,366	679	Little
	Safflower	20	23	827	Good
	Castor oil	2,456	2,580	106	Fair
Legumes	Cowpea	NA	NA	384	Fair
	Moth bean	NA	NA	67	Fair
	Faba bean	NA	NA	60	Nil
	Pigeon pea	NA	NA	9	Nil
	Lathyrus	NA	NA	51	Nil
Vegetable	Patulaca	NA	NA	16	Nil
Fiber crops	Sun hemp	221	126	113	Nil
	Kenaf	NA	NA	66	Nil
	Roselle	NA	NA	28	Nil
	Jute	NA	NA		Nil
Medicinal and aromatic plants	*Kalonji*	NA	NA	125	Fair
	Taramira	NA	NA	405	Fair

Among fruits, apple, banana, citrus, dates, guava and mango are the major fruits in Pakistan while almond, apricot, grape, peach, pear, plum and pomegranate, Loquat, mulberry, persimmon and walnut are considered minor and underutilized fruits of Pakistan (Khattak, 1997). Recently olive plants have been planted under vast area and are expected to harvest in future that will enhance edible oil availability in Pakistan. Improvement of fruit plants is trickier and require long time span, hence most of the researchers are reluctant to work on fruits. These UUC and fruits need special attention for their commercial exploitation. Among underutilized fruits, olive has attained attention by the Government, and a project has been launched for olive cultivation in the country. The project "promotion of olive cultivation on commercial scale" is to expand the cultivation and establishment of processing plants is under execution under Pakistan Agricultural Research Council (PARC), Pakistan. Many indigenous fruits including berries, nuts and stone fruits are being reported and the masses, particularly the teenagers enjoy free food just for fun, however no improvement work has been conducted on these underutilized fruits.

The UUC have been researched by individual's interest and not taken as a commodity. Comparatively fair to good research has been conducted for minor cereals, whereas pseudo-cereals are being neglected. Similarly pulses and oilseeds have also been researched improvement is obvious. The first priority of the Government is to ensure food security, hence focus has been on the major food crops, although UUC, *i.e.,* sorghum, millets, quinoa and minor cereals are very high in nutrients, especially the micro-nutrients. For majority of UUC including minor pulses, minor oilseeds, vegetables, fruits and MAPs, no systematic R&D and government policy is available in the country. Individual researchers have contributed at their own interest, especially for academic purposes. There is a need to compile all the scattered data on UUC for formulating the future R&D strategies.

Variety Development

Among the cereal crops, the improvement has been conducted for major crop including wheat, rice and maize, however few varieties were developed for minor cereals, *i.e.,* barley, sorghum, oats and millet. Buckwheat has been traditionally cultivated in northern areas of Pakistan, however due unavailability of improved high yielding varieties, this high value medicinal crop is almost going to extinct. In the recent years, barley and oat have achieved attention by the researchers due to their additional benefits along with food security. Similarly, R&D preliminary breeding work has been conducted on minor legumes including *Vigna mungo, V. unguiculata, V. aconitifolia* and *Phaseolus vulgaris*. Five varieties of blackgram and one of *V. aconitifolia* has been developed using indigenous genetic resources. *P. vulgaris* is an important legume mixed with maize or sorghum, however no improved variety is available. Recently *Phaseolus* germplasm (local as well as exotic acquired from CIIT, Columbia) was evaluated and high yielding genotypes were selected and shared with the breeders working on legumes. Pigeon pea and *Lathyrus* are neglected and no improved variety is available for any of these crops.

The country is deficient in edible oils and there is need to develop oilseed crops. Although varieties have been developed for canola, sunflower and groundnut, their potential is yet to be exploited. The underutilized oilseed crops have not been addressed properly, although these crops have a good promise for making country self-sufficient in edible oil. Some traditional crops like buckwheat and medicinal plants are mostly cultivated using landraces. Little resources both for economic and genetics have been major limitation for improving these crops. Taking the global situation, some of the countries have taken lead on these marginal crops, but major potential is still unexplored. The modern varieties of major crops have been evolved through global participation and UUC are yet to be prioritized globally or regionally. The numerous UUC vary from country to country and region to region, and without multiple participation in multidisciplinary approach with some specified crops for some particular crop, it is rather not possible to achieve the goal for UUC.

Black cumin (*Nigella sativa*), commonly known as *kalonji* in Pakistan, is an annual flowering plant investigated recently for its potential as a crop in Pakistan. A variety "NARC Kalonji" has been developed by Plant Genetic Resources Programme, Bio-Resources Conservation Institute, National Agricultural Research Center, Islamabad. Seed of this variety was multiplied and trialed in diverse areas of Punjab before it was recommended as a new variety. The performance of the variety was assessed in many parts of Pakistan. It was observed that black cumin could be successfully cultivated in most parts of the

Table 4. Prioritized list of UUC along with their nutritional value for research and varietal development

Crop group	Name of crop	Nutritional value
Cereals	Sorghum, oats, millet, barley	Good source of dietary fibers, minerals and amino acid
Oilseeds	Sesame, linseed, safflower, castor oil	Good source of minerals, vitamins, dietary fibers and oil.
Legumes	Common bean, cowpea, moth bean, faba bean, black gram, pigeon pea, lathyrus	Balanced amino acid compositions, good sources of high quality protein and gluten-free food.
Vegetables	Patulaca	Rich sources of dietary fiber, vitamins, minerals and omega-3 fatty acids
Medicinal and aromatic plants	Buckwheat, kalonji, taramira	Medicinal & anti-biotic value, contains bioactive compounds, healthy food, good source of micro nutrients and vitamins.

country (Rabbani *et al*., 2011). Additionally, 971 accessions of *Brassica* oilseeds, 275 of *Eruca sativa*, 29 of safflower, 100 of sesame and including fenugreek (60), kalonji (96), soybean (350), blackgram (258), quinoa (4), amaranthus (5), radish (17), carrot (8), turnip (5), cauliflower (9) and linseed (230) were characterized for qualitative and quantitative traits of interest. The elite germplasm of these UUC was distributed to the researchers for breeding programmes. For sustainable utilization of UUC and enhancing nutritional food security in Pakistan crop improvement of underutilize crops is needed. Significant research, breeding programmes are needed for a range of promising crops to utilize local landraces of UUC for development of approved varieties. Development of improved varieties of cereals, legumes, oilseeds UUC will have significant implications for food security as well as nutritional security in Pakistan. The varietal development for underutilize crops is prioritized in Table 4.

Cultivation Practices

UUC are mostly cultivated by farmers in traditional way. Once improved varieties are introduced, production technology also improves. Mostly the farmers broadcast the seed depending upon availability of moisture. Some of the crops are mixed cultivated or as boarder crop. However, Bio-resources Conservation Institute (BCI) has compiled production technology of some underutilized and neglected crops in national language for the farmers.

Processing, Value Addition and Product Development

Many private companies in Pakistan, in collaboration with agricultural research institutes, are working on processing, value addition and product development, especially in case of medicinal herbs. Major portion of local herbal and neglected crops are being collected by the people that are fetched by the herbalists and local *"hakeems"* at a low price. The UUC contain nutritious and are mineral rich, hence more precise advance technology is required for their evaluation and value addition for products.

Disease and Pest Management

Since introduction and development of production technology of UUC is in process, importance of disease and pest management is not yet fully realized. Therefore, no significant research work is conducted for disease and pest management of UUC.

Prioritized UUC for Variety Development/R&D

Keeping in view the latest research information and thorough discussion with stakeholders as well as in the conferences on Neglected and Underutilized Species (NUS), the crops including amaranth

(*Amaranthus sp*.), bottle gourd (*Lagenaria siceraria*), maize landraces (*Zea mays*), cowpea (*Vigna unguiculata*), black jack (*Bidens pilosa*), millets, sorghum (*Sorghum bicolor*), sesame (*Sesamum indicum*) including underutilized fruits as listed above have been prioritized for R&D in the agricultural research system. Common research themes could be included nutrition, ecophysiology, agronomy, crop modeling, food security, seed quality, breeding, and biotechnology, perceptions, climate change, postharvest, genetic resources, medicinal properties, and commercialization. However, the crops per research theme and institute are yet to be listed. The development of the strategy may involve a three-step approach, including: i) a diagnosis of challenges, obstacles and opportunities, ii) priority setting and developing a framework for addressing challenges, and iii) developing a guiding framework outlining coherent actions and activities for future funding for NUS in the country.

Challenges and Opportunities

The UUC had traditionally been cultivated on marginal lands with marginal interest with least research and development of these crops. Little resources both in terms of economic and genetics have been major limitation for improving these crops. Taking the global situation, some of the countries have taken lead on these marginal crops, but major potential is still unexplored. The modern varieties of major crops have been evolved through global participation and UUC are yet to be prioritized globally or regionally. Handling of UUC which vary with the country, region or locality is only possible through multiple participation and multidisciplinary approach.

Realizing the emerging importance of UUC, a conference was organized during 1997 in Plant Genetic Resources Institute (PGRI), NARC, Islamabad, Pakistan. During this participatory conference, priority was outlined for Underutilized and Neglected Plant Species of Pakistan and ten important plants species were prioritized for R&D. However, moringa and other highly nutritious plant resources are also addressed and few researchers work on these plant species especially for their importance and uses. No improvement work has been initiated on these important high value crop plants. At present there are key issues in improving the use of underutilized species to meet the globalization of agricultural market as well as food security through diversification. But the people who benefit from underutilized species in a globalized world are not just for the poor. The benefits in terms of more balanced diets, diversified income to farmers as well as related sectors of the society, better maintenance of agroecosystems and greater use of marginal lands along with enhanced preservation of cultural identity (Padulosi, 1999) can be shared by all the humankind. More precisely, the challenges ahead are as follows:

- Awareness among communities for food diversification for nutrition and health to promote the use of UUC.
- Research and development work should be initiated/concentrated and farmers be provided improved varieties, production technologies and marketing opportunities to get maximum benefit from cultivation of underutilized crop.
- Germplasm of UUC should be explored and conserved to save it from extinction.
- The UUC should be brought out of so called traditionally been cultivated on marginal lands with marginal interest with least research and development of these crops.
- UUC vary with the country, region or locality; hence important crop species in this category should be prioritized.

Marketing, Commercialization and Trade

There is no regular system for marketing and commercialization of underutilized crop in the country. The market is mostly driven through demand-supply chain, however due to insecure farming for underutilized crop there is exploitation by the middle man. The producers and consumers are weak stakeholder due to non-involvement of public sector in these low priority commodities. Streamlining the market for UUC, giving incentives for scaling up and rationalizing investment in farming will address issues like marketing, commercialization and trade in this group.

Strategies Adopted to Harness their Potential

There is no government policy framework and systematic programme for R&D in the country and it all depends upon the individual researcher's interest. The group of UUC is very vast and the protocol for R&D for this group of crops is rather tricky and needs multidisciplinary team, and there is not example of consolidated concerted efforts for improvement of these crops. However, research in case of UUC is being conducted through development projects.

Comparison of area and production of maize in various provinces of Pakistan is given in Fig. 2. The area under maize in the Khyber Pakhtunkhwa province is 43 per cent but production share is 29 per cent that indicate underutilization of this crop in KP due to non-adaptation of modern hybrids. It is the responsibility of policy makers and Government agencies to enable farmers to obtain maximum yield potential of crop commodities. The following strategies are required for accomplishment of R&D work on UUC Agro-climate responsive R&D:

- Exploitation of genetic potential through conventional as well as modern breeding techniques.
- Seed production of improved cultivars to support agricultural productivity through UUC.
- Improved production technology, post-harvest technology and infrastructure development for value addition.
- Policies and regulations for seed, marketing and export.
- Contractual farming to ensure farmer profit and crop insurance.
- Mechanization through technology suitable to small farmer.
- Capacity building.

Major Focus Areas

Due to high number of crops under this group, major focus was on ten crops that were prioritized under an Agricultural Linkage Program (ALP) and collection of genetic resources was accomplished. However, indigenous underutilized vegetables have great potential to promote local vegetable cultivars along with seed production for sustainable agricultural production. The production technologies of target crop species were developed. One variety of *kalunji* (*Nigella sativa*), six of blackgram and one variety of *Vigna aconitifolia* were developed for general cultivation. Germplasm of UUC have been collected from few areas depending upon financial resources. However, that is needed to strengthen for harnessing maximum genetic diversity of these crops. Some NGOs working on UUC and medicinal and aromatic

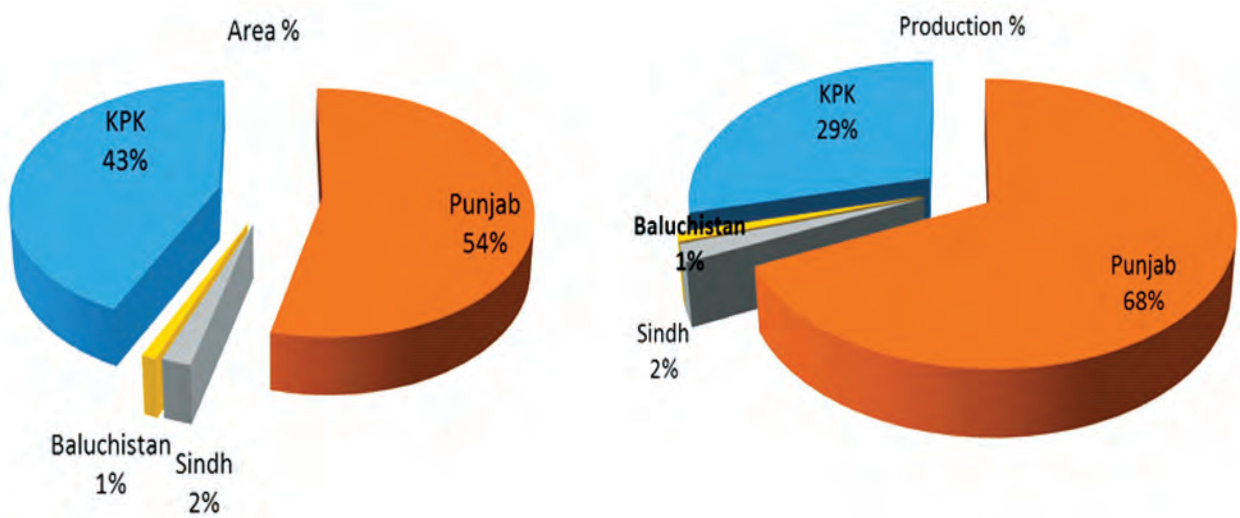

Fig. 2. Comparison of area and production of maize in various provinces of Pakistan

plants encourage the poor rural women farmers' involvement that has swift implementation. It has been a general observation that UUC are not economic to grow for most of the time. The reason behind this may be lack of high yielding cultivars due to less R&D work. Growing of *Nigella sativa* coupled with bee keeping for honey production proved highly beneficial for the farmers. However, honey production is more technical and the farmers require service providers. Similar cases may also occur for other medicinal and neglected crops that need precise research for future framework on underutilized crop species.

Establishment of plant genetic resource (PGR) collections for UUS has been advocated in the Global Plan of Action (GPA) that is one key element of the promotion process pursued by several other international organizations, including IPGRI and ICUC. Keeping in view the GPA, we have collected the genetic resources of UUC that have been conserved for sustainable utilization for crop improvement to meet national and international requirements. The future major focus areas are suggested as under:

- Germplasm collection, characterization, evaluation and conservation for exploitation of genetic potential of UUC for healthy food security.
- Variety development through conventional breeding by participatory approach and development of fine tune production technology including access to market.
- Value addition and industrialization of UUC.

Infrastructure, Capacity Building and Financial Investments

Currently, the existing infrastructure of agricultural research has no established infrastructure available for UUC. The financial support through the development projects by Government organizations and international collaborators are the only resources at present. Crops that require urgent attention in Pakistan are pseudocereals (amaranths, buckwheat and chenopods; millets - finger millet, proso millet, foxtail millet), grain legumes (rice bean, faba bean, moth bean, horse gram, blackgram, common beans), tubers (taro, giant taro), vegetables, *Moringa oleifera*, oilseeds and seabuckthorn. The benefits of these species can only be achieved with a sound multidisciplinary team with modern state-of-the-art infrastructure.

Case Studies/Success Stories for Improvement of Health and Livelihood

Based on demand driven, a project was initiated in Azad Jammu and Kashmir on collection, evaluation and conservation of neglected crops and medicinal herbs. The herbarium documentation has been displayed at PARC website to provide easy and quick access for end user. More than 100 medicinal plants- *Cretaegus oxycantha*, *Leonurus cardiaca* for heart diseases, and *Podophyllum hexandrum, Gentiana kurroo*, *Swertia* species as antibiotics were identified and documented. One hundred and thirty (130) local and fifteen (15) exotic species have been propagated and planted at two clonal repositories. These herbal plants have been used by the local people for healthcare and we have formulated the product for ready use. In addition, essential oil has been distilled from flowers and leaves of *Lavendula angustifolia* with steam distillation method by using simple distillation plant.

Future Thrust

Futures prospective of UUC are expected to streamline the research and development activities based on demand. The parameters including healthy and nutritious food are to be kept at priority. Ultimate future trusts include as under:

- Awareness about UUC for and their role in health food security for sustainable agricultural productivity.
- Conservation of genetic resources of UUC, their evaluation, documentation and utilization.
- Value addition for better marketing and mass consumption as health food.
- Increasing the consumption of UUC for diversification of food to ensure healthy food for all.
- Improve marketing system and explore international markets.

Conclusions

Research and development of UUC is at preliminary stage in Pakistan. There is need to enhance the exploration and conservation of genetic resources of UUC. Production technology and marketing of these crops should also be improved for the benefit of farmers. Changing food fashions and habits and the erosion of traditional culture, values and practices, often associated with urbanization and globalization. Most collections are entirely field collections particularly in the form of seed. Little work has been conducted for *in vitro* and *in situ* conservation, and these suffer from losses, especially due to diseases, human intervention and many have been lost over the years or near to extinct. There is no government policy framework and systematic programme for R&D in the country. There is need to strengthen R&D and formulate policy framework on underutilized crops and it will be a paradigm shift to make underutilized crops as fully utilized during next decade.

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Country Status Reports – South-East Asia

Country Status Report - Lao PDR

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Introduction

Neglected and underutilized species (NUS) are non-commodity crops or species, including thousands of domesticated and wild species. NUS are usually species or ancient domesticates under cultivation that grow without human intervention or that have been cultivated by local people for family consumption and the sale if any surplus. Such crops tend to be managed with traditional systems and have good nutritional value and are well adapted to a wide variety of local conditions.

Some of NUS are Non-Timber-Forestry Products (NTFPs) that are "All biological materials (excluding timber) collected from natural or man-made forests and riverine habitats used to support local livelihoods with providing basic necessity such as food, cash income, medicine, construction material, cultural and ritual items (NAFRI, 2007). According to one study, 44 per cent of subsistence in the households surveyed was NTFPs, 41 per cent was rice and 14 per cent were other foods (FAO, 2007).

NUS have the potential to provide food and nutritional security since many of them are nutritionally rich and adapted to low input agriculture. Thus, they may be a good option for farmers faced with the uncertain weather caused by increasing climate variability. However, there is no contemporary national research policy that specifically addresses these crops. Most national policies are aimed at major crops with high international and national trading value.

In collaboration with international organizations, the National Agriculture and Forestry Research Institute (NAFRI) has collected, conserved and identified crop germplasm, both for direct use and as genetic resources for breeding programmes. A national gene bank has been developed to conserve the germplasm of various species for the short, medium- and long-term, including rice, maize, legumes, tubers and several kinds of vegetables.

The Lao People's Democratic Republic (Lao PDR) is rich in plant species and genetic diversity, resources that contribute to national and rural well-being. However, these resources are increasingly being threatened by a variety of factors, including deforestation, over-exploitation, clearing for infrastructure development, extension of farming systems into frontier zones, mechanization of agriculture, and the adoption of new and high-yielding varieties. The change over from subsistence farming to an open market economy and the increased availability of fertilizers and other inputs are contributing to genetic erosion in several crops, including rice, local vegetables and legumes. Farmers are abandoning glutinous rice varieties, replacing them with higher yield non-glutinous varieties. Wild rice species are at risk of being eroded or becoming extinct due to the decimation of their habitats. There is insufficient information available on many crops and their crop associated biodiversity to ensure their improved use, development and conservation.

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In a survey of cultivated and wild *Vigna* in Laos, Tomooka *et al.* (2004) reported that cowpea (*V. unguiculata*) and rice bean (*V. umbellata*) are important legumes in the village and landraces of these species are still grown. These legumes are important genetic sources for breeding, and it is necessary to collect diverse genetic variation of this species. However, in Thailand and other neighboring countries, farmers prefer to grow improved varieties instead of landraces. Accordingly, it is important to collect landraces and local knowledge about them before they both disappear.

Area, Production and Productivity

The area planted and total production of crops in Laos have increased steadily increased, as shown in Table 1. In 2016, rice comprised 29 per cent of total production, root crops 20 per cent, industrial crops 17 per cent, vegetables 12 per cent, fruits 10 per cent and beans only 1 per cent (Fig. 1). Root crop production, which almost doubled from 2014-2015, remained at the 2015 level in 2016.

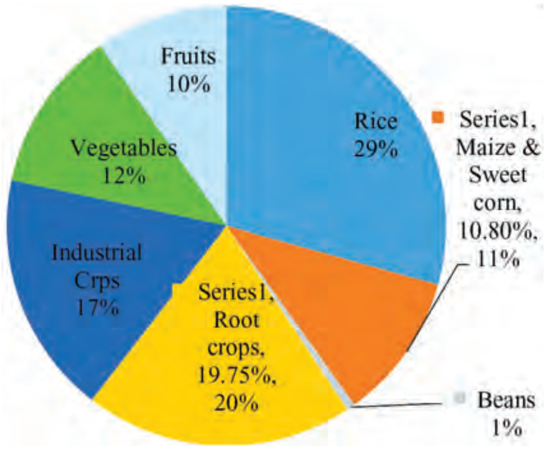

Fig. 1. *Share of total production crops in 2016*

Source: DoP (2017)

Table 1. Area and production of crops in Laos from 2014-2016

Crop Items	Planted area (ha)			Harvested area (ha)			Production (ton)		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
Rice	979,345	984,932	976,235	957,836	965,152	973,064	4,002,425	4,102,000	4,148,800
Maize and sweet corn	243,385	254,025	255,400	243,385	254,025	255,400	1,412,440	1,516,250	1,530,340
Beans	41,425	38,095	44,595	41,435	38,095	34,555	83,478	88,520	90,560
Root crops	81,345	101,885	102,830	81,345	101,885	102,830	1,872,240	2,767,190	2,797,185
Industrial crops	226,785	251,030	245,610	199,890	227,885	229,155	2,262,645	2,516,585	2,524,520
Vegetable	161,379	179,690	180,820	161,379	179,690	180,820	1,550,460	1,683,405	1,690,900
Fruits	49,510	81,765	86,885	49,510	81,765	86,705	864,702	1,362,825	1,381,044

Source: DoP (2017)

NUS crop species have the potential to decrease malnutrition and increase household income security. NUS crops could be introduced as components of agricultural diversification and sustainable development as Lao PDR adapts to climate variation. The criteria that need to be considered for NUS selection are: 1) Nutritional value: food composition and high nutrition; 2) Social value: local acceptability especially for children (malnutrition is mainly a childhood problem) and processing knowledge aimed at children; 3) Agricultural value: seed availability, local knowledge on agronomy, and environment requirements; and 4) Commercial/market value: quality, access to markets and demand. The following NUS species have been selected for promotion and research:

Roots and tubers: Several root and tuber species are found in Lao. Taro (*Colocasia esculenta*), greater yam (*Dioscorea alata*) and fancy yam (*Dioscorea esculenta*) are commonly eaten and grown in farmers' gardens and in the forest. Purple yam and fancy yam are rich in carbohydrates (over 97%) and in other elements, including potassium, phosphorus, calcium and anthocyanin (which is a good antioxidant). Tuber crops are widely consumed as snacks, but in some remote areas they are consumed as a major source of sustenance during times when the production of other crops is insufficient. There is no exact data regarding the area under cultivation or the total production of these crops in Laos.

Nuts and pulses: Pulses constitute an important group contributing towards a nutritionally good protein-rich diet. They provide nutrition for poor, marginal farmers who grow many of these crops under subsistence farming regimes.

Leguminous crops belonging to the genus *Vigna* are agronomically and economically important in Laos. Among these, *V. radiata* (mung bean) and *V. unguiculata* (cowpea) are the most widely cultivated crops. While *V. umbellata* (rice bean) is a traditional food crop of Laos, it is thought to have been domesticated in South-East Asia and therefore is expected to have high genetic variation in Laos. Mung bean is not a neglected crop but it is an underutilized crop because its production is quite limited, equaling only 4,775 t in 2015. The seeds of these species are rich in protein (20-25%) (Shabnum *et al*., 2012; Arora, 2014). Singh (2007) reported some cowpea varieties have a total protein content as 30 per cent, a value close to that reported in some soybean cultivars.

Significant Steps Needed to Support Greater Cultivation of NUS Crops

Germplasm Collection, Typology, Evaluation, Conservation and Documentation

Rice is life in Laos. Rice is the key crop for securing national food and livelihood security. Laos is a center of biodiversity for glutinous rice varieties and the primary center of origin and domestication of Asian rice (*Oryza sativa* L.). Since 1995, the Laos-IRRI project facilitated in developing the national gene bank; under this project, diversity in rice landrace was collected and conserved for improvement of yield and quality. More than 14,000 accessions of rice have been conserved, of which 80 per cent are glutinous rice. Of these, 55 per cent are upland accessions and 45 per cent are lowland accessions. Traditional glutinous rice varieties have a good aroma, eating quality, resistance to gall midge, drought tolerance, flood tolerance, pest and disease resistance, and other traits.

While rice varieties have been studied intensively, there has been far less effort directed to germplasm collection and research on NUS/crops, including tubers and legumes as *Colocasia esculenta* (taro), *Dioscorea alata* L. (yam), *Dioscorea esculenta*, *V. radiata* (mung bean), *V. unguiculata* (cowpea) and *V. umbellata* (rice bean).

Varietal Development

The National Agriculture and Forestry Research Institute (NFPRI) has conducted a plant breeding programme for rice, maize, legume and vegetables. Beginning in 1995, a rice breeding programme, the Lao-IRRI project has been developed. Over 20 improved rice varieties have been released and used. One hybrid maize variety and 2 improved soybean varieties were released in 2010. There were only landraces for mung bean, cowpea, rice bean, taro, fancy yam and greater yam. In 2012, a breeding programme for mung beans was launched at the Maize and Cash Crop Research Center.

Cultivation Practice

An estimated 77.6 per cent of the total rice-growing area is considered lowlands; they provide 93 per cent of Laos' total rice production. Only about 13 per cent of the total lowland rice area is irrigated. Upland rice is grown in the mountainous areas of northern Laos. Grown mainly for local and family consumption, it constitutes only 7 per cent of the national rice production. Lowland rice farmers may practice transplanting, either from a wet or a dry seed bed, or direct seeding by broadcasting, dry seed drilling, or wet seed drilling.

Rice is cultivated in three ecosystems: upland (for aerobic rice), rainfed lowland and irrigated. It is commonly grown to three standards: common practice (using chemical fertilizer and pesticide); good agriculture practice (GAP) and organic agriculture (OA). However, maize and legume crops (soybean, mung bean and peanut) are largely grown in upland and rainfed lowland ecosystems, but some of them are grown in the irrigated lowlands. NUS/crops are grown in upland fields and in-home gardens, mostly under traditional cultivation practices.

Disease and Pest Management

Several improved varieties of rice, resistant to pests and diseases, are cultivated in GAP or OA practices. Almost all NUS are grown using traditional cultivation practices with hardly any improved varieties having pest and disease resistance.

Challenges and Potential Benefits

Although NUS/crops are rarely cultivated in a sustainable manner, they still have great nutritional benefits and other potentialities that make them worth promoting. But several challenges confront us when we try to promote NUS production. These challenges are: 1) difficulty in entering the market and convincing people to use and consume NUS/crops, since people currently do not much use NUS/ crops; 2) cultivation of NUS/crops is fragmented, so it is difficult to harvest these in large volumes; 3) cultivation techniques are based on traditional practices, which often do not meet market demand in term of quantity and quality.

However, NUS can be developed for commercial purposes and for food and nutrition security if there are proper support policies in place and appropriate production techniques are applied. These support policies should cover all the steps in the value chain from upstream to downstream, including the production, post-harvest, storage, processing, packaging, transportation, marketing and consumption.

Marketing Commercialization and Trade

Commercial agricultural operations in Lao PDR are driven by market demand from the larger towns and from neighboring countries. Because of the small rural population and the early stage of economic development, agricultural marketing is generally on a small scale. Most crops are produced fairly close to the main towns and are transported in small quantities, while large-scale wholesale trade and transport over long distances is mainly confined to sugarcane, maize, banana, rice and coffee (NAFES, 2006)

The agricultural marketing practices in Laos are usually unsystematic, with many small traders and vehicles of different types and sizes moving about in all directions. These small traders are without any permanent store or stall; they just collect and sell to consumers or major collectors. The result of this informal system is that investment and overhead costs are minimized and the traders are able to operate with lower margins.

However, there are also some well-established trading practices, by which well-defined vegetable production groups that can move quickly from peri-urban farms or assembly points to urban markets. Produce generally arrives fresh at the retail markets or weekly organic market in town. There are also long-distance trades, for example, for cabbage from the Bolavens to Vientiane (NAFES, 2006).

Marketing channels are generally short. Most vegetables and much fruit are sold directly by farmers or collectors to the retailers of the town markets. They tend to use hand tractors, small 3-wheeled vehicles and trailers and sometimes pickups. It is not unusual for farmers or family members to take stalls in markets so as to sell in retail to urban consumers without any intermediaries. The fact that some farmers sell to collectors while others deliver their produce themselves to town markets suggests that vegetable marketing is based on free competition and that the margins of peri-urban collectors are relatively small; otherwise all farmers within reach of the market would likely opt for direct selling (NAFES, 2006).

Export crops, such as maize, peanuts, chilli, soybeans, sesame and red beans, pass from farmers to collectors and are processed by the few operating agri-businesses. However, some crops have well-established connections with neighboring countries through government agreement, and which are traded by well-established agribusiness firms. Examples include rice, banana and water melon, which are regularly exported to China. Almost all agricultural goods from Laos are exported without any processing and value added. Only two commodities, coffee and rice, undergo value-added processing before export. The export of primary products without any processing is due to the lack of facilities and knowhow concerning proper processing.

NUS/crops are still at the level of traditional practice in terms of cultivation, trade and exchange, and also consumption. Only a few firms process NUS, generally into mixed fruit chips.

Strategies to Harness Agricultural Potential

Lao agencies have developed strategies designed to ensure food security and nutrition, produce comparative and competitive agricultural commodities, develop clean, safe and sustainable agriculture and shift gradually to the modernization of a resilient and productive agricultural economy, linking rural development to the growing national economic basis.

Agriculture Development Strategy to 2025 and Vision to 2030

Ministry of Agriculture and Forestry of the Lao PDR has adopted an agriculture development strategy to 2025 and vision to 2030. The strategy includes general and specific measures. The general measures include policy, formulating and amending legislation, determining co-ordination mechanisms, promoting cooperation and investment, and restructuring the organization and human resource development in the agriculture and forestry sector. The technical measures include crop production systems and animal husbandry practices, particularly the determination and allocation of agricultural land, research and extension promotion, production labor force development and improvement, irrigation infrastructure development, technical infrastructure and others.

In addition, action plans and detailed projects have also been identified to achieve two main goals or programmes, food production, and agricultural commodity production, that will contribute to rural development and poverty reduction. These goals will be supported by into 16 action plans and 120 projects. These include 9 action plans and 62 projects for crop production, and 7 action plans and 58 projects for livestock and fisheries (MAF, 2015).

Agriculture and Forestry Research Strategy to 2025 and Vision to 2030

Aligned with the Agriculture Development Strategy to 2025 and vision to 2030, NAFRI has adopted the Agriculture and Forestry Research Strategy to 2025 and Vision to 2030, which set three goals for agriculture research. These are: 1) to ensure food security and safety, and nutrition; 2). to augment commercialized production of potential commodities and high value added; and 3) to efficiently and sustainably utilise resources and increase resilience to climate change

Four main research programmes and two supportive research programmes were created to achieve these three goals. The main programmes are: (1) sustainable forest and agro-biodiversity management, (2) resilience of agriculture production system to climate change, (3) seed/breed and technologies development, and (4) policy research and communication. The two supportive programmes are information technology and capacity building (NAFRI, 2015).

Lao National Agro-biodiversity Programme and Action Plan II (2015-2025)

In 2016, the Ministry of Agriculture and Forestry of the Lao PDR adopted a National Agro-Biodiversity Programme and Action Plan II 2015-2025 (NABP II). The NABP is designed to support three major development goals of Lao PDR: (1) achieving food security; (2) reducing poverty; and (3) enhancing government capacity to ensure the sustainable management and use of natural resources. The programme will act as the framework to better manage coordinate, multi-sector approaches in order to support those three goals.

The five indicators set in the NABP II are: (1) national on-farm genetic diversity maintained, (2) agro-biodiversity related value chains established, (3) export of agro-biodiversity products increased, (4) increased endemic plant and animal genetic material in national breeding programme, and (5) climate resilient crop/animal varieties bred (MAF, 2016).

Major Focus Areas

NUS/crops provide ways to decrease malnutrition and increase household income security. These crops may be introduced as agricultural diversification and sustainable development in the adaptation to climate variation. Existing knowledge is scattered and is mainly based on indigenous knowledge passed on from generation to generation. The marketing of indigenous crop species is limited in terms of commercialization and demand; however some NUS may have potential as alternative cash crops. Improvement of cropping systems, seed processing and marketing opportunities, particularly for niche markets is needed.

A Case Study of Cultivation of a NTFP: Passion Fruit in Khoun District, Xieng Khouang

Passion fruit has been collected from the forest in Samphanxai Kumban of Khoun district, Xieng Khouang. Farmers cultivating passion fruit have obtained yields of 3.2 tonne/ha, generating incomes of 4.8 million kip/ha. While some farmers have had problems cultivating passion fruit for the first time; the good returns are encouraging farmers to identify best practices. The private sector supported farmers through inputs of seed and training as a way to improve the supply of the fruit for processing. The Kumban fostered exchange between villages and provided a neutral environment for negotiations between farmers and the private sector.

The cultivation of passion fruit has been based on the methods inspired by the factory in its own trials. The technical problems emerging now include some that can be addressed by improved management by farmers. Best practices have been identified and shared through Kumban meetings. Other problems, such as insect infestation, require more specific technical advice. The Horticulture Research Centre, NAFRI, has provided consultation on disease and management issue, and improved techniques are being tried.

The work with passion fruit in Xieng Khouang can provide lessons for other crops, and in other areas, including: (1) cultivating of non-timber forest products, (2) engaging the private sector to support farmer production, and (3) empowering local authority in trade negotiation (NAFRI, 2009).

Future Thrust

To make these improvements successful, there is an immense need to consider all steps from upstream to downstream, including the following thrust areas:

- Conduct survey and documentation of existing NUS
- Germplasm collection and improvement
- Production, processing and value addition
- Marketing and consumption promotion
- Human resource development

Conclusions

Laos is rich in agrobiodiversity, including rice and non-rice crops. Some varieties are cultivated for commercial purposes, and some for household subsistence. The area under crop cultivation and production has gradually increased year by year.

A number of policies and strategies for crop development have been released, but these policies focus on the main staple food crops, such as rice. Meanwhile, knowledge of NUS/crops still remains limited and unclear in such areas as varietal development, cultivation techniques, processing, trade and marketing.

Availability of NUS in Laos must be surveyed to identify the potential of each crop for commercial sale and home consumption through varietal development, cultivation practices, post-harvest and processing, marketing and trade as well as the promotion of consumption of NUS.

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Country Status Report - Malaysia

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Introduction

Malaysia is recognised as one of the mega-diversity countries in the world, housing approximately nine per cent of the world's flowering plants. Flora and fauna thrive under Malaysia's humid tropical condition, warm temperatures and frequent rainfall. The available genetic resources are important for crop improvement purposes, especially in food, pharmaceutical and agro-based industries. There are a huge number of crops and plant species with potential value but are currently under-developed and/or underutilized. This paper aims to report and discuss on underutilized crops (UUC), i.e., underutilized fruits species (rare fruit species), underutilized medicinal plants and traditional vegetables grown in Malaysia.

In Malaysia, underutilized fruits grow naturally in rainforests and also in-home gardens and orchards. Salma *et al.* (2006) reported that there are altogether 285 underutilized species (UUS) grown in home gardens and orchards. These fruit species are grown in combination with other crops such as rubber, cocoa, coconut or with commercial fruits. Most of the underutilized fruits such as *Nephelium ramboutan-ake* (*pulasan*), *Mangifera foetida* (*kuini*), *Baccaurea macrocarpa* (*tampoi*), *Bouea macrophylla* (*kundang*), *Durio kutejensis* (*nyekak*) and *Garcinia prainiana* (*cerapu*) are consumed fresh while some are used for medicinal purposes such as for general health, weight loss and to improve the digestion system (Mohd. Shukri *et al.* 2009). Some species undergo simple processing to enhance their flavor and taste. For example, *Canarium odontophyllum* (*dabai*) and *Dacryodes rostrate* f. *cuspidata* (*kembayau*) are soaked in warm water with a pinch of salt before being consumed. The skin of *Garcinia forbesii* (*aroi-aroi*) is dried and used as an ingredient in cooking. The immature *Mangifera* species are used to make salad (Salma *et al.*, 2009).

Approximately 1,200 medicinal plant species are also found in Malaysia's protected forests. However, the number of scientific studies reporting on medicinal properties of plant species in Malaysia is scanty and limited. Thus far, only twenty-two per cent of Malaysia's total flora were studied for their phytochemical properties (Soepadmo, 1991). Medicinal plants are a primary source of natural products in the pharmaceutical sector. They are used in preparation for a wide spectrum of products ranging from traditional remedies to extracts with standardized contents of active constituents to chemically pure products used in drugs. Herb and medicinal plants are also used in food and beverage, flavour and fragrance industries (Indu Bala and Teik, 1999).

Malaysia has also diverse species of traditional vegetables. It is estimated that there are more than 120 species commonly grown in home gardens or in the wild tropics (Rukayah, 2001). In recent years,

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consumption of traditional vegetables is becoming popular. *Barringtonia racemosa* (*putat*), *Solanum torvum* (*terung pipit*), *Solanum melongena* (*terung telunjuk*), *Athyrium esculentum* (*tender fern shoots*), *Psophocarpus tetragonolobus* (*kacang botor*), *Colocasia esculenta* (*keladi*) and many other salad vegetables (*ulam*) are popular traditional vegetables served in hotels and restaurants (Mohd Shukor *et al.,* 2003, 2011; Erny Sabrina *et al.,* 2005; Mohd Shukri Mat Ali *et al*., 2009; 2011; Mohd Zulkhairi *et al.*, 2016; Umikalsum *et al*., 2017).

Since 1970, the Malaysian Agricultural Research and Development Institute (MARDI) collected and conserved selected UUC for the purpose of carrying out research and development (R&D) for crop improvement. Species are conserved *in situ* and *ex situ* i.e., seed genebank, field genebank and arboretum.

Area, Production and Productivity

Generally, the production area of underutilized fruits is small due to the inferior fruit quality and relatively low demand. However, a few species that have economic potential are planted in the home gardens and orchards because they fetch a high market price. For example area planted under *Salacca glabrescens* (salak) was recorded to be about 1,190 ha while that for *Nephelium ramboutan-ake* (pulasan) was 1,410 ha and *Lansium domesticum* (langsat) was 6,925 ha. For salak the production, is 4,530 metric ton per year, pulasan 4,930 metric ton per year and langsat 25,600 metric ton per year (Ministry of Agriculture and Agro-Based Industries, 2011). Other potential underutilized fruits planted in the home gardens and orchards in Peninsular Malaysia that have high demand from consumers are *Parkia speciosa* (*petai*), *Nephelium ramboutan-ake* (*pulasan*), *Archidendron jiringa* (*jering*), *Mangifera odorata* (*kuini*), *Garcinia atroviridis* (*asam gelugur*), *Mangifera pajang* (*bambangan*), *Artocarpus odoratissimus* (*terap*) and *Canarium odontophyllum* (*dabai*).

Currently for herbs and medicinal plants, emphasis has been towards the cultivation and production of 19 herbs such as *Eurycoma longifolia* (*tongkat ali*), *Marantodes pumilum* (*kacip fatimah*), *Orthosiphon aristatus* (*misai kucing*), *Phyllanthus niruri* (*dukung anak*), *Centella asiatica* (*pegaga*), *Morinda citrifolia* (*mengkudu*), *Hibiscus sabdariffa* (roselle), *Ficus deltoidea* (*mas cotek*), *Andrographis paniculata* (*hempedu bumi*), *Clinacanthus nutans* (*belalai gajah*), *Zingiber officinale* (*halia*), *Momordica charantia* (*peria katak*), *Senna alata* (*gelenggang*), *Zingiber zerumbet* (*lempoyang*), *Piper betle* (*sireh*), *P. sarmentosum (kaduk*), *Moringa oleifera* (*merunggai*), *Gynura procumbens* (*sambung nyawa*) and *Melastoma malabathricum* (senduduk) (Table 1).

Table 1. Area, production and value of production of herbs in Malaysia (2016)

Name of herb (local name)	Planted area (ha)	Harvested area (ha)	Production (mt)	Value of production (RM'000)	Average yield (mt/ha)
Major herbs					
Archidendron jiringa (*jering*)	170.28	139.91	815.84	1,794.86	5.83
Ficus deltoidea (*mas cotek*)	11.12	11.12	44.31	N.A	3.98
Morinda citrifolia (*great morinda*)	4.65	4.65	9.05	N.A	1.95
Orthosiphon aristatus (*misai kucing*)	12.27	12.59	80.28	N.A	6.38
Pandanus amaryllifolius (*pandan*)	147.42	137.91	791.36	1,582.73	5.74
Centella asiatica (*pegaga*)	27.46	27.46	230.75	1,569.12	8.40
Parkia speciosa (*petai*)	1,575.71	1,074.48	6,744.57	4,721.32	6.28
Cymbopogon nardus (fragrant lemon grass)	83.88	71.75	858.82	-	11.97
Cosmos caudatus (king's salad)	2.68	2.68	24.33	-	9.08
Total	**2,035.47**	**1,482.55**	**9,599.32**	**9,668.02**	**6.47**

Name of herb (local name)	Planted area (ha)	Harvested area (ha)	Production (mt)	Value of production (RM'000)	Average yield (mt/ ha)
Minor herbs					
Clinacanthus nutans (*belalai gajah*)	61.20	60.30	80.35	N.A	1.33
Kaempferia galanga (*cekur*)	6.71	6.69	21.96	62.59	3.28
Senna alata (*gelenggang*)	1.50	1.50	7.55	N.A	5.03
Zingiber officinale (*ginger*)	2.20	2.20	5.42	N.A	2.46
Andrographis paniculata (*hempedu bumi*)	5.00	5.00	15.00	N.A	3.00
Lawsonia inermis (*inai*)	2.39	2.39	3.96	N.A	1.65
Pereskia sacharosa (*jarum tujuh bilah*)	0.03	0.03	0.51	N.A	16.83
Marantodes pumilum (*kacip fatimah*)	10.10	5.10	25.15	N.A	4.93
Piper sarmentosum (*kaduk*)	0.56	0.56	2.07	N.A	3.70
Persicaria odorata (*kesum*)	26.60	26.08	516.17	2,217.18	19.79
Curcuma caesia (*kunyit hitam*)	0.10	0.10	0.41	N.A	4.10
Backhousia citriodora (lemon myrtle)	1.00	1.00	36.00	N.A	36.00
Aloe barbadensis (aloe)	5.91	5.91	26.62	N.A	4.50
Brucea javanica (*melada pahit*)	3.00	3.00	0.06	N.A	0.02
Strobilanthes crispus (*pecah beling*)	2.00	2.00	6.00	N.A	3.00
Leucaena leucocephala (*petai belalang*)	0.61	0.61	1.89	N.A	3.10
Mentha arvensis (mint)	34.75	34.75	623.28	N.A	17.94
Ocimum basilicum (*selasih*)	13.37	11.37	201.42	N.A	17.71
Piper betel (betel vine)	70.52	68.52	420.27	N.A	6.13
Stevia rebaudiana (stevia)	0.10	0.10	7.00	N.A	70.00
Solanum torvum (Turkey berry)	11.30	10.90	37.51	N.A	3.44
Eurycoma longifolia (long jack)	18.00	7.00	10.80	N.A	1.54
Total	**276.95**	**255.11**	**2,049.40**	**2,279.77**	**8.03**
Grand total	**2,312.42**	**1,737.66**	**11,648.72**	**11,947.79**	**6.70**

Source: Herbs and Spices Statistics, Malaysia (2016); Department of Agriculture, Peninsular Malaysia (2016)

According to Agricultural Statistics of Malaysia, in 2011, demand for traditional vegetables are picking up in the market. Unfortunately, these crops are not commercially grown and cultivated by majority of farmers. This is attributable to the fact that most farmers lack the knowledge on the importance of these vegetables to human well-being (nutrient content), quality of seeds used and the cultivation systems. Some species have been planted in small scale, e.g., *Cleome gynandra* (*maman*) the area planted is approximately 28 ha while *Athyrium esculentum* (*pucuk paku*) 42 ha and *Gigantochloa albociliata* (*rebung madu*) 66 ha. For *maman*, the production is 226 metric ton per year, *pucuk paku* 283 metric ton per year and *rebung madu* 181 metric ton per year (Department of Agriculture of Peninsular Malaysia, 2016).

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Collection

MARDI, Forest Departments and Universities continuously collect data and information concerning UUC in Malaysia. Generally, the most common fruit tree genera found in homegardens, orchards and forests are *Artocarpus, Baccaurea, Durio, Garcinia, Lansium, Sandoricum, Bouea, Mangifera, Cynometra, Dialium, Parkia, Nephelium* and *Xerospermum* (Raziah, 2008; Salma, 2009; Chung *et al*., 2005).

Currently, collection activities of four genera of crop wild relatives *viz*. *Oryza*, *Musa*, *Ipomoea* and *Solanum* are being carried out. This project is funded by the Global Crop Diversity Trust and Royal Botanic Gardens, Kew. Forest Departments and the Department of Wildlife and National Parks Peninsular Malaysia conduct annual programmes on botanical inventory of the diversity of flora and fauna of forest reserves and parks throughout Malaysia. Scientists from various agencies, institutions and organizations such as MARDI, Universities, Forest Research Institute of Malaysia (FRIM) and NGOs join in this scientific expedition. Examples of some of the scientific expeditions are Belum Rainforest (Perak), Tioman Island (Pahang), Pangkor Island (Perak), Hutan Simpan Sungkai (Perak), Tasik Bera (Pahang), Bukit Bauk Forest (Terengganu), Endau Rompin (Johore), Forest Reserve Gunong Stong (Kelantan), Sabah Parks (Sabah), Wang Kelian (Perlis), and Lanjak Entimau Wildlife Sanctuary (Sarawak). Objectives of such expeditions are to: i) take stock of baseline data of the flora; ii) determine the biodiversity of the species; and iii) collect underutilized fruit species for conservation. During technical seminars, discussions are held pertaining to discoveries of new species, new records, diversity and endangered species. The seminar proceedings are then translated into a publication.

MARDI has also taken initiatives to collect and conserve medicinal plant species. A total number of 194 species consisting of 424 accessions were collected and currently conserved in the herbal garden at MARDI station in Jerangau. It has also carried out a comprehensive collection activity in collaboration with World Vegetable Center, Department of Agriculture Sabah and Department of Agriculture Sarawak to collect indigenous vegetables or local vegetable land races. A total of 1,170 accessions consisting of 54 species from 36 genera (Mohd Shukor *et al.*, 2003) were collected. The seeds of the collections are conserved and stored in the seed genebank (MyGeneBank™) at MARDI Serdang. Some of the species collected are shown in Table 2.

Table 2. Collection of indigenous vegetable species

Family and species	Accession (no.)	Family and species	Accession (no.)	Family and species	Accession (no.)
Umbellifarea		**Cucurbitaceae**	2	**Solanaceae**	
Centella asiatica	5	*Cucumis sativus*	1	*Solanum melongena*	25
Labiatae		*Cucumis* sp.	1	*Solanum torvum*	10
Ocimum basilicum	2	*Lagenaria siceraria*	12	*Solanum ferox*	10
Leguminoseae		*Momordica charantia*	2	*Solanum nigrum*	5
Psophocarpus tetragonolobus	12	*Momordica* sp.	3	*Solanum indicum*	3
Ipomoea aquatica	1	*Cucurbita moschata*	9	*Solanum xanthocarpum*	2
Ipomoea sp.	1	*Luffa aegyptiaca*	7	*Solanum sarmentosum*	1
Phaseolus vulgaris	1	*Luffa acutangula*	1	*Solanum* sp.	9
Vigna sinensis	3	*Luffa* sp.	4	*Capsicum frutescens*	48
V. unguiculata	2	*Melothria affinis*	2	*Capsicum annuum*	7
Vigna sp.	1	***Capparidaceae***		*Capsicum* sp.	15
Canavalia gladiata	3	*Cleome gynandra*	8	*Lycopersicum esculentum*	1
Cassia occidentalis	5	**Malvaceae**		**Amaranthaceae**	
Dolichos lablab	2	*Hibiscus sabdariffa*	1	*Amaranthus gracilis*	1
Moringaceae		*H. esculentus*	3	*Amaranthus viridis*	4
Moringa oleifera	2	**Dioscoreaceae**		*Amaranthus tricolor*	11
Passifloraceae		*Dioscorea esculenta*	1	*Amaranthus blitum*	2
Passiflora foetida	2	**Euphorbiaceae**		*Amaranthus spinosus*	4
Chenopodiaceae		*Sauropus androgynus*	1	*Amaranthus* sp.	9
Basella alba	1	**Compositae**			
Basella rubra	1	*Cosmos caudatus*	9		

Source: Malaysian NISM database (2013)

Characterization and evaluation

Characterization and evaluation of the UUC accessions are the primary activities of the germplasm collection. Most of the accessions are characterized and evaluated using morpho-agronomic characters. However, in majority of germplasm holdings, the accessions or species are partially (75-90%) characterized or evaluated (Mohd Shukor *et al*., 2007). In MARDI, the 118 underutilized fruit species conserved in the field genebank are characterized and evaluated using morphological characters. In addition, molecular markers are also used for accessions of *Durio* and *Mangifera* species, *Phyllanthus pulcher* while some collections such as *Andrographis paniculata, P. pulcher* and *Colocasia esculenta* are characterized using biochemical markers. Only a small portion of the total collection in MARDI is evaluated for biotic and abiotic stress. Additionally, 30 species of selected traditional vegetables were evaluated for nutritional values (Erny Sabrina *et al.*, 2005) (Table 3).

Table 3. Nutritional values and antioxidant activities of five traditional vegetable species

Traditional vegetables (Botanical name)	Total phenolic content (g GA/100g extracts)	Vitamin C (mg/g)	Antioxidant activity IC50 (mg/ml)
Premna foetida	37.56 ± 1.17	21.52 ± 0.72	0.58
Pluchea indica	26.96 ± 0.57	13.82 ± 0.20	0.18
Annacardium occidentale	119.13 ± 0.72	82.58 ± 0.04	0.11
Ardisia crispa	16.13 ± 0.67	56.05 ± 0.04	0.29
Colubrina asiatica	13.99 ± 0.27	133.20 ± 2.02	2.56
Eugenia polyanthia	44.54 ± 0.31	54.78 ± 2.02	0.06

Source: Mohd Shukri et al. (2013)

Conservation

***In situ* conservation:** Underutilized fruits are conserved as *in situ* in protected areas. These protected areas serve as refuge for threatened plants (Saw *et al*., 2009). The National Forestry Policy, 1978 recognizes the need for the protection of habitats, flora and fauna. In 2005, approximately 5.04 million ha of forest areas were designated as protected areas (Saw *et al*., 2009). Many of the wild crop relatives and wild plants for food are still found in the forest. *In situ* conservation of wild fruits requires effective protection of large undisturbed forest areas having high species diversity and high intra-specific diversity for different species. However, selecting candidate for genetic reserves is not an easy task due to the lack of basic floristic data. The 87 Virgin Jungle Reserves (VRJ) covering 23,002 ha is in Peninsular Malaysia serves as permanent nature reserve and natural arboreta (Nazir Khan and Mohd. Yunus, 2005). Other protected areas include National Parks and State Parks, amounting to approximately 0.58 million ha. In Sabah, the two conservation areas, Danum Valley and Maliau Basin cover an area of 100,000 ha while in Sarawak, protected natural forests occupy 290,086 ha, which is equivalent to approximately 2 per cent of the total land area.

A study on the wild fruit tree species in Taman Negara showed that only 9 per cent of the wild fruit trees are known (Kochummen, 1990). Pasoh Forest Reserve, a lowland Dipterocarp forest provides an excellent example of *in situ* conservation. A total of 820 species in 294 genera and 78 families of trees measuring > 1 m diameter at breast height were enumerated in a 50 ha plot (Kochummen *et al*., 1990). Of these, 76 species are known to bear edible fruit and the most diverse species are the mango (12 *Mangifera* spp.), mangosteen (13 *Garcinia* spp.) and rambutan (5 *Nephelium* spp.) (Saw *et al*., 1991). Generally, the most common fruit tree genera found in the forests are *Artocarpus, Baccaurea, Durio, Garcinia, Lansium, Sandoricum, Bouea, Mangifera, Cynometra, Dialium, Parkia, Nephelium* and *Xerospermum* (Chung *et al*., 2005).

***Ex situ* conservation:** In Malaysia, *ex situ* conservation is the most common method of conserving crop plants and their wild relatives. The planting area and the number of accessions to be planted is rather limited due to unavailability of land. *Ex situ* conservation of underutilized fruits is being carried out by various governmental institutions such as MARDI, DOAs, universities and also private sector (Nordin *et al.,* 2015). The most common method of conservation is to maintain underutilized fruits of interest in field genebanks. MARDI has *ex situ* collections of underutilized fruits in 30 ha of land, housing a total 118 species (1,927 accessions) at various MARDI stations such as Serdang (Selangor), Jerangau (Terengganu), Sintok (Kedah) and Bintulu (Sarawak). A new field genebank (26 ha) of underutilized fruits was established in MARDI Jelebu, Negeri Sembilan.

MARDI conserves and maintains medicinal plants (424 accessions) and vegetable (478 accessions) seeds in the field genebanks in MARDI Serdang (MyGeneBank), MARDI Seberang Perai and MARDI Jerangau. DOA Peninsular Malaysia, Sabah and Sarawak also maintain a sizeable plant genetic resource of fruits and medicinal plants. The cryopreservation technique is now becoming important and being used by National University of Malaysia and FRIM to conserve *Citrus* and forest species. MARDI has recently began research activities on cryopreservation of underutilized fruits. DNA storage is relatively a new technique and currently, FRIM maintains their forest species in the DNA genebank. Botanical gardens such as Rimba Ilmu, Penang Botanical Garden and Putrajaya Botanical Garden also play important roles in conserving wild plant species.

Documentation of information system

Documentation of UUC in the country are maintained and stored in various databases. These databases include Agrobiodiversity Information System (AgroBIS), Malaysian Biodiversity Information System (MyBIS) and Traditional Knowledge developed by MARDI, FRIM and Sarawak Biodiversity Centre, respectively, as a tool towards information sharing. AgroBIS is a pioneer information system for management of information on agrobiodiversity in MARDI. Through this system, researchers or scientists will gain benefits in their research work by maintaining systematic and efficient records of important data and findings. The database on the system is for rice, indigenous fruits and vegetables, medicinal plants, arthropod collection and microbial culture collection. Currently, the data bank contains 123 species and 15,517 accessions.

Variety development

Elite accession of selected underutilized fruits were identified based on their superior fruit quality such as taste and texture. For example, the five accessions of *Mangifera odorata* (kuini), were selected based on their sweetness, strong flavours, mild pungency, firm texture and fine fibre. In the case of *Nephelium ramboutan-ake* (pulasan), their sweetness, detached sarcotesta and juicy fruit were evaluated. All this consideration incorporated for varietal development is seen to assist in increasing market demand and farmers income (Salma, 2009). Other selected elite accession of fruit species includes *Mangifera foetida* (bacang), *Mangifera caesia* (binjai), *Baccaurea macrocarpa* (tampoi), *Bouea macrophylla* (kundang) and *Garcinia atroviridis* (asam gelugur).

Cultivation Practices

Cultivation practices of underutilized fruits and vegetables follow commercial fruit species. The cultivation practices of herbs and medicinal plants such as *Marantodes pumilum* (*kacip Fatimah*), *Phyllanthus niruri* (*dukung anak*), *Andrographis paniculata* (*hempedu bumi*), *Centella asiatica* (*pegaga*), *Orthosiphon aristatus* (*misai kucing*) and *Clinacanthus nutans* (*belalai gajah*) follow the commercial scale propagation and cultivation techniques.

Cultivation of traditional vegetable such as *Solanum melongena* (*terung telunjuk* and *terung rapuh*), *Colocasia esculenta* and *Xanthosoma sagittifolium* (*keladi*), *Melicopelunu-ankeda* (*tenggek burung*) and *Stenochlaena palustris* (paku midin) emphasize more on the selection of potential varieties and production systems so as to increase the consumption in order to offer greater health benefits to the population of Malaysia. A total of one thousand planting material for large-scale cultivation of keladi has been developed using culture techniques is being explored. Up-scaling of selected traditional eggplant planting is also being carried out extensively. Research findings reported that some traditional vegetables have adapted well to weather changes such as droughts and floods, even with minimal agricultural input.

Processing, Value Addition and Product Development

Added-value products such as pickle, jam and beverages from underutilized fruits has assisted to promote these species to the public. *Garcinia atroviridis* (*asam gelugor*) has been processed into juice, dried *asam gelugur*, pickle and food supplement. *Mangifera odorata* (*kuini*) has also been processed into juice, pickle, yoghurt drink and pudding. Further, *Canarium odonthophyllum* (*dabai*) fruits and *Arenga pinnata* (kabung) syrup are exported to Japan. Other underutilized fruit species that has been processed into pickle are *Spondias cytherea* (*kedondong*) and *Sandoricum koetjape* (*sentul*).

As for underutilized vegetables, *Cleome gynandra* (*maman*) and *Gigantochloa* sp. (bamboo shoot) are processed into pickles. Standard operating procedure for standardized cultivation, processing and ingredient production has also been established for *Phyllanthus niruri* (*dukung anak*). The generated technology has been licensed to a local herbal company, Furley Sdn. Bhd.

Disease and Pest Management

Pest and disease of UUC are managed by using Integrated Pest Management (IPM) approach. IPM is found to be environmentally friendly, consumer-safe, compatible and sustainable in managing and tackling pest and disease. Pest and disease of underutilized fruit species from genera *Mangifera, Baccaurea, Citrus, Artocarpus, Nephelium* and *Lepisanthes* are controlled by using chemical pesticide when necessary. On the other hand, biopesticides are used to control major pest and disease for *Marantodes pumilum* (*kacip fatimah*), *Phyllanthus niruri* (*dukung anak*), *Andrographis paniculata* (*hempedu bumi*), *Centella asiatica* (*pegaga*), *Orthosiphon aristatus* (*misai kucing*) and *Clinacanthus nutans* (*belalai gajah*).

Challenges and Opportunities

Diversification of food sources including from traditional and UUC has been identified to improve health and nutritional status, to counter the impacts of global warming and to ensure food and nutritional security in the future. The main objectives of the National Agro-Food Policy (2011-2020) are to ensure adequate food supply, develop competitive and sustainable agro-food industry and increase the income level of agricultural entrepreneurs. However, these objectives were mainly targeted to primary food crops such as rice, premium fruits, herbs and industrial crops. More efforts are required to raise the awareness level of consumers and farmers in realizing and harnessing the nutritional benefits that UUC can offer. Public and private sectors should find avenues to joint efforts in promoting UUC to international markets.

Malaysia is unable to export local herbs due to non-compliance to international regulations. Among other factors, lack of standardization on herbs planting material due to varied quality of genetic materials used has been observed as one contributing factor. Additionally, the effects of climate change are another pressing factor affecting herbs quality.

Marketing, Commercialization and Trade

The herbal local market is projected to increase from RM7 billion in 2010 to around RM29 billion by 2020 (Bernama, 2013). There is an increasing trend in the production and marketing of local herbal products since the 1990s. It reached 8,550 in 2000 and has more than doubled in 2013 (Table 4 and 5).

Strategies Adopted to Harness their Potential

- Selection, breeding and upscaling to improve quality and demand
- Fingerprinting and genetic study
- Awareness, promotion and conservation of UUC (Sea Games, 2017, medalists received UUC seedlings to be grown at Green Valley, KL and Forest Reserve Areas - Sport and Youth Ministry)
- Diversity products from UUC for food security or nutritional security towards health supplement
- Conservation (Biodiversity Act- Access and Benefit Sharing Policy)

Table 4. Number of herbal products registered

	2006	2007	2008	2009	2010	2013
Prescription	533	449	409	412	441	241
Non-prescription	696	413	272	313	235	54
Natural/ traditional	1,729	1,342	953	1,040	582	578
Health supplements	0	0	0	0	0	85
Veterinary	0	0	0	0	54	63
Total	**2,958**	**2,204**	**1,634**	**1,765**	**1,312**	**1,021**

Table 5. Number of products registered (cumulative)

	2006	2007	2008	2009	2010	2013
Prescription	11,356	11,805	12,214	12,626	13,067	13,308
Non-prescription	8,685	9,098	9,370	9,683	9,918	9,972
Natural/ traditional	16,858	18,200	19,153	20,193	20,775	21,353
Health supplements	0	0	0	0	0	85
Veterinary	0	0	0	0	54	117
Total	**36,899**	**39,103**	**40,737**	**42,502**	**43,814**	**44,835**

Source: Farizah et al. (2015)

- Production through advanced propagation (shorten plant juvenility)
- Networking with organizations working in this group (GEF, Genesys, Bioversity International, Crop Trust, Millennium Seed Bank, Royal Botanic Gardens, Kew, London)

Major Focus Areas

There are three major focus areas of interest and concern with respect to UUC that falls under the purview of agriculture sustainability: i) conservation; ii) utilization; and iii) awareness. Conservation is important to secure food source and preserved these species from extinction. Conserved underutilized species offer great potential for utilization. These species will be utilized for selection (i.e. climate adaptation or mitigation accession), breeding, field testing and followed by commercialization. The nutritional value of the selected UUC will be determined to ascertain their high nutrient density and essential micronutrients. Bioprospecting of UUC offers huge potentials in developing novel cosmetic, nutraceutical and pharmaceutical products. Unfortunately, the priceless benefits and value that underutilize crops offer is not well understood by most people. In order to tackle concern, public awareness and promotional campaigns of these lesser known crops have begun. The Malaysian Agriculture, Horticulture and Agrotourism (MAHA) held once in two years and the annual Farmers and Fisher folks' Day or commonly known as *Hari Peladang, Penternak dan Nelayan Kebangsaan* (HPPNK) are avenues where these crops are introduced to the general public/visitors. Similarly, The recent 29th SEA Games held in Malaysia have also promoted UUC as souvenirs [seedlings of *Syzygium polyantum* (*salam*), *Garcinia hombroniana* (*beruas*) and *Syzygium malaccense* (*jambu bol*)], awarded to winners during the medal ceremonies.

Infrastructure, Capacity Building and Financial Investment

Infrastructure: MyGeneBank™ complex for seed storage; Field genebank for conservation of underutilized fruit species; Laboratories (nutritional analysis, cryopreservation).

Capacity building: Millenium Seed Bank, Kew, London (training on seed collection, seed processing and seed storage); In-house training on propagation technique of underutilized fruits.

Financial investment: Herbs and medicinal plant (Furley Sdn. Bhd.)

Case Studies/Success Stories for Improvement of Health and Livelihoods

Underutilized fruit: The UNEP/GEF project titled "Conservation and Sustainable use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security and Ecosystem Services" is being executed out at six sites in Malaysia (Yan, Bukit Gantang, Serian, Sibuti, Kota Belud and Papar). Salient achievements are:

- Communities at Kg. Kakeng, Serian participated in the conservation of tropical fruit trees in the diversity block.
- A 5 ha fruit tree garden was established in 2012 in which fruit trees from the genera *Mangifera, Nephelium, Garcinia, Durio, Artocarpus* and many more were planted. Fruit trees are conserved in their ecological niches and thus enhanced the ecosystem.
- Propagation techniques of *Garcinia atroviridis* (*asam gelugur*) in Bukit Gantang, Perak developed by farmers.
- Induced stress tab root.
- Marcotting, patch and grafting processes demonstrated and training impacted
- The farmers at Sibuti, Sarawak were trained to use the underutilized mango species for production of pickles.
- The farmers at Yan, Kedah were trained to produce International Maritime Organization (IMO) as an organic fertilizer for fruit trees in the orchard.

Herbs and medicinal plant: The plant species *Phyllanthus watsonii* (*dukung anak*) has double the production of molecular marker (geraniin/ corilagen) compared to the commercial variety. The exposure to stress conditions and UV light managed to improve the production of active ingredient by two folds. This technology, inclusive of the extraction and post-harvest technology has been licensed to a local herbal company which is currently producing this herb at a commercial scale.

Future Thrust

Issues	Way forward
Maintenance of UUC in the field genebank is high due to: ● Lack of funding ● Insufficient staff ● Lack of training ● High labour cost ● High rate of mortality and exposure to biotic and abiotic factors	Funds are needed to support and maintain the existing *ex situ* collection as well as alternative long-term conservation strategies such as cryopreservation for seed storage and on-farm conservation
Underutilized fruits normally have inferior fruit quality	To carry out intensive R&D for underutilized fruits in order to promote a new market; improve selection and pre-breeding
Lack of awareness on the benefits of UUC	● Increase the awareness within the civil service at federal, state and local ● Enhance mass media coverage on UUC ● Recognize the role of non-governmental organizations (NGOs) in the conservation and sustainable utilization of UUC
Limited number of plant species used in nutraceutical and pharmaceutical field	Screening of medicinal properties and bioactive compounds

Issues	Way forward
Lack of standardization in herb production	Planting of herbs in soilless cultivation under semi-controlled environmental conditions will be undertaken to standardized planting
UUC have traits that cannot be used directly in breeding programme	Carry out pre-breeding to identify traits that can be transferred to an intermediate set of materials that breeders can use further in producing new varieties of farmers
Lack of record on the status of conservation and sustainable utilization of UUC and its wild relatives	Monitoring records on UUC based on: • National Policies on Biodiversity (2016-2025) • The National Strategies and Action Plans on Conservation and Sustainable Utilization of Agrobiodiversity (2012-2020)
IF food security, nutrition and climate change at national level involving all crops	National Agro-food Policy (2011-2020)

Malaysia has realized the importance of UUC species such as herbs and medicinal plants, traditional vegetables and underutilized fruits. Therefore, in the 10th Malaysian Plan (2011-2015) and 11th Malaysian Plan (2016-2020), few R&D projects related to UUC were approved and on-going. The projects involved promotion, further research on agronomic practices, post-harvest and product development as well as up-scaling.

The following priority species under crop group(s) include:

No.	Crop group(s)	Species (common name)
1	Herbs and medicinal plants	*Eurycoma longifolia* (long jack) *Marantodes pumilum* (*kacip fatimah*) *Phyllanthus niruri* (*dukung anak*) *Orthosiphon aristatus* (*misai kucing*) *Ficus deltoidea* (*mas cotek*) *Andrographis paniculata* (*hempedu bumi*) *Zingiber officinale* (ginger) *Kaempferia galanga* (*cekur*) *Centella asiatica* (*pegaga*) *Stevia rebaudiana* (stevia)
2	Traditional vegetables	*Solanum spp.* Taro and yam (*Colocasia spp.* and *Xanthosoma spp.*) *Luffa cylindrica* (*petola wangi*) *Euodia redleyi* (*tenggek burung*) *Psophocarpus tetragonobolus* (*kacang botol*)
3	Underutilized fruits	*Lepisanthes fruticosa* (*ceri terengganu*) *Mangifera* spp. *Garcinia* spp. *Baccaurea* spp. *Artocarpus* spp.

Conclusions

From the above discussion, it can be ascertained that UUC offer vast potential benefits and as such study on the evaluation and utilization of these crops should intensify. The importance of these crop species should be disseminated widely so as to encourage everyone, particularly local communities to participate on-farm conservation.

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Country Status Report - Thailand

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Introduction

Thailand can be divided into four parts or regions, these being the North-eastern, North, Central Plain and southern region. Most of the field crops growing areas in each region are under rainfed conditions with only 10 per cent of these areas having access to irrigation (Field Crops Research Institute, 2005; Songkhla Field Crops Research Center, 2002; SFCRC Technical Working Group, 1999). Eight underutilized crops (UUC), soybean, mung bean, peanut, sesame, specialty corns, sorghum, sunflower and bambara groundnut are cultivated.

Area, Production and Productivity

Table 1 provides the planted areas and productivity of the eight UUC in Thailand.

Table 1. Planted areas and productivity of UUC in Thailand

Plants	Planted area (ha)	Productivity (tons/ha)
Soybean	25,783	1.65
Mung bean	135,346	0.73
Peanut	19,825	1.68
Sesame	54,502	0.60
Specialty corns	37,088	13.14
Sorghum	33,651	1.64
Sunflower	26,933	0.72
Bambara groundnut		2.5

Significant Achievements

For conservation of UUC germplasm in Thailand, there are two rooms for seed conservation with MTS (medium term storage) functioning at 5°C, 60% relative humidity (RH) and LTS (long-term storage at -10°C.

Medium term storage (5°C, 60% RH)	Long term storage (-10°C)
• 5-20 years	• 20-50 years
• Room area is 86 m^2 with 24 m height	• The room 76 m^2
• Capacity is about 150,000 accessions	• Capacity is about 40,000 accessions
• Automatic Bullet Crane System	• Vacuumed aluminum foil packages
• Use PET plastic bottles	

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Production of UUCs

Soybean: Soybean is the most important grain legume in Thailand, and is grown in three main seasons. The first season crop is grown in irrigated areas, from mid-December to mid-January, after the rice harvest. The dry season crop is the main crop, which comprises 45-50 per cent of the total soybean planted area. The second crop is grown in the uplands during the early rainy season and is grown from May to mid June. The crop is followed by mung bean cultivation. This planting season accounts for about 25 per cent of the total soybean planted area. The remaining soybean crop is grown in the late rainy season, and grows from August to mid September, after the corn harvest, mainly in the central plains. The late rainy season covers about 25 per cent of the total soybean planting area. Recommended varieties are Chiang Mai 60, SJ.5 and Sri Samrong 1.

Mung bean: Mung bean can be sown throughout the year. Rainy season plantings are normally done on the uplands, due to the sensitivity of mung bean to water-logging. Dry season planting of mung bean is usually done on paddy fields. Traditionally, farmers have grown mung bean in the early and late rainy and dry seasons. Recommended varieties are Chai Nat 84-1, 72, 36.

Peanut: Peanut is grown on small farms in all parts of the country. The major peanut growing areas are in the North and North-East. Peanut generally has three growing seasons: mid May-June for early rainy season; July for the mid rainy season; December until January for dry season under irrigation, and; November for dry season peanut production using the residual soil moisture. Recommended varieties are KhonKaen 84-8, 84-7, 60-2, 5 Tainan 9 Kalasin 2.

Sesame: Sesame is an oilseed crop grown as a supplement alongside main crops such as rice and corn. Sesame is normally grown in the rainfed areas of Thailand, mainly in the upland and mid lowland areas (before rice). In the upland areas of the North and central regions, the planting times are in the early rainy season (March-May) and late rainy season (July). In the mid lowland areas of the North-East and in some parts of the north, farmers grow sesame in the early rainy season (February-April), before rice. Recommended varieties are Ubon Ratchathani 84-2,1, 2, 3.

Specialty corns: Specialty corns consist of sweet corn, waxy corn and baby corn. The production areas for specialty corns are scattered around the country. Production areas for baby corn are usually found in the central part of Thailand, while sweet and waxy corns are mainly grown in the central plain and the North-East, respectively. Recommended varieties are Chai Nat 86-1 (Sweet corn) Chai Nat 84-1 (Waxy corn), Songkhla 84-1 (Sweet corn).

Sorghum: Sorghum is generally referred to as a second crop, grown in the late rainy season. It is mainly corn and soybean that are grown in the early rainy season. The reduction of the sorghum planting area is due to the increasing area used for growing sunflower and area of main crop, corn to grow sugarcane as year-round crop. Recommended varieties are U-thong 1, Suphan Buri 1,60.

Sunflower: Sunflower is utilized mainly in the form of edible oil, but it is also incorporated into snacks, confectioneries and bird feeds. It has planting time during mid August to September. Recommended varieties are Hyson 33 SF-CM Synthetic.

Bambara groundnut: Bambara groundnut is a locally important crop grown widely in the South of Thailand. Bambara groundnut is commonly used as an intercrop in para-rubber plantations, fruit tree orchards and between other young trees before shading becomes a problem for its growth. This crop is mostly used for its fresh pods, similar to peanuts. Other parts or the plant such as the young pods, mature pods and dried seeds can also be used in several dishes and snacks. Recommended varieties are Local variety SongKhla 1.

The financial investments in eight UUCs in Thailand is given in Table 2.

Table 2. Financial investment of UUCs in Thailand

Plants	Financial investment in 2018 (USD)
Soybean	173,810
Mung bean	148,458
Peanut	80,868
Sesame	42,249
Specialty corns	260,175
Sorghum	10,984
Sunflower	9,061
Bambara groundnut	-

Conclusions

There is an urgent need for sustainable development of underutilized species for farmers with respect to the following:

- Seed production
- Types suitable for low water input
- Increasing yield per hectare
- Development of stress tolerant varieties in response to climate change

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Country Status Report - Vietnam

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Introduction

Vietnam is situated in South-East Asia, bordering China, Laos and Cambodia, and has a total land area of 330,541 km^2. Vietnam covers the length of the Indo-Chinese peninsula extending along the South-eastern coastline of Asia for 3,260 km. Vietnam is located between longitude 102°09´ and 109°30´E, and latitude 8°30´ and 23°30´N. Its territory encompasses a vast sea area that includes various islands and the continental shelf. Vietnam is endowed with considerable diversity and can be divided into four physiographic regions. The northern most section of North Mountains consists of rugged and heavily forested mountains and includes the country's highest point at 3,143 m at Fan Si Pan. The Red River Delta is a triangular-shaped alluvial plain that stretches along the Gulf of Tonkin. The Annam Highlands, including the Central Highlands, lie to the South of the delta and form the backbone of Vietnam. The southern most region is the Mekong Delta, stretching from the southern edge of the Central Highlands to the mangrove swamps of the Ca Mau peninsula in the South (Fig. 1).

Vietnam's climate is hot and humid. North Vietnam is located in the tropical zone but has cold winters due to the monsoon influence; the climate is subtropical with a temperate character in the high mountainous areas. The northern part is characterized by large differences in temperature between summer and winter while the southern part is characterized by differences in humidity between the rainy and dry seasons.

Rainfall is plentiful throughout the country, although most precipitation in southern and central Vietnam occurs during summer when monsoon winds sweep in from the sea. The average annual rainfall is about 1,680 mm in the Red River Delta, 1,650 mm along the Central Coast, and 1,980 mm in the Mekong Delta. Typhoons periodically strike the Central Coast, and some have caused considerable loss of life and cropland destruction (ADB, 2013).

The agricultural land area is 27,302,206 ha, or 82.43 per cent of the total land area. Rice is the dominant crop, occupying 36 per cent of total land for agricultural production. Vietnam can be divided into eight eco-agricultural zones (Fig. 1), based on topography, climate, soil pattern and agro-economy. The different ecological zones have different cropping patterns. There are four main starch food crops in Vietnam namely rice, maize, potatoes and cassava. The traditional farming base is an integrated system of rice and other crops. It also reflects major characteristics of agro-forest ecosystems (Phuong *et al*., 2012). Vietnam's share of agricultural economic output declined from about 25 per cent GDP in 2000 to 18.14 per cent GDP in 2016 (World Bank and OECD, 2016; GSO, 2017).

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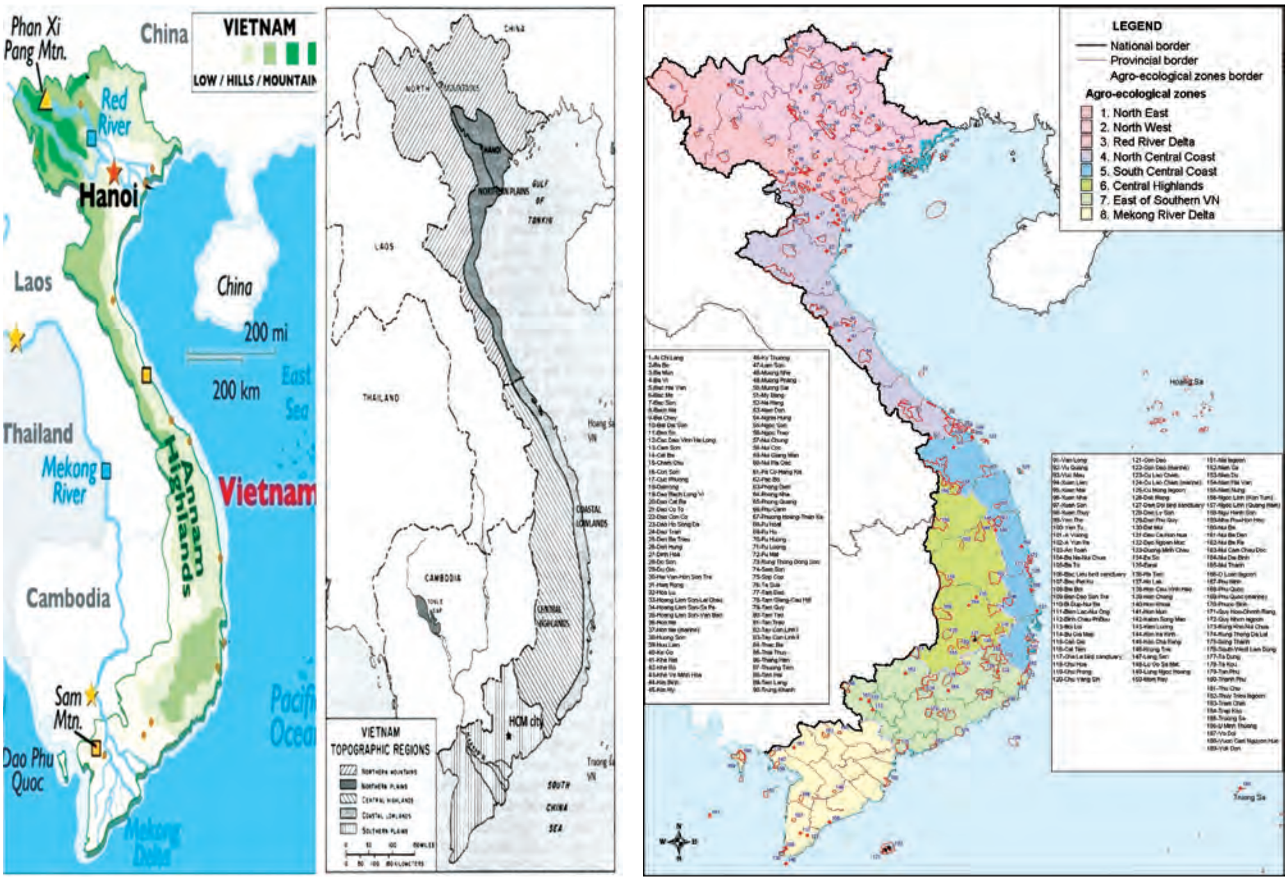

Fig. 1. *Physiographic zones of Vietnam (left and centre); Agro-ecological zones (right)*

Vietnam has diverse plant genetic resources (PGR) excluding water microalgae, with 16,428 recorded plant species (MONRE, 2011) of which 60 per cent originate from Vietnam (Sen and Trinh, 2010). More than 800 plant species are cultivated in diversified agro-systems throughout Vietnam, including starchy foods, non-starchy foods, fruit, vegetables, oil, fibre, beverage, medicinal, spice, cover and bare hill re-greening, ornamental, woody and shading. Regarding fruit plants, there are over 130 recorded fruit species of 39 families including tropical, sub-tropical and temperate origin. The most important tropical fruits are banana, pineapple, mango, papaya, jackfruit, guava, durian, mangosteen, coconut palm, cashew, tamarind, carambola, pomelo, and annona. Subtropical fruits include citrus, litchi, longan, persimmon, and chestnut. Temperate fruits include peach, plum, apricot, apple, pear, and strawberry. A large proportion of the fruit grown in Vietnam is local in origin, many with a diverse genetic base including banana, jackfruit, citrus, carambola and mango (Sen and Trinh, 2010). Crop wild relatives number >1,300 species and include many neglected and underused species. There are also many valuable, untapped species for agriculture (Dinh *et al*., 2009).

Vietnam is predominantly rice country, occupying 94 per cent of arable land, so the cropping pattern is based on it being the staple crop. There are three major crop seasons per year in the north (winter–spring/spring, summer, and winter) and two in the South (wet and dry). In the midland and mountainous regions, other cropping systems exist for upland crops and integrated agroforestry. In recent decades, it has been rapidly increasing the intensive farming systems with higher levels of input per unit of agricultural land area to increase crop productivity, more monoculture areas have been expanding with only one or two varieties of one species to obtain homogeneous output for export particularly rice and corn, this leads serious crop erosion. Being the dominant crop, most government policies and production techniques have focused on rice production. High-yielding rice varieties have largely replaced traditional varieties in Vietnam. As a result, minor crops have gradually disappeared from Vietnamese farming systems.

Food consumption in Vietnam is influenced by regional, ethnic, cultural, income and agricultural production differences. Cereals are the primary source of energy in the Vietnamese ration providing 78 per cent of total energy. The mainly starched food is rice with consumption per capita 166 kg/person/year in 2011 (FAO, 2011; Thang and Hoa, 2016). Average rice consumption per capita is around 400 g per day across all regions. Besides rice, other staple foods, vegetables, tubers, fruits, oily nuts, beans and soy products (sprouts, tofu, soysauce, cakes, and soymilk) are an integral part of the Vietnamese meal. The range of vegetables includes water spinach, Indian spinach, luffa, bottle gourd, radish, broccoli, cabbage, kohlrabi, chayote, pumpkin, squash, jute, amaranth, star-gooseberry, celery, lettuce, beans and fruits. The amount of meat and animal products in the Vietnamese ration has increased significantly since 2000, and there is plentiful seafood.

Area, Production and Productivity

Neglected and Underused Species (NUS) are those that communities have traditionally used for food, fibre, animal fodder, oil or for medicine, but which are seen as having further undeveloped potential uses (Arora, 2014). Most NUS crops tend to be grown by local and smallholder farmers in areas where they are still an important food source for local communities but they remain inadequately characterized and neglected by research, conservation and the economy at large (Markus *et al*., 2007).

The total planted area of the country in 2016 was more than 11 million ha, of which the focus is mainly rice, corn (cereal), roots and tubers; therefore NUS have been lost gradually in agricultural production with about 80 per cent local crop varieties been lost recently. Regarding NUS/crops are fragmented areas and not included in the local production plans, so official statistics for individual minor crops are not available, for example, tubers, other starches, vegetables and legumes (Table 1). There are many plant species have been utilized by local people as vegetables that are nutritious but have not been studied, evaluated and expanded (Table 5). The area, yield and output of perennial fruit trees are presented in Table 2, which lists the main fruit trees. Other minor fruit trees are listed in a group of other fruits (Table 2).

Table 1. Area, production and productivity of annual crops

Crop name	Area (1000 ha)	Yield (quintal/ha)	Output (1000 tons)	Remark
Rice (whole year)	7,790.40	56	43,604.50	
Corn	1,152.40	45.3	5,225.60	
Millets, wheat, barley, sorghum and other cereals	5.1	7.5	3.8	NUS
Sweet potato	121.4	106.2	1,289.10	
Cassava	569.9	191.8	10,931.80	
Taro	11.4	98.9	112.8	NUS
Edible canna	10.5	210.3	220.8	NUS
Other starch crops	16.5	103.8	171.3	NUS
Groundnut	191.3	23.1	441.4	
Soybean	94	15.7	147.5	
Sesame	49	8.4	41.4	
Vegetables	908.1	176.7	16,044.90	NUS
Legumes	159.6	10.7	170.1	NUS

Source : MARD, http://webold.mard.gov.vn/ (viewed 15 Sept., 2017)

Table 2. Area, production and productivity of perennial fruit trees

Crop	Area (ha)	Yield (quintal/ha)	Output (tons)
Grape	1396.3	108.7	15182.3
Mango	84140.3	52.1	438735.9
Banana	131748.7	83.4	1098993.2
Dragon fruit	42944.1	97.6	419310.7
Coconut	40318.6	96.9	390862.1
Sweetsop	20977	25.3	53027.6
Papaya	5360.6	57.1	30632.9
Jackfruit*	18406.8	52.9	97403.1
Guava	10303	77.7	80054.7
Sapodilla	3809.6	82.2	31324.2
Orange	66524.5	36.7	243975.2
Tangerine	18067.5	57.5	103875.7
Pomelos	51128	32.0	163733.2
Apple	5901.2	60.6	35757.7
Plum*	6937.1	50.9	35279.4
Longan	67105	25.5	170795
Litchi	63713.1	46.2	294234.9
Rambutan	25830.9	70.8	182839.1
Other fruits (i.e. langsat, chestnut, Chinese black-olive, sugar palm, wampi, kaki persimmon, etc.)*	29156	42.7	124473.9

Source: MARD, http://webold.mard.gov.vn/ (viewed 15 Sept., 2017)
**indicates NUS*

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Until 2016, more than 26,000 accessions of over 200 plant species including food crops, fruit trees, medicinal plants and some other plant categories are conserved by *ex situ*, *in vitro* and DNA conservation. Simultaneously, *in situ* conservation is being developed for industrial trees and fruit trees which are rare, precious and endemic to some specific regions in Vietnam (Table 3). Some indigenous vegetable sources are preserved *ex situ* and *in situ* in the communities that serve consumption demand of local people and tourists (Tables 4 and 5).

So far, 70 per cent germplasm collections conserved at National Genebank have been evaluated primary characteristics. However, only 6,143 genetic resources (equivalent to 23.6 per cent) have been adequately assessed for their agronomic characteristics. These are mainly rice, maize and other cereals. The minor crop groups were low priority for evaluating agro-traits e.g. indigenous vegetables, some of beans and fruit trees.

Table 3. List of crop genetic resources being conserved in the National Genebank

Crop (crop group)	Accession number	Conservation method
Cereals	11,975	*Ex situ*, ADN
Vegetable, herbs, fungi	4,110	*Ex situ*, *In vitro*
Fruit trees, industrial trees	4,277	*Ex situ*, *In situ*, ADN
Roots and tuber plants	2,282	*Ex situ*, *In vitro*

Crop (crop group)	Accession number	Conservation method
Leguminous crops- beans and peas	3,092	*Ex situ*
Flower and ornamentals	230	*Ex situ, in vitro*
Crops for soil fertility and fodder	123	*Ex situ*
Others	13	*Ex situ*
Total	**26,102**	

Source: Report on conservation status of crop genetic resources, Plant Resources Center (2015-2016)

Table 4. *Ex situ* conservation of wild vegetable germplasm collected from different agro-ecological regions at Plant Resources Center (up to December, 2010)

Agro-ecological regions	Accession (no.)	Species (no.)	Representative species	Characterization and evaluation status
North-West region	1635	53	*Ficus callosa*	Detailed evaluation of agro-morphological characteristics
North-East region	919	57	*Erythropalum scandens*	
Red river delta	848	51	*Meliantha suarvis*	
Central North	533	37	*Gynura procumbens*	
Central South	77	29	*Centella asiatica*	
Highlands	332	50	*Bihaunia viridescens*	
South-East	162	42	*Peperomia pelluciada*	
Mekong delta	139	30	*Moringa oleifera*	

Table 5. On-farm conservation of some indigenous vegetables at Bavi Ecological Tourist Company (BAVIECO) (as on Sept. 30, 2014)

Local name	Scientific name	Size	Utilization part
Tai voi (Xích đồng nam)	*Clerodendrrum japonicum*	100 plants	Leaves
Bướm xanh (Móng bò xanh)	*Bauhinia viridescens*	50 plants	Leaves, young fruits
Cây Báng (Da chai, Gừa)	*Ficus callosa*	50 plants	Yong leaves, fruits
Tai sóc D1 (Chùm ngây) *Rau Tai sóc dạng 2*	*Moringa oleifera*	50 plants 3 plants	Young leaves, fruits
Rau Lưỡi hổ (Bồ công anh VN)	*Lactuca indica*	50 m^2	Leaves
Rau sau sau/ Thau	*Liquidambar formosana*	10 m^2	Shoots, young leaves
Rau ngót rừng	*Sauropus androgynus*	500 m^2	Leaves
Rau càng cua (Đơn kim)	*Bindens pilosa*	200 m^2	Leaves
Rau chua đỏ	*Hibiscus sabdariffa*	30 m^2	Leaves.
Rau mơ rừng	*Paederia foetida*	30 m^2	Leaves
Bướm Trắng (Móng bò trắng)	*Bauhinia aculata*	10 plants	Flowers
Măng củ	*Bamboos multiplex*	500 m^2	Young shoots
Xương sông	*Blumia lanceolaria*	30 plants	Leaves
Bưởi bung	*Toddalia tonkinensis*	30 plants	Leaves
Rau lang đồi	*Ipomoea batatas*	200 m^2	Leaves
Rau rút rừng (Họ Trinh nữ)		20 plants	Young shoots, leaves
Bò Khai	*Erythropalum scandens*	10 plants	Young leaves

Local name	Scientific name	Size	Utilization part
Rau muống đồi	*Ipomoea aquatica*	200 m^2	Leaves
Đậu khế (Đậu rồng)	*Psophocarpus tetregonolobus*	200 m^2	Leaves
Rau Sắng	*Meliantha suavis*	5 plants	Leaves
Rau xương chua	*Hibiscus surattensis*	10 plants	Leaves
Rau Vách núi (lốt rừng)	*Piper lolot*	50 m^2	Leaves
Cây cánh gà	*Strophioblachia fimbricalyx*	50 plants	Leaves
Rau cải mán	*Brassica juncea*	200 m^2	Leaves
Mướp rừng (lặc lày)	*Trichosanthes anguina*	100 m^2	Fruits

Source: Report of five-year conservation of some indigenous vegetable (2010-2014), Plant Resources Centre (2014)

Nutritional value of prioritized UUC from Vietnam: Lack of micronutrients causes bad effects on health, physical development, intellectual development but people do not feel this deficiency. As a result, micronutrient deficiencies are also termed "latent hunger." Micronutrient deficiencies include: Vitamin A, D, B1, C, K, B12 deficiency, riboflavin, folic acid, and minerals such as iodine, iron, zinc, manganese and selenium. In Vietnam, micronutrient deficiencies such as vitamin A, anemia and zinc are still unsolved problems. In comparison with other countries in the region and in the world, the lack of micronutrients (iodine, vitamin A, iron, zinc, folate) in Vietnam is still high, most concentrated in rural and mountainous areas (Vietnam Ministry of Health, 2012; 2016). These vitamins and micronutrients can be added to the body through using diversity of local and indigenous NUS products. So the priority UUC are listed in Table 6.

Table 6. List of neglected and underutilized species and their priority in Vietnam

English/Local name	Scientific name	Accessions	Priority
1. Cereals			
Finger millet/ *Kê chân vịt*	*Eleusine coracana*	74	I
Foxtail millet/ *Kê đuôi chồn*	*Setaria italica*	37	V
Pearl millet/ *Kê trân châu*	*Pennisetum glaucum*	45	VI
Proso millet/ *Kê châu âu*	*Panicum miliaceum*	16	
Sorghum/ *Cao lương*	*Sorghum bicolor*	301	IV
Buckwheat/ *Tam giác mạch*	*Fagopyrum esculentum*	20	II
Adlay millet / *Ý dĩ*	*Coix lacryma-jobi*	115	III
2. Roots and Tubers			
Taro/ Khoai *môn sọ*	*Colocasia esculenta*	779	I
Arrowroot/ *Hoàng tinh ngự*	*Maranta arundinacea*	3	
Greater yam/ *Củ mỡ*	*Dioscorea alata*	117	II
Asiatic yam/ *Củ từ*	*Dioscorea esculenta*	80	V
Tannia/ *Khoai mùng*	*Xanthosoma sagittifolium*	155	VI
Edible canna/ *Dong riềng*	*Canna edulis*	61	IV
Elephant-yam/ *Khoainưa*	*Amorphophallus konjac/ A. campanulatus*	13	III
Mealy kudzu/ *Sắn dây*	*Pueraria thomsoni*	3	
Chinese yam/ *Hoài sơn*	*Dioscorea opposita*	1	
Yam/ Khoai *vạc dại*	*Dioscorea persimilis*	2	
3. Nuts and Pulses			
Azukibean/ *Đậu đỏ*	*Vigna angularis*	76	IV

English/Local name	Scientific name	Accessions	Priority
Lima bean/ *Đậu ngự*	*Phaseolus lunatus*	37	VI
Ricebean/ *Đậu nho nhe*	*Vigna umbellate*	49	III
Cowpea/ *Đậu các loại*	*Vigna unguiculata*	1193	I
Velvet bean/ *Đậu mèo*	*Mucuna cochinchinensis*	65	
Snap bean/ *Đậu cô ve*	*Phaseolus vulgaris*	588	V
Sword-bean/ *Đậu kiếm*	*Canavalia gladiata*	39	
Mungbean/ *Đậu xanh*	*Vigna radiata*	701	II
Chickpea/ *Đậu gà*	*Cicer arietinum*	25	
Lablab-bean/ *Đậu ván*	*Lablab purpureus*	205	
4. Horticulture			
Potato-bean/ *Cây củ đậu*	*Pachyrhizus erosus*	115	V
Amaranth/ *Rau dền*	*Amaranthus* spp. (*A. acutilobius; A. tricolor; A. caudatus; A. spinosus; A. viridis*)	330	I
Yardlong bean/ *đậu đũa*	*Vigna unguiculata* subsp. *unguiculata* forma *sesquipedalis*	578	
Gigantea/ *Dọc mùng*	*Colocasia gigantea*	13	
Pumpkin/ *Bí ngô*	*Cucurbita moschata*	600	III
Chives/ *Hẹ*	*Allium tuberosum*	6	IV
Cardiopteris/ *Lắc lày*	*Cardiopteris quinqueloba*	35	II
Snake gourd/ *Dưa trời*	*Trichosanthes anguina*	30	
Melientha/ *Rau sắng*	*Melientha suavis*	2	VI
Winged bean/ *Đậu rồng*	*Psophocarpus tetragonolobus*	35	
5. Others			
Banana/ *Chuối*	*Musa acuminate*	254	
Jackfruit/ *Mít*	*Artocarpus heterophyllus*	7	I
Langsat/ *Bòn bon*	*Lansium domesticum*	5	II
Chestnut/ *Dẻ Trùng Khánh*	*Castanea mollissima*	1	
Chinese black-olive/ *Trám*	*Canarium tramdenum/ C. album*		III
Sugar palm/ *Búng báng*	*Arenga pinnata*	wild	
Wampi/ *Quất hồng bì*	*Clausena lansium*	1	IV
Kaki persimmon/ *Hồng*	*Diospyros kaki*	5	VI
Plum/ *Mận*	*Prunus salicina*	4	V

In terms of nutritional requirements and adaptability to climate change, many UUC meet the criteria, as shown in Table 6. However, Table 7 gives first priority list for R&D in Vietnam, so as to meet all the social and economic criteria, and give farmers the opportunity to make extra income.

Variety Development

Up to now, all agencies of the national network of plant resource conservation system have bred and introduced 152 new varieties by utilizing the PGR. The Plant Resources Center has successfully utilized traditional germplasm to research and expand for production, such as 10 rice varieties including herbal coloured rice (red and black); 7 taro varieties, 3 bean varieties; indigenous vegetables varieties; 9 flower and ornamental plants; Some varieties of sweet potato, tubers. Recently, some nutritious NUS/UUC having good commercial value have been promoted for use such as gac, buckwheat, yam, taro and red bean.

Table 7. Prioritized list of NUS for R&D in Vietnam

English/Local name	Scientific name	Agro-ecological zone	Characteristics
Cereals			
Buckwheat/ *mạch ba góc*	*Fagopyrum esculentum*	North-West and North-East	This annual plant is well-adapted to moist climate but has weak cold tolerance. It grows well at temperatures of 15-22°C and takes 70-90 days to mature.
Roots and Tubers			
Taro/ *Khoai môn sọ*	*Colocasia esculenta*	Nationwide	An annual plant and tuber stem. Taro thrives in poor soil and attracts few diseases and pests. It is good for intercropping and rotation with other crops
Greater yam/ *Củ mỡ*	*Dioscorea alata*	Nationwide	This perennial is suitable for intercropping and can be grown from seeds or tubers.
Nuts and Pulses			
Cowpea/ *Đậu các loại*	*Vigna unguiculata*	Nationwide except Mekong River Delta	A drought-tolerant and warm-weather crop, well-adapted to the drier regions with poor soils. It is good for intercropping.
Mungbean/ *Đậu xanh*	*Vigna radiata*	Nationwide	Erect or semi-erect, herbaceous annual that thrives in the warm seasons. It improves soil *via* nitrogen fixation and can be easily intercropped.
Horticulture			
Pumpkin/ *Bí ngô*	*Cucurbita moschata*	Nationwide	Annual, herbaceous, climber with tolerance to hot, humid weather and resistance to disease and insects.

Cultivation Practices

Cultivation practice is the application of agro-forestry models. This can improve the incomes of local community and ensures sustainable use of land in accordance with sustainable forest management such as: model of growing cinnamon with rice, corn, cassava of Dao ethinic minority group in provinces of Lao Cai, Yen Bai, Quang Ninh and Quang Nam; the model of cinnamon grown under the forest canopy or in gaps in the forest of K'Ho ethnic minority people in Quang Nam and Quang Ngai provinces, the model of bamboo combined with corn and upland rice in the first two years of bamboo growth period of Muong ethnic minority people in Thanh Hoa province, the model of growing tea under forest canopy of bodhi, pine and acacia plants in the Northern mountainous provinces; the model of growing pineapple under the forest canopy and the model of growing cardamom under the forest canopy of ethnic minorities in Yen Bai province.

Processing, Value Addition and Product Development

In order to develop market-oriented agricultural products, there have been many initiatives to support local communities to develop their products such as One Commune One Product (OCOP) programme. It is a solution to develop the economy from agricultural products and others that are potential advantages of the regions are still not yet promoted previously. It creates the linkage in the chain from production to consumption. In this programme, the State plays the role of creating a "playground" by promulgating appropriate mechanisms and policies to support development such as knowledge training, credit interest support, product standards, promotion and orientation to product distribution channels and people play a major role in this platform, they decide themselves to choose and develop what products have competitive advantages. In the meantime, farmers must make sure that the products are of the best quality in accordance with the standards to meet the market demand. The OCOP started since 2013 in Quang Ninh province and has produced 210 branded products and many of them are originated from NUS.

Some localities have been promoting the processing of NUS products linkage with tourism, landscape and traditional agro-ecological systems such as buckwheat in Dong Van Karst Plateau, Ha Giang province; herbal coloured rice in Soc Trang province, folk remedies of Red Dao people made from herbal plants in Lao Cai province etc.

Disease and Pest Management

NUS trees are small areas, fragmented or semi-wild existence, therefore pests and diseases have not been addressed at large production level therefore this issue is done at research institutions for the target crops in R&D projects. In addition, due to the diversity of NUS, pests are not able to break out the epidemic. NUS trees often have the advantage of adapting to local ecological conditions so being a limiting factor for pests and diseases.

Challenges and Opportunities

Most UUC tend to be grown by local and smallholder farmers in areas where they are still an important food source for local communities. They could also be crops that were once widely grown but have fallen into disuse due to a variety of agronomic, genetic, economic and cultural factors. Some of these species may be globally distributed, but tend to occupy special niches in the local ecology and in production and consumption systems (Padulosi *et al.*, 2013). While these crops continue to be maintained by sociocultural preferences and use practices, they remain inadequately characterized and neglected by research, conservation and the economy at large.

Some UUC have nutritional value and potential for economic value can be developed commodities, others have local use in terms of nutrition, food and culture. Many consumers are increasingly interested in UUC products due to the movement of using organic safety products. Most UUC have been contributing to ensuring food security and nutritional balance for a part of native people living in areas with difficult socio-economic conditions.

In Vietnam, climate change is a major impact on UUC. Epidemics are going to be complicated and easy to outbreak, then urbanization and conversion of land use will deprive the habitat of many UUC groups (François Fortier, 2010; Ole Bruun *et al.*, 2013). High input costs such as fertilizer, pesticides, variable market trends, linkage of product chain not tight by participating stakeholders, are some of the important issues. There is no concentrated material area due to small production area; UUC product quality is not uniform so it is difficult to produce large commodities and low economic value. The UUC are of less concern to the government policies, although they have significant contributions to food security and local livelihood, especially for disadvantage groups or ethnic minority people.

General communication and awareness are limited issues. Information on many UUC is only mentioned in botany dictionaries and in the list of medicinal plants or valuable crops species or on relevant websites. Only scientists, few local people and business persons are interested in information on UUC functions and biological characteristics. People are still lacking in information on UUC, because knowledge on this group is rarely disseminated by mass media. Meanwhile, popular or commonly used crops/plants are more often mentioned in the extension programmes, in television, radio, newspapers or on websites. The displayed information is on marketing issues, productions, post-harvest techniques, biological characteristics, etc. Villagers themselves do not understand the full value of the UUC trees so most knowledge is based on local knowledge passed on from generation to generation and utilization is according to the habit and traditional experience. However, this information is still scatted and less systematic.

Marketing, Commercialization and Trade

Vietnam is basically agricultural economy with 63 provinces and cities, each province has high plant diversity, and some of them are endemic or valuable crops which can be made specialties with different advantages. As mentioned before, there are various crops and plant species of high potential values but under-developed and underutilized. Promoting their development and commercialization has been of insufficient concern. This is because of the lack of appropriate long-term plans/strategies and visions, and also of suitable policies. While farmers focused their attention mainly on the plants that bring them immediate and clearly foreseen income, scientists are in short of resources to carry out researches and demonstrations to farmers the benefits of growing under-utilized plants. In addition, there is very limited good quality seed source of these plants; institutions did not spend their limited budgets for production of, and trade in, low demand seeds. Marketing of UUC products is also difficult, requiring not only time and effort but also significant financial inputs.

To increase the market value of UUC, some provinces addressed the primary causes of underutilization. On the demand side, it is necessary to comprehend the impediments to increasing demand and how to overcome them. An underutilized plant species cannot be successfully commercialized without a well-articulated and strong demand for its products. At present, some provinces have started to build their brands and promote their products, most of which come from the NUS.

A successful marketing chain must be able to bring a product of satisfactory quality onto the market at a reasonable price. Stakeholders including farmers, government, enterprises and researchers have also been actively involved in some supply chains for domestic and export markets. There are NUS products that are variously processed, good quality and packaged and labeled with food safety and hygiene standards. These products are preferably used by consumers in exploiting nutritional and medical aspect such as herbal colored rice, buckwheat, Gac fruit, jackfruit, tubers and indigenous vegetables, etc. Some localities built mechanism for supply control. One example is One Community One Product (OCOP) programme stared since 2013 in Quang Ninh province has now expanding to other provinces. Other example is Herbal bath remedy made from hundreds different plant species by Red Dao ethnic group was developed by the Sapanapro Company at Lao Cai province, so far, this product became famous nationwide and they expanded some other herbal products.

Strategies Adopted to Harness their Potential

Most of the documents related to underutilized plant species can be accessed in the libraries of MARD, the Vietnam Academy for Agricultural Sciences (VAAS), the Institute of Ecology and Biological Resources and the National Institute of Medicinal Materials (NIMM). A total of 120 policy-related documents were collected and reviewed, and 76 of them were found to be concerned with promoting or inhibiting the advancement of NUS, at different levels (Binh, 2006; Dinh *et al*., 2009).

Recently, the government has commissioned a project to strengthen the capacity to manage access and benefit sharing arising from the use of genetic resources (strengthening national capacity to perform Nagoya Protocol - ABS). The Programme for the Conservation and Sustainable Use of Genetic Resources by 2025, and the 2030 vision; and Decree no. 59/2017 / ND-CP on management of access to genetic resources and benefit sharing from the use of genetic resources. All the mentioned documents are directly or indirectly related to NUS.

Major Focus Areas

To promoting the exploitation and utilization of NUS as future food crops, the government should invest in the following areas:

- General communication, awareness and understanding of the value of NUS, for policy makers, NGOs, scientists and local people needs to be improved.
- Encourage all stakeholders (farmers, NGOs, scientists and policy makers) to develop strategies for a sustainable use of NUS and preventing genetic erosion. Home garden conservation should be a point of interest.

- Establishing and strengthening facilities for *in situ* and *ex situ* conservation for NUS. A network for conservation and exchange of genetic resources is needed.
- Profound research on ecological conditions, culture, and customary laws influence on exploitation and conservation of NUS.
- Planning area for NUS under master plan should be developed for stabilizing NUS in long-term.
- Research and recommend propagation, cultural practices, pest and disease control, post-harvest techniques for NUS.
- Developing marketing channel for NUS.

Infrastructure, Capacity Building and Financial Investment

At present, infrastructure development, capacity building and financial investment for NUS have not been programmed separately from the Vietnam government. There are some research projects that exploit and use genetic resources regarding economic, rare and endemic species under the programme on conservation and sustainable use of genetic resources mentioned in Section 6. In addition, the Vietnamese Government's orientation is socialization to mobilize resources from businesses for research and developing commercial gene sources.

Case Studies/Success Stories for Improvement of Health and Livelihoods

Development of herbal remedies for Dao people to improve their income for the native community and promote health: Sapanapro is the unique community based company of the Red Dao ethnic group who provide medical services, formed and produced by a group of artisans of Ta Phin commune and scientists from Hanoi University of Medicine and Hanoi Agricultural University. This combination has created a unique and valuable product line for the Sapanapro Company and community health.

In the indigenous knowledge on herbal medicine and ethno-botany, women also know more about herbs that can be used for treatment of common diseases of humans and animals. For some ethnic minority groups, such as H'mong, Dao and San Diu, the finding and processing of herbal medicines seems to be the main task of women. Therefore, encouragement of women participation in biodiversity conservation and the activities of responding to climate change are very important in order to ensure the success. The Red Dao artisans are women who impart knowledge about traditional herbs which learned from their ancestor, how to find, collect and produce medicaments for bathing different ages of men and women. The Sapanapro Company organizes people to collect medicinal plants in a sustainable way, preserving and propagating medicinal plants. People benefit from commercialized products, the community and tourists using healthy remedies. Some pictures by Dao'spa - Sapanapro are given in Fig. 2.

Future Thrust

Considering challenges under climate change scenarios, thrust to continue research, exploitation and utilization of NUS is foreseen. Based on financial and socio-economic conditions, selection and prioritization of some NUS for adequate investments in research, development and expansion of production in appropriate areas to be undertaken. Priorities of NUS groups should be targeted for cereals and pseudo-cereals, roots and tubers, nuts and pulses, horticulture, and others. Priority of NUS should also be based on factors such as nutritional value, productivity, adaptation to ecological conditions, cultivation practices, harvest and post-harvest, socioeconomic status, etc. Based on that, interventions in support of NUS are many and include:

- The development of better varieties
- Improved cultivation practices
- Enhanced value addition technologies

__Fig. 2a.__ Red Dao women collecting and processing plants for herbal remedies

__Fig. 2b.__ Some herbal medicinal products from Red Dao- Sapanapro Company

- Better access of producers to markets
- Validation and promotion of nutritional benefits
- More effective maintenance of genetic and cultural diversity on-farm
- Sustained capacity building of stakeholder groups
- Policies at the national and international levels for supporting the sustainable conservation and use of these crops

Conclusions

The NUS continue to play an important role in the subsistence and economy of poor people throughout the developing world, particularly in the agro-biodiversity-rich tropics. Despite their potential for dietary diversification and the provision of micronutrients such as vitamins and minerals, they attract little R&D

attention. Along with their commercial potential, many of the UUC also provide important environmental services, as they are adapted to marginal soil and climate conditions.

The UUC in Vietnam represent considerable biodiversity and great potential to contribute to improving the local income, food security and nutrition (micronutrients such as vitamins and minerals). It is suitable for National target programmes and National nutrition strategy for 2011-2020 with vision towards 2030.

Acutely aware of the importance of biological resources, in particular, agricultural resources, for the sustainable development of the country, the Vietnam government has directed relevant agencies to issue policies and regulations for the conservation and exploitation of agricultural genetic resources. Minor crops such as FSF are of less concern to the government agencies, but they provide food and valuable nutrition for enhancing human health, with significant contributions to food security and local livelihoods, especially for disadvantaged groups or ethnic minorities who live in remote mountainous areas. These crops are less used or neglected and lack the necessary investment in R&D to expand production. The UNDP warned against genetic degradation due to commercial agriculture in Vietnam.

The indigenous knowledge attached to NUS in general and FSF, in particular, has not been well studied. Thus, various NUS and crop relatives of agricultural value may not have been included in the list of plants to be protected and developed for sustainable use. Another limitation is that only a small number of natural protected sites have been established despite the country's diverse topographical, ecological and other natural conditions. Moreover, existing sites have not been properly managed due to both technical and financial limits. The weak and incomplete database is also a major limitation. Information sharing is limited among stakeholders.

The main cause of the erosion of crop-related NUS is a lack of strategic, long-term plans as well as appropriate policies. Farmers usually focus on producing crops with immediate benefit; even scientists do not have sufficient resources to implement the necessary research and management to promote the benefits of NUS. Also, seeds of NUS are limited because agencies/companies are not willing to provide funds for the production and commercialization of lower-demand crops. Market development of agricultural products for these plants will face difficulties, not only with time and effort but a financial investment.

Therefore, NUS are important crops for our present and future. The review and development of policies for NUS conservation and use are urgently needed. With the current population pressure, urbanization and climate change, NUS genetic resources are being eroded, so it is important to develop mechanisms, policies and national strategies, and resources investment to promote the exploitation and sustainable use of these precious genetic resources. The main recommendations are to: (i) provide policy support for conservation (*in situ*/*ex situ*; central or community genebank); (ii) expand national database and documentation; (iii) improve communication networks and public media (papers, advertising, TV); (iv) allow communities to participate in FSF development, (v) develop marketing channels; (vi) plan areas for NUS development; (vii) provides government subsidies for training, fertilizer use and farm techniques.

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Country Status Report - The Philippines

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Introduction

Fruits and vegetables are key component of a healthy diet. These also constitute the Filipino diet. However, a Food and Nutrition Research Institute of the Department of Science and Technology (DOST-FNRI) study in 2013 showed that fruits and vegetables consumption of Filipinos does not meet the recommended amount of fruits and vegetables per meal (Buencamino, 2016). Per capita consumption of fruits and vegetables in the Philippines is relatively low with only 31 kg and 22 kg, respectively (PSA, 2017a). Worse, hunger and malnutrition continue to persist in the high poverty and low-income population.

The Philippines has adopted the global 2030 Sustainable Development Agenda which targets to end hunger and all forms of malnutrition by 2030 (Briones *et al.,* 2017). In particular, the Sustainable Development Goal No. 2 under the said agenda aims to end hunger by ensuring access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round. One of the strategies to achieve this goal is to promote increased dietary diversity in communities under nutrition-sensitive production systems. Dietary diversity is where several underutilized crops (UUC) can be utilized as available and accessible food sources. Among the UUC in the Philippines are fruits, vegetables, root crops and a cereal.

There are more than 300 edible fruit and nut species reported from the Philippines. Among the major fruits are banana (*Musa* sp.), pineapple (*Ananas comosus*), mango (*Mangifera indica*), and *calamansi* (*Citrofortunella microcarpa*) (PSA, 2017b). Fruit crops grown in the Philippines that have lesser economic importance than the major fruits are considered as minor fruits. The remaining fruit species which are neither major nor minor are considered as underutilized (Coronel, 2011).

Of the 300 fruit species that have been recorded in the country, 170 species are indigenous or native to the Philippines. Most of these indigenous fruits are either underutilized or neglected. Listed in Table 1 are some of the native fruit species (Fig. 1). The uses of these fruits vary from being eaten raw, processed into products such as jams and wines, or cooked as vegetable. Further, many underutilized fruits have potential for commercial production because of the known products that can be derived from them. For instance, *duhat* or black plum (*Syzygium cumini*) and *bignay* (*Antidesma bunius*) are potential sources of anthocyanin extracts that has nutraceutical and antioxidant properties (Jebitta and Allwin, 2016). There are also underutilized fruits introduced to the Philippines such as *abiu* (*Pouteria caimito*) and miracle fruit (*Synsepalum dulcificum*).

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Fig. 1. *Selected indigenous fruit species in the Philippines*

Table 1. Botanical classification of some fruit species indigenous to the Philippines

Common name	Scientific name	Family
Galo	*Anacolosa frutescens*	Olacaceae
Kamansi	*Artocarpus camansi*	Moraceae
Pili	*Canarium ovatum*	Burseraceae
Kubili	*Cubilia cubili*	Sapindaceae
Mabolo	*Diospyrus blancoi*	Ebenaceae
Binukaw	*Garcinia binukaw*	Clusiaceae
Alupag	*Litchi chinensis* subsp. *Philippinensis*	Sapindaceae
Paho	*Mangifera altissima*	Anacardiaceae
Dagwey	*Sauraria bontocensis*	Dilleniaceae
Lipote	*Syzygium curanii*	Myrtaceae
Alimani	*Vaccinium myrtoides*	Ericaceae

Source: Coronel (2011)

Indigenous vegetables (IV) are also an important component of traditional farming systems and home gardens in the Philippines. It includes those that are naturalized or materials from another geographical area and grown over a long period of time. They have been an indispensable component of the Filipino food. However, they are underutilized despite their recognized importance in supplementing food and nutritional need of the people.

The DOST-FNRI reported the following IV in the Philippines: *alugbati* (*Basella alba*), *alukon* or *himbabao* (*Broussonetia luzonica*), *katuray* (*Sesbania grandiflora*), *kulitis* (*Amaranthus viridis*), *kadyos* (*Cajanus cajan*), *kalabasa* (*Cucurbita maxima*), *labanos* (*Raphanus sativus*), *labong* (*Bambusa sp.*), *malunggay* (*Moringa oleifera*), *mustasa* (*Brassica juncea*), *pako* (*Athyrium esculentum*), *patola* (*Luffa acutangula*), *pipino* (*Cucumis sativus*), *saluyot* (*Corchorus olitorius*), *sayote* (*Sechium edule*), *sigarilyas* (*Psophocarpus tetragonolobus*), *sitaw* (*Vigna unguiculata* ssp. *sesquipedalis*), *talinum* (*Talinum triangulare*), *talong* (*Solanum melongena*) and *upo* (*Lagenaria siceraria*).

Nine traditional (IV) for health and wellness have also been identified by the Department of Agriculture-Bureau of Agricultural Research (DA-BAR), Bureau of Plant Industry (BPI), and the University of the Philippines Los Baños (UPLB). These include *malunggay, alugbati, saluyot, talinum, ampalaya* (*Momordica charantia*), *labong, kulitis, paco* and *himbabao*. These plants have been reported to have phytochemicals which have antioxidant, anti-cancer, anti-inflammatory and cholesterol-lowering properties.

Major root crops in the Philippines are sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), potato (*Solanum tuberosum*) and yam or *ubi* (*Dioscorea esculenta*) which are usually utilized for food and/or feed. On the other hand, taro or *gabi* (*Colocasia esculenta*) is classified as a minor root crop (Pardales *et al*., 2002) but is now gaining popularity because of its essential nutrients and vitamins. Another UUC is *adlai* (*Coix lacryma-jobi*), a cereal that is given attention because of its potential as staple food.

UUC with Potential Value

Amongst the different species of fruits, vegetables and root crops described above, this report will only focus on *duhat* and *bignay* which have potential in nutraceuticals, and *pili* as an important food source, rich in vitamins and minerals (Imperial, 2012). *Adlai*, taro or *gabi*, and underutilized vegetables *katuray*, *kulitis* and *pako*, will also be discussed as potential food sources to address nutritional gaps.

Fruits

One of the underutilized fruit is *duhat* (*Syzygium cumini*). It is an invasive species and fast growing, preferring moist, riverine habitats, that is valued for its fruit, and as such has been widely introduced from its native South Asia. Fruit is sweet and readily consumed. It has naturalized in many other countries where introduced and is likely to spread further.

Another fruit species, *bignay* (*Antidesma bunius*), is a small, smooth, 4 to 10 meters high dioecious tree, with 8-10 cm long, shiny and oblong leaves, pointed at the tip, rounded or pointed at the base. Spikes are axillary or terminal, simple, and usually 5-15 cm long. Flowers are small and green. Fruit is fleshy, red, acid, edible, ovoid, and about 8 mm long, single-seeded, and borne in grapelike pendant clusters (often paired), wrinkled when dry, the seed becoming somewhat compressed (Stuart, 2017). Common from northern Luzon to Mindanao, occasional in forests. Also reported in Sri Lanka, India, eastern Himalaya, Burma, Indo-China, China, Thailand, Indonesia, and Australia.

Pili (*Canarium ovatum*) is an indigenous tree nut species in the Philippines (Coronel, 1996). The seedling trees of *pili* start flowering and fruiting 5-6 years after seed germination. Most flushes in mature trees are reproductive, and the trees may live to be more than 100 years.

Vegetables

Katuray (*Sesbania grandiflora*) is a small, erect, fast-growing tree, 5-12 m high (Fig. 2). Leaves are pinnate, 20-30 cm long, with 20-40 pairs of leaflets which are 2.5 to 3.5 cm long. Flowers are white to purple, 7-9 cm long. Pods are linear, 20-60 cm long, 7-8 mm wide, pendulous and somewhat curved, containing many seeds (Stuart, 2016). It usually grows at low and medium altitudes from northern Luzon to Mindanao.

Himbabao (*Broussonetia luzonica*) is a tree reaching a height of about 10 m and a diameter of 40 cm. Leaves are simple, alternate, ovately oblong, membranous, 15 cm in length and 7 cm wide, acute or acuminate. It can be grown throughout the Philippines in thickets, secondary and lower edges of forests, at low or medium altitudes, grows up to 15 m. Young leaves and flowers are used as vegetable food (Fig. 2).

Kulitis (*Amaranthus viridis*) (Fig. 3) is possibly of Asian origin, but now it has become a cosmopolitan weed (Das, 2016) in the tropical and subtropical regions of the world, also reaching far into temperate regions. It is an annual herb, attaining height of 75-100 cm. Stems are rather slender,

Fig. 2. *Indigenous flower vegetables in the Philippines, katuray (Sesbania grandiflora) (left) and himbabao (Broussonetia luzonica) (right)*

Fig. 3. *Indigenous leafy vegetables in the Philippines, kulitis (Amaranthus viridis) (left) and pako (Athyrium esculentum) (right) (Image Credit: Prof. Nestor C. Altoveros, UPLB).*

sparingly to considerably branched, angular, glabrous or more frequently increasingly hair upwards. Leaves are glabrous or shortly to fairly long pilose on the lower surface of the primary and most of the venation.

Pako (*Athyrium esculentum*), naturalized *paca,* is an edible fern (Fig. 3). It is medium-sized, terrestrial, usually unbranched and slender. Usually thrives in large, untidy, straggly stands in shady valleys with wet, swampy soils, often along streams, at lower elevations. This is commonly eaten from South-East Asia and the Pacific and was probably introduced as a garden vegetable.

Root crop

Taro or locally known as *gabi* is an herbaceous plant which grows to a height of 1-2 m. The plant consists of a central corm (lying just below the soil surface) from which leaves grow upwards, roots grown downwards, while cormels, daughter corms and runners (stolons) grow laterally (Fig. 4). This crop is commonly planted in areas not really suitable for its culture since traditional staples (i.e., rice and corn) and vegetables are given priority to occupy good production areas (ViCAARP, 1987).

Fig. 4. *Gabi (Colocasia esculenta) plant (left) and its corm (right)*

Cereal crop

Another UUC which is a potential alternative to Filipino staple food (rice and corn) is *adlai* (*Coix lacryma-jobi*) (Fig. 5). In fact, the Department of Agriculture (DA) has been promoting *adlai* as a staple food since 2010 under its Food Staples Sufficiency Program (FSSP) (Domingo, 2016). *Adlai* is a tall-grain bearing tropical plant from Poaceae (grass family), the same family to which wheat, corn, and rice belong. It has been abundantly growing in the country and is being cultivated since ancient times as staple food. In Midsalip, Zamboanga del Sur, *adlai* is extensively cultivated synonymous to rice (Dela Cruz, 2011).

Fig. 5. *Seeds of adlai (Coix lacryma-jobi)*

Area, Production and Productivity

In the year 2015, total area planted with *pili* was 2,288 ha while total number of bearing trees was 164,901. The Bicol region, major producer of *pili* in the country, accounts for 76 per cent of the total area planted under *pili* in the Philippines. Volume of production in the same year was 7,362 mt (PSA, 2017c). For taro, area planted in the same year was 15,345 ha while volume of production was 111,988 mt. The statistics on the area and volume of production of IV are not available. Further, while researches on *adlai*, *duhat*, and *bignay* have been conducted, data on area and production are limited.

Significant Achievements

Different varieties and accessions of indigenous and introduced fruit, cereal, vegetable, and root crop species including those mentioned in this report, are being maintained at the National Plant Genetic Resources Laboratory (NPGRL) located at the Institute of Plant Breeding (IPB), University of the Philippines Los Baños (IPB-UPLB). The NPGRL is the Philippines germplasm bank of economically important plants in Asia and South-East Asia. The bank ensures biodiversity and conservation of useful, traditional and wild varieties as genetic resources for breeding new improved varieties and for future utilization.

Further, an ongoing programme titled 'Restoring Crop Diversity at the National Germplasm Repository' funded by the DOST and Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) focused on the collection, regeneration and conservation, characterization, evaluation, and assessment of diversity and sustainable utilization of fruit and vegetables genetic resources which also covered the focused UUC in this report. The said programme has six projects, wherein Projects 1, 3, and 6 deal with vegetables, cereals, and fruit crops, respectively.

IV are also a priority of the Bureau of Plant Industry, Los Baños National Crop Research, Development and Production Support Center (BPI-LBNCRDPSC). Numerous species are currently conserved at their genebank located at Los Baños, Laguna.

Varietal improvement has also been initiated with UUC. For instance, the recommended varieties for *pili* are 'Lanuza', 'Laysa', 'Magayon', 'Magnaye', 'Orolfo'. These varieties are high yielding, bear fruits all year round, produce large fruits (33.6-39.5 g), and tolerant to pest and diseases. Other registered varieties are 'Katutubo', 'Mayon', and 'Oas'. With *duhat*, the commonly grown varieties are 'Seedless' and 'Giant'. Studies conducted by the Department of Agriculture Regional Field Unit 4 (DA-RFU 4) identified four local varieties of *adlai* in the southern Philippines. These include 'Gulian' (white), 'Tapol' (purple), 'Ginampay' (brown), and 'Pulot' (white glutinous) (DA-RFU 4). Other commonly grown varieties identified through adaptability trials were 'linay', 'mataslai', 'agle gestakyan', 'NOMIAC dwarf', 'jalayhay', and 'ag-gey' (Domingo, 2016).

For cultivation practices, a trial propagation of *himbabao* using stem cuttings was conducted. While in processing, value addition and product development, *pili* and *duhat* have high potential in these areas. Processed *pili* pulp also yields edible oil used for cooking or as a substitute for cottonseed oil in the manufacture of soap and edible products. Two root crop centers have also been established in the Philippines. These are the Northern Philippines Root Crops Research and Training Center in La Trinidad, Benguet, and the Philippine Root Crop Research and Training Center in Baybay City, Leyte. These centers spearhead, coordinate, and implement the national root crops research, development, and extension programmes. Areas covered by the centers are crop improvement and management, seed production, postharvest, processing and utilization, engineering, socio-economics and policy, and training and extension. Among the notable achievements of the centers is the systematic conservation of taro genetic materials. Varieties collected from all over the Philippines are currently maintained at their genebank. Promising accessions are also conserved *in vitro.*

Challenges and Opportunities

Indigenous vegetables are underutilized despite their recognized importance in supplementing food and nutritional need of the people. Possible major reason is that they are not profitable to grow due to the following factors: lack of available germplasm for widespread use, lack of seeds and seed system, lack of information on use and importance, lack of information about their performance and input requirements, lack of information of how they can fit into production systems, the preferential emphasis on the production, marketing and consumption of high-value vegetables, and the low regard of some consumers toward the consumption of IV.

Constraints besetting the *pili* processing industry have also been identified. These include unavailability of superior quality planting materials; limited institutional support on production development, lack of pili nut supply, poor marketing systems, unavailability of cost saving post-harvest and processing facilities, high cost of transportation, drastic fluctuation in prices, and lack of appropriate credit support to farmer producers. While for *duhat* and *bignay*, the main problem is their high perishability.

On the positive side, there are opportunities for the improvement of UUC. Studies have been conducted to determine the nutritional content of *himbabao*, *katuray*, *kulitis*, *pako*, *bignay*, *duhat*, *pili*, taro, and *adlai* (Table 2). *Kulitis* has beta-carotene content of 4,745 mcg per 100 g edible portion, more than half of the beta-carotene of carrots which is 8,285 mcg. The beta-carotene content of *pako* (3,100 mcg) is also comparable to that of *kulitis*. Ascorbic acid content of *himbabao*, *katuray*, *kulitis*, and *pako* are much higher than that of carrots which has only 5.9 mg. *Himbabao* and *kulitis* are also rich in calcium. *Pili* has high amount of calcium and phosphorus.

There is also a great opportunity for *pili* in the export market since only the Philippines produces and processes its nuts commercially. Taro as a potential staple food is tolerant to adverse growing condition and low input-farming practice compared to other food crops.

Adlai can be an alternative staple food since it contains high amount of energy (368 k cal), carbohydrate (73.3 g) and phosphorus (280.0 g). The importance and potential of *adlai* are : more nutritious than rice and corn due to its high protein content; contains calcium, phosphorus, iron, vitamin A, thiamine, riboflavin and niacin; helps enhance/increase food biodiversity; tolerant to pest and diseases; involves minimum cost of production because it can be ratooned. Further, *adlai* does not require irrigation and it is resilient to drought and flood (Velasco, 2010).

Table 2. Composition of selected UUC per 100 g edible portion

Composition per 100 g edible portion	*Himbabao**	*Katuray**	*Kulitis*	*Pako*	*Bignay*	*Duhat*	*Pili*	*Taro*	*Adlai*
Energy (kcal)	88.0	53.0	48.0	44.0	35.0	71.0	699.0	141.0	368.0
Protein (g)	5.6	1.6	3.4	3.8	0.7	0.8	14.2	2.3	13.1
Fat (g)	1.6	0.6	0.8	1.7	0.8	0.4	68.5	0.2	2.5
Carbohydrate (g)	12.9	10.2	6.8	3.3	6.3	16.0	6.4	32.6	73.3
Calcium (mg)	362.0	33.0	364.0	36.0	37.0	23.0	135.0	39.0	63.0
Phosphorus (g)	120.0	35.0	88.0	76.0	22.0	19.0	520.0	62.0	280.0
Iron (g)	8.4	1.2	11.1	3.0	0.7	0.4	2.6	0.9	6.8
B-carotene (μg)	645.0	90.0	4745.0	3100.0	5.0	0.0	0.0	30.0	0.0
Total Vit A (μg)	108.0	15.0	791.0	517.0	1.0	0.0	0.0	5.0	0.0
Thiamin (mg)	0.1	0.1	0.0	0.0	0.0	0.0	1.0	0.2	0.4
Riboflavin (mg)	0.3	0.1	0.3	0.1	0.1	0.0	0.1	0.0	0.1
Niacin (mg)	1.5	2.3	1.4	1.9	0.3	0.3	0.4	1.2	2.6
Ascorbic acid (mg)	41.0	32.0	84.0	10.0	7.0	18.0	29.0	9.0	0.0

**flower*

Marketing, Commercialization and Trade

The Philippines is the sole exporter of processed *pili* products in the foreign market. Bicol Region in the Philippines is the major producer of *pili* in the country with a share of 78 per cent domestic production. In 2000, *pili* is one of the top seven agricultural exports of the Philippines. Among the export destinations for *pili* nut products are Guam, Australia, Canada, and the United States (Reyes, 2000). In contrast, *duhat* is seasonal and sold in domestic markets.

While fresh taro corms and leaves are available in any local market and used as food ingredient to "sinigang" or Bicolano's "laing", processed taro products can be found only in specific stores. The same is true for *himbabao*, *katuray*, *kulitis*, and *pako* which are usually found in few local markets.

As reported by the Department of Agriculture-Regional Field Office 8, *adlai* is now being grown in Biliran, Biliran; Salcedo, Eastern Samar; Macrohon, Southern Leyte; Pambojan, Northern Samar; and, Sta. Rita, Samar. The seeds of *adlai* are not for commercial sale and not available in the market yet. Further, there is no definite price of the crop at present (Marga and Rosaroso, 2016).

Strategies to Harness their Potential

R&D on *duhat* and IV covering *himbabao*, *katuray*, *kulitis*, and pako is being undertaken at present. First is the DOST funded programme titled 'Emerging Interdisciplinary Research (EIDR): *In vitro* Release Properties and *In vivo* Biochemical Activities of Microencapsulated Anthocyanin Extracts prepared with *duhat* [*Syzygium cumini*] and *bignay* [*Antidesma bunius*]' being implemented by the UPLB. The programme aims to produce anthocyanin-containing microcapsules from *duhat* and *bignay* to bridge the gap between research on anthocyanins and desired food applications through *in vitro* and *in vivo* methods. This will also provide a platform in pursuing future human studies using microencapsulated anthocyanin extracts with nutraceutical properties.

For *pili*, a Philippine National Standard (PNS) for processed *pili* nut products has been developed by the Bureau of Product Standards of the Department of Trade and Industry (DTI, 2010).

For underutilized vegetables, DOST-PCAARRD has recently approved a project on 'Documentation of Indigenous Vegetables in the Philippines', which will be implemented by UPLB. The project aims to assemble, document, and publish on-the-ground information and available printed and electronic resources on IV from all 81 provinces of the Philippines, as well as from national and regional agencies/ institutions.

The DA-Bureau of Agricultural Research (BAR) implemented a R&D programme for *adlai* which pushes for the commercialization of the crop as food. Under this 49 projects are being implemented through the DA regional field offices, state universities and colleges, and the Philippine Center for Postharvest Development and Mechanization (PhilMech) with the Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG).

Major Focus Areas

Research areas for ongoing initiatives on UUC discussed in this report focuses mainly on their utilization as food or as processed and value-added product for nutraceuticals.

Infrastructure, Capacity Building and Financial Investment

In 2014, the Naga City Pili Processing and Packaging Center was established through the collaboration of DOST, DTI, DA and City Government of Naga. The facility is equipped with different food processing equipment to capacitate and empower small entrepreneurs in the Bicol Region (DOST, 2014). The Regional Pili Research and Training Center was also established to develop new propagation techniques, evaluate performance of promising cultivars, identify, index and collect elite *pili* varieties.

Further, as rationalized in the Agriculture and Fishery Modernization Act (AFMA), establishment of a mechanized *pili* processing center was included in the Bicol Region Postharvest Development Plan (DA-PhilMech).

Capacity building in R&D for UUC would involve the previously mentioned programmes on restoring crop diversity, EIDR programme on *duhat* and *bignay*, and the newly-approved project on the documentation of IV of the Philippines.

Future Thrust

DOST-PCAARRD recognizes *pili* as a regional priority crop and a programme to address gaps in the pili industry is in the pipeline, which covers production, product development, packaging, mechanization, marketing, and by-product utilization. *Pili* is also a priority commodity in the Harmonized National R&D agenda (HNRDA) for 2017-2022. Under this agenda, research priorities involve the following germplasm evaluation and conservation, utilization and management; varietal improvement and selection; production of good quality seeds and planting materials; cultural management practices; crop production systems research; postharvest, processing, and product development. Technology transfer and socio-economics and policy research are also priorities under the HNRDA.

The above-mentioned research priorities may also be applicable to UUC to explore their potential as food and nutraceuticals.

Conclusions

Duhat, *bignay*, *pili*, *himbabao*, *katuray*, *kulitis*, *pako*, *adlai* and taro are UUC which are potential food sources to address nutritional gaps and eventually contribute to the reduction of hunger and malnutrition in the country. Further, *duhat* and *bignay* have been explored and found to have antioxidant and nutritional properties. Studies on these crops can have important applications in the field of medicine. Therefore, the importance of UUC should be recognized and continuous R&D to explore the potential of these crops particularly on their use for food and nutraceuticals, should be undertaken. Outputs from R&D efforts on UUC can be key contributors to the attainment of food and nutritional security in the Philippines.

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Country Status Report - Taiwan

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Introduction

Plant germplasm is the basis of crop improvement, plus the genetic variations and biodiversity are the motivating forces for continuous of progress in plant breeding. In recent years, the cultivation of hybrids and fixed commercial varieties has threatened the survival of indigenous varieties and wild plants. The obsolete crop varieties and the wild relatives of crop plants frequently carry useful genes or alleles that, if not preserved, may no longer be available. These primitive types may have genetically high resistance to disease or environmental tolerance and are considered as precious source for utilization in future. In view of the long-term needs of ecological system, the sustainable conservation and utilization of plant germplasm have called attention of the scientists and governors in countries all over the world.

Taiwan has long been realized for its importance of sustainable conservation and utilization of plant genetic resources (PGR). During the past decades, a crop committee of germplasm conservation and multiplication system has been organizing to assist in the development of high priority technologies for improving agricultural productivity. At that time, the National Plant Genetic Resources Center (NPGRC) was constructed and placed at Taiwan Agricultural Research Institute (TARI) in Taichung. The NPGRC was inaugurated on August 10, 1993 and initiated operations. The center is administered by TARI under the supervision and funding from government. By September 2017, the NPGRC has stored a total of 91,782 accessions in its long-term and medium-term storage facility. These accessions represent 185 families, 785 genera and 1,510 species of plant germplasm (Table 1). The collections of seeds include 34,801 accessions in the long-term and 71,045 accessions in the medium-term storage. For the field genebank, the collection and preservation of germplasm including fruit trees and medicinal plants representing about 4,800 accessions are grown and maintained in several repositories. A total of 1,734 accessions of clonal germplasm are maintained as *in vitro* cultures (TARI, 2017).

It is well recognized that the establishment of information system of germplasm enables users and breeders to search for needed information and to choose appropriate genetic materials in use on crop improvement programme. In order to modernize genebank operations, promote information exchange and international cooperation on germplasm collection, a computerized information system of NPGRC was completed in 1993. NPGRC finally aim to become a regional center for tropical and subtropical crop, through international collaboration on collection.

Mr Keng Chang Chuang* is the Researcher cum Head of breeding section, TARI, COA. He focused research on fruit tree germplasm conservation and heat stress breeding of pear. He turned to anthurium and flower bulb research in the Floriculture lab. He recently aims at anthurium breeding, genetic research, and Calla lily and Aroid family indoor plants cultivation and collection. Dr Chuang contributes to improve the competitiveness of the flower industry in Taiwan by developing new varieties and cultivation systems.

**Mr Keng presented country report on behalf of Dr Ien-Chie Wen, Director, National Plant Genetic Resources Center, TARI, Taiwan.*

Table 1. Summary of germplasm accessions conserved in NPGRC (Sept. 2017)

Crop	Scientific name	Accession (no.)
Soybean	*Glycine max*	21,698
Rice	*Oryza sativa*	14,054
Mungbean	*Vigna radiata*	7,849
Tomato	*Lycopersicon esculentum*	7,181
Pepper	*Capsicum annuum*	5,391
Eggplant	*Solanum melongena*	3,648
Corn	*Zea mays*	2,989
Peanut	*Arachis hypogaea*	2,199
Watermelon	*Citrullus lanatus*	1,960
Asparagus bean	*Vigna unguiculata*	1,931
Common flax	*Linum usitatissimum*	1,819
Sugarcane	*Saccharum officinarum*	1,397
Sweet potato	*Ipomoea batatas*	1,309
Sorghum	*Sorghum bicolor*	989
Lettuce	*Lactuca sativa*	981
Edible amaranth	*Amaranthus tricolor*	872
Cucumber	*Cucumis sativus*	813
Chinese cabbage	*Brassica campestris,* Pekinensis group	731
Snap bean	*Phaseolus vulgaris*	712
Adzuki bean	*Phaseolus angularis*	604
Black gram	*Vigna mungo*	584
Cauliflower	*Brassica oleracea,* Botrytis group	457
Muskmelon	*Cucumis melo*	454
Spinach	*Spinacia oleracea*	432
Millet	*Setaria italica*	393
Tobacco	*Nicotiana tabacum*	385
Squash	*Cucurbita moschata*	355
Barley	*Hordeum vulgare*	352
Snow pea	*Pisum sativum*	326
Luffa	*Luffa cylindrica*	320
Bottle gourd	*Lagenaria siceraria*	300
Chinese kale	*Brassica oleracea,* Alboglabra group	280
Mustard	*Brassica juncea*	278
Jute	*Corchorus capsularis*	266
Peach	*Prunus persica*	260
Radish	*Raphanus sativus*	249
Wheat	*Triticum aestivum*	237
Banana	*Musa* spp.	232
Bitter melon	*Momordica charantia*	224
Mulberry	*Morus* spp.	209
Garlic	*Allium sativum*	204
Chinese mustard	*Brassica campestris,* Chinensis group	202
Asparagus	*Asparagus officinalis*	185

Crop	Scientific name	Accession (no.)
Mango	*Mangifera indica*	183
Sunflower	*Helianthus annuus*	134
Taro	*Colocasia esculenta*	132
Buckwheat	*Fagopyrum esculentum*	128
Tea	*Camellia sinensis*	102
Others		4,792
Total		**91,782**

Strategies for Collecting and Utilizing Plant Germplasm in Taiwan

The plant germplasm are augmented through sources including the species available under domestic research programmes, new varieties bred by the breeding programmes, local varieties, international exchange materials, material used in breeding programme and germplasm collection teams from foreign countries. While introducing germplasm from abroad, as per the Bureau of the Animal and Plant Health Inspection and Quarantine (BAPHIQ) regulations, the plant material is only released upon confirmation of no infection; and vegetatively propagated crops are isolated for a certain period of time and only released after no pests and diseases are found.

Once plant materials are collected, they are processed for regeneration, characterization and evaluation, utilization, before distribution. Germplasm distribution remains a major function of the NPGRC. Germplasm materials stored and maintained at NPGRC are not only for conservation purposes but also used to support research and utilization. These genetic materials are available for academic purpose and can be supplied through on line request. The supply of plant materials including relative information is free of charge. The varieties distributed from NPGRC and transferred to research institute were approximately 1,200 accessions each year. TARI has engaged in international exchange of crop seeds and seedlings. During the past five years, the average numbers of varieties introduced or collected from foreign countries was more than 2,000 accessions each year.

Crop Variety Breeding Direction in Taiwan

In general, the aim of crop breeding in Taiwan is for improving crop yield, pest and disease resistance, quality, and stress response to climate change. Taking rice breeding as an example, it is expected that global warming will be a major problem in rice cultivation leading to lowered grain fertility and quality deterioration. Rice breeders have screened 30 rice cultivars for heat tolerance. The results showed two cultivars - 'TC65' and 'Koshiibuki' had higher percentage of head rice and lower chalkiness. Cultivar 'Koshiibuki' showed the best performance under high temperature environment in two consecutive years.

In order to cope with the impact of high temperature stress due to climate change on rice yield and quality, breeders used plastic greenhouse for heat stress screen nursery and delay the transplantion time to April 14 to meet higher temperature at rice heading stage. The temperature of greenhouse and outdoors at heading stage (4 July - 31 July) was measured. The temperature of greenhouse increases 2.1°C and 2.6°C more than outside temperature during daytime and at spikelet blossom period, respectively. To compare the air temperature in May (rice heading period of first crop), July (rice heading period of experiment), and October (rice heading period of second crop), results showed that the mean temperature of July was higher than May and October at 4.3°C and 4.6°C, respectively. Spikelet fertility is one of the major indicators for heat stress evaluation in rice. One hundred and five rice varieties from NPGRC were grown in greenhouse for evaluation of fertility. The fertility of local variety N22 was highest than other trial materials, and seven varieties (lines) were over 80 per cent. Introgression lines using wild rice, *Oryza australiensis* or *O. officinalis*, were less fertile than their recurrent parent TNG67. A set of molecular marker were also designed for screen BC1F2 with heat tolerance QTL. Thirteen homozygosis individuals were obtained.

Rice bacterial blight (BB) caused by *Xanthomonas oryzae* pv. *oryzae* has been an important rice disease in Taiwan. In order to develop new rice varieties with the better resistance to bacterial blight, 272 materials including 82 differential lines from International Rice Research Institute (IRRI), Philippines and 199 lines from NPGRC were planted in 2014. At the booting stage of rice, all materials were inoculated with Taiwanese isolates (XG91, XE12 and XF89b) of BB by clipping off their leaves. Results showed that there were 20 lines with better resistance performance to XG91, XE12 and XF89b strains in first crop season and six lines with better performance in second crop season. Another study was to screen the resistance of 82 genotypes (including 29 isogenic lines with resistant genes Xa4, xa5, Xa7, xa13 and Xa21) from IRRI. Results showed that IRBB50, 54, 58, 62, 64, 65 and 66 with better resistant performance to examined strains in first and second crop season.

Methods of Promoting New Varieties

Three ways are adopted to promote a new variety: free license, exclusive license and non-exclusive license. Growers get authorization to propagate seeds or seedlings to grow or sell to farmers. Sometimes new variety, especially in rice, is released through free license.

Results of Germplasm Utilization

TARI is committed to breeding new varieties of cereals, fruits, vegetables and flowers which with the characteristics can meet the consumer needs (such as high yield, appropriate sugar and acid ratio, good colour/ pattern /aroma, fruit improvement, extended storage and transportation period, enhanced taste of food, etc.). Table 2 lists the new breeding crop varieties, characteristics and promotion results of the crops grown in last five years.

Table 2. Summary of plant germplasm utilization in last five years

Crop, Variety name	Variety characteristics	Promotion results
Rice Tainung No. 76	*Japonica* yellow kernel rice variety	Plant variety right licensed; planting area about 30 ha
Rice Tainung No. 77	Carries several superior traits such as mid-early maturity, lodging resistance, high yield potential, and excellent performance in rice appearance and aroma flavor	"Tainung77" was listed as the domestic recommended high-quality rice; planting area about 200 ha
Rice Tainung No. 79	Possesses rice blast resistance and low sprouting genes; has high quality and suitable for formed-processed rice food	Non-exclusive license to local company; planting area about 200 ha
Rice Tainung No. 80	*Japonica* giant embryo rice variety	
Rice Tainung Sen Glutinous No. 24	*Indica* glutinous purple rice variety	Plant variety right licensed; planting area about 30 ha
Rice Tainung Sen Glutinous No. 26	*Indica* glutinous red rice variety	Plant variety right licensed; planting area about 10 ha
Maize Tainung No. 6	Uniform plant height, ear height, plant and ear type, 20 cm ear length, 12 row, middle kernel, with pink silk color; ear fresh weight with husk and ear fresh weight larger than that of white-pearl, the control variety by 29.4% and 26.8%, respectively	
Pineapple Tainung No. 22-Honey Fragrance	Fruit is 1.5 Kg with cylinder shape. Mature fruit is yellow but slightly orange and thin peel with shallow cupules. Fine and dense texture fruit with medium fibers. Average content of total soluble solids is 17.6°Brix, and acidity is 0.43%, i.e. high ratio of sugar to acidity 41 to present special fragrant flavor	Non-exclusive license to farmers; planting area about 0.3 ha.

Crop, Variety name	Variety characteristics	Promotion results
Indian Jujube Tainung No. 9 -New Honey King	Large fruit (150 g in average), with high total soluble solid content (16°Brix. in average)	Planting area about 5 ha
Papaya Tainung No. 10 -Orange Baby	Large fruit size about 1,200 grams; bright yellow-orange color and high density of flesh; aroma is soft; fine fiber; big fruit size; thick skin; easy storage; spider mite tolerance	Exclusive license to Sinon Cooperation; production area is 18 hectares
Peach Tainung No. 6 -Sweet Heart	Low chilling, fruit symmetric and round with shallow stalk cavity, red fruit skin color with sugar spot, non-fuzz; melting yellow flesh, high soluble solid content fruit with sub-acid; obovate shape, cling stone	No technical transfer yet
Wax Apple Tainung No. 2-V&R	Big fruit size with rose red to dark red skin, flesh is crispy, juicy and high sugar content. Few fruit-cracking	Planting area about 20 hectares
Wax apple Tainung No. 3 -Sugar Barbie	Huge fruit size with long-conical fruit shape; mature fruit skin is rose red to dark red, obviously bright, protuberant and intensive surface. Flesh quality is juicy and good balance of sugar/acid with light herb aroma. Few fruit-cracking with good transportation and storage ability	Non-Exclusive License to 3 production and marketing associations, and 2 co-farmer associations; Planting area about 33 hectares.
Pitaya Tainung No. 1 -Candy-Candy	Fruit small (average 297 g), oval, the scale outwardly stretches but not anti-winding, scale and fruit peel hand over to connect a whole fruit smooth have no spine, the peel orange, red-purple pulp in a ellipse pattern , the peel does not have the shine, high soluble solid content in core and whole fruit (core 20.5°Brix, whole fruit 15.3°Brix)	Cultivation to 6 farmers has been non-exclusive authorized; total cultivated area about 3 hectares
Peach Tainung No. 7 -Red Bell	Low-chill variety, symmetric, round fruit shape with shallow stalk cavity; red fruit skin color; melting white flesh, high soluble solid content fruit with sub-acid; obovate shape, cling stone.	
Mustard Tainung No. 3	Medium-maturity; moderate resistance to Turnip mosaic virus	
Cauliflower Tainung No. 1	Open pollination spontaneous; plant type medium; curd medium-maturing, medium cotyledon, weight about 660 g, oval, medium thickness, purple red color, fine bud grain tightness medium and no leafy; sticks of green and white. About 55~65 days from sowing to harvest	
Bitter gourd Tainung No. 7	Hybridized bitter melon, fruit colour remains white even without bagging, with saving manpower; white bitter melon has a shiny appearance, single fruit weighs approximately 450-600 grams, fit for small family use	Suitable for the central region of Taiwan in summer cultivation; cultivation area about 3 hectares.
Ionocidium Tainung No. 5 -Jaunty	Height of 35 cm and peduncle of 25 cm; pseudobulb about 5.4 × 2.3 cm; flower 2.3 × 1.7 cm; peduncles on pseudobulb after developing mature. Main colour of flower magenta; can blossom for about one month. Main flowering time is from November to December; a good potted variety	Authorized contracts was signed with TARI in October 7, 2015; propagated by tissue culture.
Ionocidium Tainung No. 4 -Snow White	Height of 21 cm, peduncle of 52 cm; pseudobulb 7 x 3 cm, flower 4 x 3cm; main colour of flower white, lip white, sepal and petal with brown; main flowering time in September-February; a good potted or cut flower variety	Taiwan has more than 100 flower growers signing authorized contracts with TARI; 100,000 are planted in Taiwan; Xinshe district grows more than other places
Doritaenopsis Tainung No. 1 -Purple Butterfly	Multiple small size flowers with light purple color which is rare for *Phalaenopsis.* This cultivar has many elite horticultural characters including controllable flowering, long flowering time, high rate of two-spike, multiple branches, highly arranged florescence, no abortion buds, round flower with proper overall proportion. It fits to 9 cm pot for commercial production.	Not many mericlone shoots proliferated. Plants cultivated in the greenhouse for traits evaluation; mass propagation, cultivation, and selling not reach yet in this stage.

Crop, Variety name	Variety characteristics	Promotion results
Amaryllis Tainung No. 1 -Pink Lady	Multi-petal type flower with pink colour and clear fragrance; 17-18 cm in width and used for pot or beds plants.	01 ha
Amaryllis Tainung No. 2 -Star of Taiwan	A star shape flower with pink colour and 14-16 cm in width.	
Phaelaenopsis Tainung No. 1 -Pixie	Mini type (leaf span less than 12 cm), short juvenility (6 months), flower size 3.5 cm, multi flowers (more than 10 florets), petals are white with purple stripes	No production due to close down of company
Flowering cherry Tainung No. 3	Plant semi-upright tree type, leaf stalk short with glands, no pubescence; young foliage green color, no pubescence on mature leaf back. Flower medium pedicels, calyx tube yellow color, funnel-shaped, entirely double flowers, medium flower diameter, flower bud white color, petal white color also, no stamens with leaf-like pistils, fruitless variety	No technical transfer yet
India date Tainung No. 12 -Water Honey	Strong growth vigour and easy to cultivar; mature stem soft, mature leaf shape small and a circular form; fruit oval shape with total soluble solid content of 12-14°Brix. Flesh texture fine and juicy, lower acid, and good fruit characteristics, large fruit (149 g in average)	New variety plant

Conclusions

For strengthening the acquisition, conservation, and utilization of crop germplasm, an advisory committee of plant germplasm and biodiversity has been organized to evaluate academic research proposals and the other issues pertaining plant genetic resources for supporting research and utilization. The plan calls for an amalgamation of existing capabilities of all agricultural research institutions with TARI playing a nuclear role. Under the system, TARI coordinates and collaborates with all research institutions and university on field collection, post-entry quarantine, conservation, regeneration, documentation, dissemination, and international cooperation. Germplasm is the foundation of agricultural production. Regardless of future development in biotechnology (e.g. gene manipulation, tissue culture, etc.), the practical use of advanced biotechniques is not possible without germplasm. With the rapid loss of germplasm materials nowadays, the gathering and preservation of germplasm take on new urgency. Although we now have good facilities and equipments, NPGRC need help from all concerned people to provide information on germplasms and materials so to expand our holdings and raise the level of research and agricultural production through richer germplasm collections.

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Country Status Reports – The Pacific

Country Status Report – Fiji

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Introduction

The agricultural sector plays an important role in Fiji's economy. It offers both employment and opportunities for sustaining livelihoods, and there are strong linkages between the sector and the rest of the economy. Thus, Fiji requires an inclusive development framework for its agriculture economy to move forward by addressing new domestic and global challenges in line with food and nutrition security, climate change, feedstock for renewable energy, the utilization of water resources for aquaculture, agriculture export, and the rehabilitation of its traditional agriculture export industries, the sugarcane and coconut industries.

The goal of the development agenda is to contribute to the national goal as envisioned in the national government's agriculture policy in the Roadmap for Democracy and Sustainable socio-economic Development. This national goal for agriculture in Fiji is to Build Sustainable Community. Directly in line with this goal is the main purpose of the development agenda, which is the immediate result to be attained by the year 2020 and based on the analysis of identified development objectives. This underlying goal or purpose is to establish a diversified and economically and environmentally sustainable agriculture economy in Fiji. To attain this purpose, five agriculture development objectives must be attained together. These objectives are:

(i) To build modern agriculture in Fiji as an organized system of producing, processing, and marketing crops, livestock, and aquaculture products.

(ii) To develop integrated production, processing, energy, and transport infrastructure support system for agriculture.

(iii) To improve delivery of agriculture support services.

(iv) To enhance capabilities to generate fund and secure investment through foreign investment, private public partnership, and other innovative business arrangements.

(v) To improve project implementation and policy formulation capability within the Ministry of Agriculture (MoA) and its partner institutions.

The status of underutilized crop (UUC) species in Fiji has not been fully tapped by the agriculture sector, leading to the development of major commodities such as taro, cassava, sweet potato, rice, potato, to name a few. However, efforts have been initiated for production of processed products (chips) for potato, cassava and taro (Fig. 1). Nutritionally rich local colored sweet potatoes are also

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cultivated in Fiji (Fig. 2). There are a number of crops that are grown in Fiji but their full potential remains underutilized in terms of use, processing, trade, value addition and marketing. These range from traditional crops (fruits and vegetables), introduced species and wild relatives of crops. A few examples are coco yam (*Xanthosoma sagittifolium*), Asian taro (*Colocasia escultenta* var. *antiquorum*), squash, bottle gourd, sponge gourd, drumstick (*saijan*), edible fern (Fig. 3), avocado, *Saccharum edule, bele* (*aibika*), traditional nuts (chestnut, almond), wild yams [*Dioscorea bulbifera, D. pentaphylla* (Fig. 4)], soursop, sweet mangosteen and rambutan.

Fig. 1. *Processed products (chips) in Fiji*

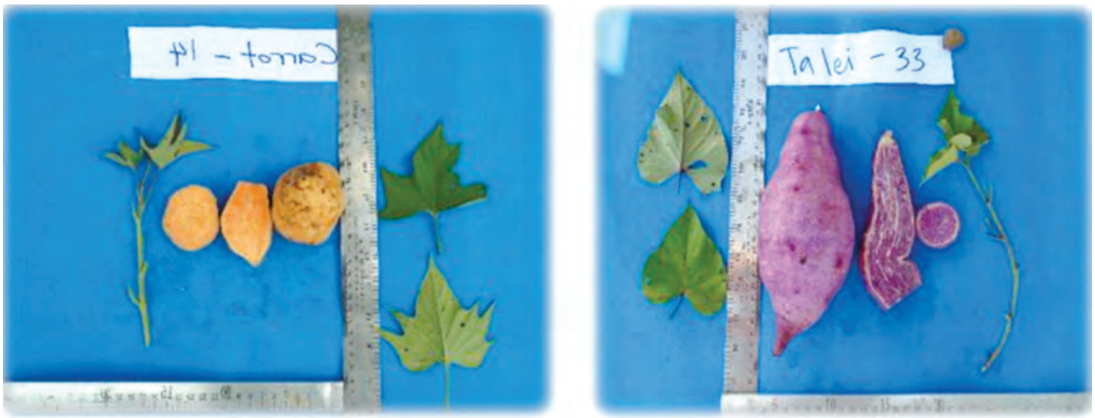

Fig. 2. *Colored local sweet potato in Fiji are of nutritional benefits*

Fig. 3. *Edible fern is a delicacy in Fiji but it is underutilized*

Fig. 4. *Dioscorea pentaphylla (wild yam) thrives well in drought areas, edible and tastes like table potatoes*

Area, Production and Productivity

Location

Fiji lies in the heart of the Pacific Ocean, midway between the Equator and the South Pole and between longitudes 174°E and 178°W and latitudes 12°S and 22°S. Fiji's Exclusive Economic Zone contains approximately 330 islands of which about one third are inhabited. It covers about 1.3 million km^2 of the South Pacific Ocean. Fiji's total land area is 18,333 km^2.

Population

Fiji is a multi-cultural and multi-racial country. The nation's population in 2002 was about 826,281 of which about 53 per cent live in rural areas. Fijians comprise 53.4 per cent of the total population, Indians 39.7 per cent, with the balance made up of Rotumans, Chinese, Part-Europeans, Europeans and other Pacific Islanders. Fiji's population grew at an annual average of 1.3 per cent between 2000-2002. Whilst indigenous Fijians are usually classed as Melanesians, they are actually a mixture of both Polynesian and Melanesian elements.

Climate

Fiji enjoys a tropical South sea maritime climate without great extremes of heat or cold. The islands lie in an area which is occasionally traversed by tropical cyclones, and mostly confined between the months of November to April every year. Temperatures average 22°C for the cooler months (May to October) while November to April temperatures are higher with heavy rainfall.

Agriculture in Fiji

Agriculture remains a major sector of the economy, accounting for 43 per cent of Fiji's foreign exchange earnings. It provides 50 per cent of the country's total employment and contributes 19 per cent to Fiji's Gross Domestic Product (GDP). Fiji has a total land area of 1.8 m ha. Only 16 per cent is suitable for farming and are found mainly along coastal plains, river deltas and valleys of the two main islands of Viti Levu and Vanua Levu. The rest can be found in the smaller outlying islands of the group. Of the arable land, 24 per cent are under sugarcane, 23 per cent coconut and the remaining 53 per cent under other crops. The indigenous people own about 83 per cent of the land in Fiji. And through the Landlord and Tenants Act (ALTA), the Indian farmers have had the privilege to farm on arable Fijian land through long-term leases.

State of Food Security in Fiji

The current trend of food production cannot sustain the demand in Fiji, and the country imports most of the basic food items of everyday use such as onions, potatoes, garlic and vegetables. The tourist industry which is the current biggest foreign exchange earner opted for importation of quality vegetables from New Zealand and Australia. This is because quality vegetables and fruits cannot be produced locally to meet the demand. Rice is also imported, though Fiji was self-sufficient in rice in the 1980s, while other root crops and vegetables are produced locally to meet the local demand. Food shortage is normally experienced after natural disasters such as flooding and cyclones. This is compounded by the rapid increase in population and urban drift, rising sea level for atoll islands and the changes in weather patterns

Significant Achievements

Germplasm Collection, Characterization, Evaluation, Conservation and Documentation

Ex situ conservation is carried out by the Research Division of the Ministry of Primary Industries in Fiji. This is mainly in the form of field genebank, tissue culture and cool storage facilities. These collections are maintained at eight research station located at different ecological zones in the country mainly in the two main islands of Viti Levu and Vanua Levu.

Germplasm collecting is an on-going activity for *ex situ* collection in Fiji, through annual data collected. Recent studies have indicated the increase in non-communicable disease in Fiji and the Pacific, so there is a need to collect wild plant varieties with medicinal properties, such as "fei" or karat bananas, breadfruit, noni etc.

There is a plan in place to assess the genetic erosion of plant genetic resources for food and agriculture (PGRFA), which is carried out through *ex situ* collection monitoring. Some of the recent collecting missions carried out are as follows:

- Breadfruit collections in Natewa district (22 accessions)
- *Xanthosoma* (4 varieties) to establish a collection
- *Duruka (Saccharum edule,* 7 varieties) from the highlands of Fiji
- Traditional fruits and wild vegetables
- Domestication of three varieties (Fig. 5) of edible ferns ('Ota') (MOA, Fiji, 2011)

The MoA in Fiji with its Land Use Division has the facilities for GIS, which can be used to map out diversity and indicate hot spots for future collecting missions.

There is a need to regenerate the traditional varieties of taro in Fiji. There is a situation in Taveuni where farmers are planting only the export variety and landraces are slowly eroding. Secretariat of the Pacific Community (SPC) in collaboration with the MoA in Fiji established a collection of

Fig. 5a. *A cultivar of Lalabe (Diplazium proliferum)*

Fig. 5b. *A cultivar of Ota Loa (Diplazium esculentum)*

Fig. 5c. *A cultivar of Ota Dina (Diplazium esculentum)*

traditional cultivars in this area to introduce these varieties back to the farmers. For *ex situ* collection at Koronivia re-collection is needed for traditional taro varieties. *Duruka* varieties need to be rescued since old records indicate the presence of 14 accessions. Cold storage has been upgraded and well-maintained to store seeds of tropical fruits and needs to be stored for long-term for future use.

Fiji has a tissue culture laboratory at Koronivia Research Station. It was established with the support of SPC. Some PGRFA are maintained including kava, wetland taro, upland taro, ginger, TLB taro. The lab has been very useful in the conservation and multiplication of PGRs for farmers. Plan is in place to expand its role in disaster mitigation in terms of making available disease-free planting materials to support crop production.

Documentation works in Fiji on PGRFA are in the form of a database where data are fed annually as genebanks managers update their germplasm collections. Assistance is highly recommended from bigger institutions to assist Fiji on germplasm documentation.

Variety Development

Taro breeding was carried out in the early 1980-1990s for the sole purpose of improving the yield components of taro in Fiji, as it is one of the important staple not only for local but for export markets. Through this breeding programme three high yielding taro hybrids ('Vulaono', 'Wararasa' and 'Samoa hybrid') were developed and released to farmers. Two of these hybrids are still widely cultivated and accepted by farmers and consumers in Fiji.

Fiji recently through its crop improvement programme from 2011-2016 has successfully released the new varieties to farmers in mung bean ('Samarat'), tomato ('Melrose'), cherry tomato ('Rio Gold') and guava ('Green Pearl'). Future releases will be focusing on climate change and resilience, including aerobic rice, drought tolerant sweet potato, taro leaf blight tolerant varieties, etc.

Cultivation Practices

Fiji has more than 18,000 km^2 land and only 16 per cent is arable. The country's pace of transformation from subsistence to commercial scale agriculture is still slow and the current quarantine regulated export sector is inadequate for the agriculture of the country to move forward. A firm decision to embrace forward looking development agenda is needed. On this basis, Fiji requires a long-term agenda that provides the framework in using the agriculture resources more productively through sound technology and financing and management strategies. The agenda is eventually used to generate the fund and attract investment necessary to support the modernization of Fiji's agriculture.

About 80 per cent of the farmers in Fiji are small-holder farmers and cultivation practices are concentrated around subsistence, semi-commercial and commercial farming. For large-scale farming such as sugarcane, mono cropping is practiced over a long period of time. On flat alluvial soil, farming is normally aided with the use of tractors for mechanization, small farming equipments and machineries. On sloping land, traditional cultivation practices are used by farmers, but the use of farm machineries has increased to speed up the land preparation for farmers and is cost-effective. The MoA is promoting the Sustainable Land Management (SLM) practices on these sloping areas due to the increase in desertification and land degradation due to unsustainable cultivation practices.

Processing, Value Addition and Product Development

Processing of agricultural produce in Fiji has increased due to government policy on diversification. Processing is done by the private sector, especially by big companies like Punjas Fiji Ltd., Flour Mills of Fiji, Food Processors Ltd. and Food Pacific, to name a few. Local and imported potatoes are processed by Flour Mills of Fiji into chips and are exported overseas, around the Pacific and in local supermarket chains.

The MoA in Fiji is strengthening its Product Development Unit to carry out research with the private sector and farmers to reduce post-harvest losses. In Fiji during the fruiting season of crops such as mangoes, oranges, pineapple etc., there is profuse loss in these crops. Research is targeted to develop products from the harvest of these crops linking up with the private sector to expand the product development programme in Fiji.

Ginger in Fiji that is harvested at 5 months' time is called green ginger (Fig. 6a) is normally processed into the following products like crystallized ginger, ginger syrup, confectionaries and ginger lollies, for the export market (Fig. 6b). Mature ginger is normally harvested at 10 months and sold to local markets and overseas markets. Rejects are normally collected from exporters and there are some small business ventures using dried ginger for making powder. This is sold for cooking purposes.

Fig. 6a. *Five months old ginger for processing*

Fig. 6b. *Fiji's ginger products*

Disease and Pest Management

Fiji, like any other country, is prone to incidence of pest and diseases, and the effect of climate variability can further aggravate the situation. Chilli anthracnose has been a challenge for the last five years and attempts are being made to solve the issue of this disease, by identification of strains.

Taro beetle *(Papuana uninodis)* remains the biggest economical pest for taro growers in Fiji. Research with development partners are conducting control measures in Fiji with Farmers Field Schools. It is estimated that this pest contributes to 30 per cent loss in the industry in Fiji. Further, Fiji is also under threat from the devastating Taro Leaf Blight (TLB) in Samoa and other neighboring

Pacific countries. Efforts are under way to access tolerant taro varieties and make them available to farmers.

Pest and disease management in Fiji has been prioritized by the government as a top priority, due to the export markets, border control, local production and quarantine measures. Other agencies which assist the Fiji government in these areas are the Australian Centre for International Agricultural Research, New Zealand Aid Programme and some universities like the Queensland University of Technology and University of the Sunshine Coast in Australia.

The Fiji coconut industry is threatened by the coconut rhinoceros beetle, with a new biotype which has been found in Guam and has spread to the Solomon Islands.

Challenges and Opportunities

The UUS have an enormous potential to boost Fiji's agricultural development. The Fiji 2020 Agriculture Policy Agenda (MOA, Fiji, 2014) is addressing this important area as it is normally under-developed in Fiji. With the effect of climate and the need for food security and increasing trade, work on UUS needs to be enhanced.

Challenges

- Characterization and domestication of some wild relatives e.g. wild edible fern *(Athyrium esculenta)*, wild species of yams *(Dioscorea pentaphylla* and *D. bulbifera)*.
- Climate change – some of these UUS are resilient and better for climate change adaptation and enhancing food availability during and after natural disasters.
- Very little research carried out – there is a need for Fiji to work with research institutions that deal with UUS, have a good strategy and have joint research ventures.

Opportunities

There is a huge opportunity to develop UUS in Fiji, in the following areas:

- Strengthen collaborative research and development with development partners
- Have a conducive policy direction from government
- Strengthen conservation and sustainable use of these resources
- Carry out survey and determine hot spots areas
- Nutritional studies
- Value addition and product development

Marketing, Commercialization and Trade

In Fiji most of these UUS are sold in local markets and very little information on export and commercialization. For crops such as *Xanthosoma* spp., a small quantity is exported to New Zealand mainly to former Fiji nationals and Pacific Islanders who resides there. Table 1 gives values *Xanthosoma* exported overseas, even though there is a huge potential in Fiji to develop this crop.

Table 1. Tuber crops exported from Fiji (2009-2015)

Commodity	2009 (Mt)	2010 (Mt)	2011 (Mt)	2012 (Mt)	2013 (Mt)	2014 (Mt)	2015 (Mt)
Taro	69,302.80	61,137.70	67,197.18	60,000.00	87,044.00	62,747.65	60,927.97
Xanthosoma	2,196.69	2,261.30	6,570.80	3,721.10	5,888.40	3,595.95	3,771.61

Source: MoA Fiji (2016)

Sweet potato, to some extent, is underutilized in Fiji as small amount is exported overseas but the rest are sold in local markets. The processing capabilities, nutritional value of sweet potato is not fully tapped by the Fiji agriculture sector and it is grown mostly for food security and as a disaster crop.

Strategies Adopted to Harness their Potential

The Fiji agriculture sector has adopted a new Fiji 2020 Agriculture Policy, but still has a gap in addressing UUS. This policy document is also subject for review in few years to come. The following strategies are implemented in Fiji to harness their potential:

- Collaborative approach at national level with the National Food and Nutrition Center to promote these UUS for nutritional and food security.
- Policy development by the MoA– Fiji has ratified the International Treaty for Plant Genetic Resources for Food and Agriculture.
- Domestication, conservation and characterization – research is taking the lead role in Fiji and also promoting and creating public awareness on their importance.
- Publications – posters, leaflets, booklets to strengthen public awareness.
- Collaborative research initiatives on UUS – Thailand government visits to Fiji have identified potential areas for development.

Major Focus Areas

The major focus area in Fiji for UUS are on the strengthening the conservation, characterization and documentation. While other focus areas have been discussed above.

Case Studies/Success Stories for Improvement of Health and Livelihoods

A case study was conducted at Sigatoka Research Station in Fiji on the domestication of an edible fern in Fiji. This fern grows in the wild and thrives well in forest conditions and no efforts were carried in the past to domesticate this species. With the funding assistance of SPC, three varieties were collected from the wild and domesticated at the research station using nursery methods. Technology developed is detailed below.

Technology developed for domestication of *ota* (*Diplazium esculentum*; syn. *Athyrium esculentum*)

Ota is a traditional vegetable fern mostly found in cool, shady and moist areas; usually on the riverbanks and in the forests. It is a highly nutritious vegetable gaining popularity amongst all the population in the country. Very recently, *ota* is also being processed and exported into cans for utilization by our people residing in foreign countries. People for a number of years have been relying on the forest to provide the constant supply of *ota* for their daily use. However, due to the increase in logging and uncontrolled fire, it has become necessary to cultivate *ota* not only to ensure constant supply but to also preserve this PGR from extinction. This technology will assist the urban dwellers to establish plots in their backyards for regular supply of the healthy green vegetables (NFNC, 2017). Table 2 provides the food composition data for raw and cooked *ota* leaves.

Materials Required

- Posts: 15 x 2 m length
- Rafters: 3 x 10 m length (use mature bamboo)
- Purlin: 9 x 5 m length
- Sarlon cloth: 30 m length

Planting Details

- Mark an area of 10 x 5m
- Construct the structure using bamboo
- Put the sarlon cloth on top of the structure
- Broadcast poultry manure on the soil
- Dig with fork and leave for a week
- Get ota seedlings and plant at the spacing of 0.5 x 0.5 m apart
- Mulch with saw dust
- Apply 0.5 kg urea every month for the first 3 months
- Apply water regularly

Costing

Sarlon cloth - $150 (can be substituted by coconut fronds)

Yield

1 bundle of ota weighing 0.5 kg can be harvested weekly.

Table 2. Food composition data for raw and cooked *ota* leaves

Composition per 100 g of food	Raw	Boiled
Water	90.9 g	94.0 g
Energy	89 kJ	61 kJ
Protein	3.4 g	2.4 g
Fat	0.6 g	0.4 g
CHO Available	0.7 g	0.5 g
Dietary Fibre	3.6 g	2.1 g
Ash	1.3 g	0.6 g
Cholesterol	0 mg	0 mg
Sodium	11 mg	6 mg
Potassium	562 mg	234 mg
Calcium	27 mg	17 mg
Magnesium	43 mg	19 mg
Iron	4.0 mg	2.4 mg
Zinc	2.8 mg	1.8 mg
Total Vitamin A Equivalent	496 μg	422 μg
Retinol	0 μg	0 μg
Carotene Equivalent	2976 μg	2530 μg
Riboflavin	0.19 mg	0.15 mg
Niacin	0.7 mg	0.6 mg
Vitamin C	7 mg	2 mg

Conclusions

Fiji needs to makes some concerted efforts in research and development of UUS. Climate change is going to further impact the agriculture sector. There is a need to build resilience to the Fiji agriculture sector given the vulnerability of the current farming systems and crop varieties to changing climatic conditions. The UUS will play a significant role in the food security sector, providing food and nutrition to the people. If these resources are fully realized and potential areas are identified for development, this will enhance the agriculture sector and also contribute to more economic activities. Countries like Thailand, Malaysia, Indonesia can provide a good training to build capacity in Fiji to develop strategies on the potential on UUS.

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Country Status Report - Papua New Guinea

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Introduction

Papua New Guinea (PNG) is located on the eastern part of the island of New Guinea, the second largest island in the world (Fig. 1). It is a part of the Oceania Region and by far the largest country amongst the Pacific Island countries and territories in terms of landmass (463,000 km^2) and population (7.3 million) (NSO, 2013). The country is divided into islands, the lowlands (0-1,200 m) and the highlands (1,200-2,800 m). PNG has extensive mountain ranges over many areas and there are a number of peaks over 4,000 m.

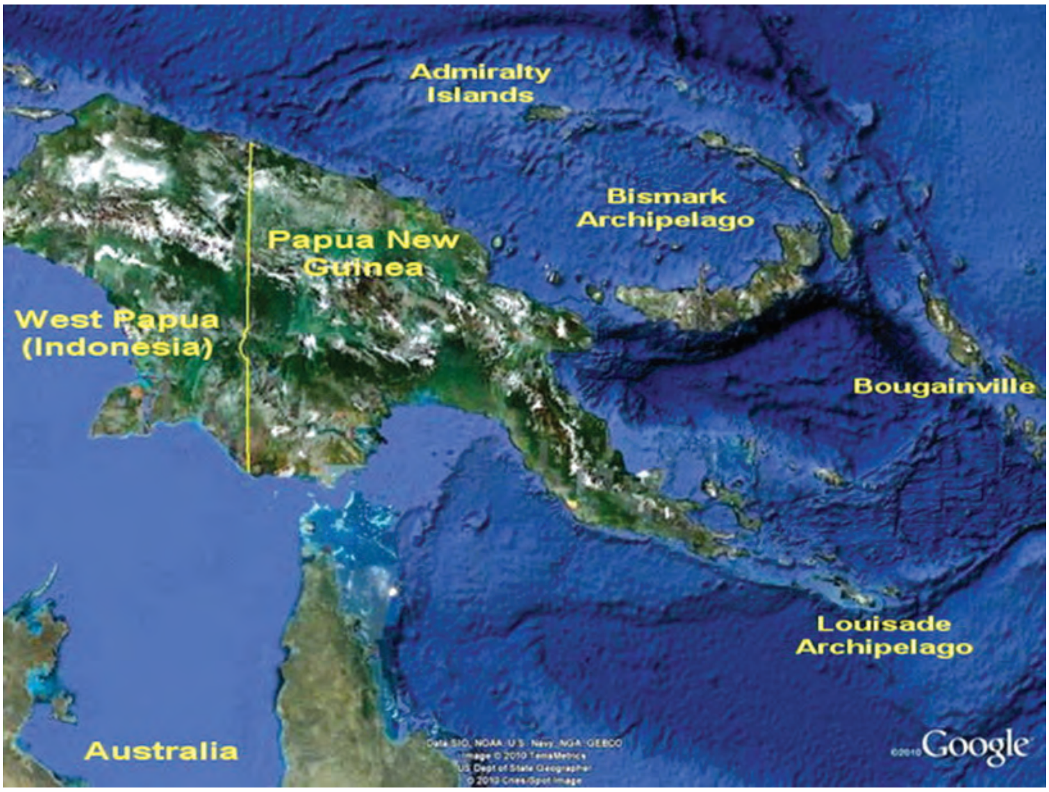

Fig. 1. *Papua New Guinea*

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The average annual rainfall varies from very high and continuous with more than 8,000 mm in some mountainous areas, to relatively low and seasonal with 1,000-1,500 mm in a number of coastal areas. Average temperatures vary mainly with altitude, with tropical temperatures in the lowlands and islands and milder temperatures in the highland areas. Areas above 1,500 m often experience the occurrence of frosts.

General vegetation of the country varies with elevation and rainfall. PNG flora has some similarities with those occurring in Indonesia, Malaysia, Australia and other Pacific Island countries. The tropical rainforest areas of the central and the North-western parts of the mainland PNG are rich 'store houses' of millions of species of flora and fauna, many of which are unique to this part of the world.

Majority of its population (>80%) lives in rural areas on their own land under customary titles and depend on agriculture supported by fisheries and forestry for their food, income and monetary and non-monetary employment. Customary land accounts for about 97 per cent of the total land area. More than 90 per cent of rural people are semi-subsistence small-holder farmers who produce food and cash crops for their own consumption and barter (subsistence) or sell their produce. A small percentage engages in fully commercial activities. On the other side of the spectrum there are subsistence farmers that live in mostly isolated areas in the country. Agricultural systems are highly diverse and closely adapted to the wide range of agro-ecological zones.

Traditional Food Systems

Traditional food systems are based on root and tuber crops and banana as major staple crops (Table 1). Rice has become an important staple food but only about 1,000 t are produced in country and rest imported (139,000 t/annum, on average).

Table 1. Most important staple crops in PNG

Species	Total production estimate (t/year)	Consumption (kg/person/year)
Sweet potato (*Ipomoea batatas)*	4,600,000	416
Banana (*Musa* spp.)	703,000	84
Yam (*Disocera* spp.)	440,000	53
Cassava (*Manihot esculenta*)	438,000	52
Taro (*Colocasia esculenta*)	377,000	45
Chinese taro (*Xanthosoma sagittifolium*)	364,000	44
Sago (*Metroxylon sagu, M. salomonense*)	134,000	16

Source: Estimates based on those in Bourke and Hardwood (2009) (Table A2.1.1); updated for population growth between 2006 and 2016 (NSO, 2003, 2013); no adjustment for minor changes in composition over past decade; estimates rounded to 1,000 tons

Among the staple crops, sweet potato (*Ipomoea batatas*) is the most important staple crop grown and consumed in the country. The second most important crop are bananas (*Musa* spp.), especially the cooking bananas. All three main genomic groups of bananas and seven wild species are found in PNG. Most landraces or farmer cultivars from the 'diploid' and 'triploid' genomes are grown and consumed as cooking bananas. PNG, Solomon Islands, Vanuatu and New Caledonia are perhaps the only few countries in the world that are still cultivating and consuming 'AA' diploids (NARI, 2009).

There is a large array of vegetable crops in traditional food systems which are dominated by leafy greens which are eaten with most main meals in PNG (Gibson, 2001). Table 2 shows a list of the most commonly eaten vegetables in the country and the proportion of rural population growing them.

Table 2. Most important vegetables and per cent population growing them

Name	Scientific name	Per cent population growing
Corn	*Zea mays*	94
Pumpkin (tips)	*Curcurbita moschata*	72
Aibika	*Abelmoschus manihot*	60
Amaranthus	*Amaranthus tricolor, A. dubius, A. blitum*	60
Highland pitpit	*Setaria palmifolia*	54
Lowland pitpit	*Saccharum edule*	52
Common bean	*Phaseolus vulgaris*	48
Cucumber	*Cucumis sativus*	44
Rungia	*Rungia closii*	42
Winged bean	*Psophocarpus tetrogonolobus*	40
Tulip	*Gnetum gnemon*	37
Snake bean	*Vigna unguiculata* cv. group *sesquipedalis*	37
Kumumusong leaves	*Ficus copiosa*	33
Water dropwort	*Oenanthe janvanica*	32

Source: Bourke and Harwood (2009)

Underutilized Food Crops

Locally grown food crops provide over 80 per cent of food energy and 57 per cent of protein consumed by rural people (>80% of the population) in PNG and it still originates from a relatively wide range of about 400 plant species that are grown or harvested by rural communities (Bourke and Harwood, 2009). Many of them are not major staples and hence, considered underutilized in the PNG context. They grow in the wild habitats, in farmers' fields and home gardens and often harvested only when needed or during the time when garden foods are in short supply (NARI, 2009; Quartermain, 2006). Bruce French, an Australian Academic who worked in PNG in the late 1970's and 80's undertook the task to comprehensively document the vast array of PNG food crops in the 'PNG Food Crop Compendium' (French, 1986). He categorized the underutilized crops (UUC) into the following categories - 'overlooked', 'undervalued', 'unrecognized' and 'poorly known'. While Quartermain (2006) adds another category of PNG staple food crops which are not fully utilized to the extent of commercialization, export potential, downstream processing or added value and alternative uses. Examples of crops in each of those categories from a PNG viewpoint in relation to a wider use, research investment and commercialization efforts are given in Table 3. Crops are prioritized within each of the categories based on NARI strategic priorities for 2011-2020. Nutritional values for selected crops as far as they are available are provided in Table 4.

Among the large number of UUC that are available in PNG, the following three crops have been selected for the other sections in this paper with more details on current development in research for development in PNG. The crops are taro (*Colocasia esculenta*), aibika (*Abelmoschus manihot*) and other traditional leafy vegetables and galip nut (*Canarium indicum*).

Area, Production and Productivity

Taro (*Colocasia esculenta*)

Taro (*Colocasia esculenta* var. *esculenta*) is a crop widely grown in PNG but falls under the category of 'not fully utilized' to the extent of commercialization, export potential, downstream processing or added value and alternative uses. Worldwide it is considered a neglected root crop and an

Table 3. Categories of UUC with examples in PNG

Name	Scientific name	Use
Not fully utilized		
Taro	*Colocasia esculenta*	Staple
Sweet potato	*Ipomoea batatas*	Staple
Aibika	*Abelmoschus manihot*	Vegetable
Chinese taro	*Xanthosoma sagittifolium*	Staple
Yam	*Dioscorea esculenta, D. alata*	Staple
Sago	*Metroxylon sagu, M. salomonense*	Staple
Overlooked		
Breadfruit	*Artocarpus altilis*	Staple and nut crop
Marita	*Pandanus conoideus*	Fruit
Winged bean	*Psophocarpus tetrogonolobus*	Vegetable
Pitpit (highlands, lowlands)	*Saccharum edule, Setaria palmifolia*	Vegetable
Karuka	*Pandanus julianettii, P. brosimos*	Nuts
Undervalued		
Galip nut	*Canarium indicum*	Nut
Okari nut	*Terminalia impediens, T. kaernbacchii*	Nut
Ton	*Pometia pinnata*	Fruit
Yam	*Dioscorea nummularia*	Staple
Banana	*Musa* – AA group	Staple
Swamp taro	*Cyrtosperma* spp.	Staple
Giant taro	*Alocasia macrorrhizos*	Staple
Tulip	*Gnetum gnemon*	Vegetable and nut
Valangur	*Polyscias fruticosa, P. verticillata*	Vegetable
Unrecognized		
Banana	*Musa*, Fe'i group	Staple
Yam	*Dioscorea pentaphylla, D. bulbifera*	Staple
Dicliptera	*Dicliptera papuana*	Vegetable
Poorly known[1]		
Black berried nightshade (*karakap*)	*Solanum nigrum*	Vegetable
Kumumusong	*Ficus copiosa*	Vegetable
Watercress	*Rorippa nasturtium-aquaticum*	Vegetable
Rungia	*Rungia klossii*	Vegetable
Highland breadfruit	*Ficus dammaropsis*	Vegetable
Indigenous cabbage	*Nasturtium schlechteri*	Vegetable
Kalalava	*Ormocarpum orientale*	Vegetable

[1]also often very localized consumption in the country
Sources: Arnaud and Horry (1997); Bourke and Harwood (2009); French (1986); Lebot et al. (2017); NARI (2009); Quartermain (2006)

Table 4. Food composition information of selected UUC of PNG (per 100 g)

Scientific name	Water (g)	Energy (kJ)	Protein (g)	total fat (g)	Iron (mg)	Zinc (mg)	Vit A (mg)	Vit C (mg)
Colocasia esculenta (corm, raw)	75	407	2.2	0.4	1.2	0.4	2	8
C. esculenta leaves, raw	83	207	5.8	1.3	2.8	0.6	508	81
Abelmoshus manihot	88.5	197	5.7	0.6	1.8	0.87	990	27
Solanum nigrum	88	183	5.0	0.8	19	0.3	-	11
Canrium indicum (kernel)	35	1931	8.2	45.9	3.5	2.4	14	8
Artocarpis altilis (seed)	61.9	650	7.9	2.5	0.7	0.8	-	6.1
A. altilis (flesh)	66.3	506	1.5	3.6	0.4	0.2	-	25

Sources : Dignan et al. (2004); Preston (1998); Ragone (1997)

"orphan" species with no international research centre with the mandate to assist producers with the development of improved varieties (Lebot *et al*., 2018).

There are no accurate data on area of cultivation as most taro is still produced on small plots in multi-cropped gardens in mostly subsistence systems. Sar *et al*. (1998) estimated an area of 70,000 ha. Areas where taro is important traditionally is shown in Fig. 2. Total production and consumption estimates are shown in Table 1. Yield of taro are low in general, ranging between 6-8 t/ha.

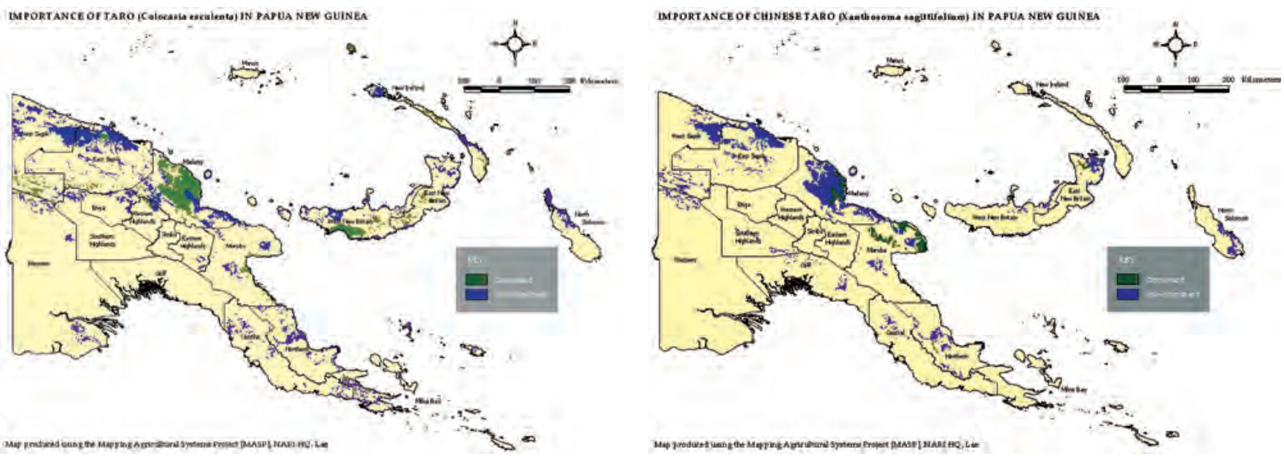

***Fig. 2.** Importance of taro and Chinese taro in PNG*

Aibika (*Abelmoschus manihot*) and Other Traditional Leafy Vegetables

Leafy vegetables play a major role in traditional food systems in PNG and other Pacific Island Countries (PIC) (Table 2). Green leafy vegetables can contribute 20-30 per cent of daily protein in some areas (Preston, 1998). However, despite their importance in PNG many of the traditional leafy vegetables are undervalued and their use very localized and not known throughout the country. Among the leafy traditional vegetables in PNG, aibika is probably the best researched of the crops in PNG and the Pacific. Aside from the contribution to food and nutrition, many of these vegetable crops are also known to have medicinal properties (French, 1986; Preston, 1998).

There is no information on area of cultivation or production volumes of leafy traditional vegetables in the country. There is also no yield information available for the vegetables grown under village conditions. Some experimental data are available on a few of the leafy traditional vegetables shown in Table 5.

Table 5. Experimental yield data of selected leafy traditional vegetables in PNG

Crop	Yield over total harvest period (t/ha)	Period to first harvest (weeks)	Period to last harvest (weeks)
Aibika	3.7-4.7	24	76
Amaranthus	1.5	14	54
Water dropwort	9.7	14	76
Black berried nightshade	2.8	14	70
Rungia	6.4	15	76

Source : Bourke and Harwood (2009)

Galip Nut (*Canarium indicum*)

Galip nut (*Canarium indicum*) is an indigenous tree of the lowland forests of Melanesia (Papua New Guinea, Solomon Islands, Vanuatu) and parts of Indonesia producing edible nuts, commercial timber and some minor products (Nevenimo *et al*., 2007; Orwa *et al*., 2009a; Thomson and Evans, 2006). In, in some parts of PNG (Fig. 4) it has high cultural value and is used as a food crop. However, overall this tree crop has been undervalued and was little known outside of the Melanesia. It is related to the pili nut (*Canarium ovatum*) that are processed and sold in markets in the Philippines (Coronel, 1996). In PNG, feasibility studies conducted in early 2000s also confirmed that this tree crop has considerable potential for further domestication and commercialization (Evans, 1996; McGregor *et al*., 2003; Nevenimo *et al*., 2007).

Galip nut is a forest tree and found in an estimated area of 6 million ha in PNG (Evans, 1996). Domestication of the tree species began a very long time ago when inhabitants started to select and protect naturally regenerating seedlings and developed local varieties through selection of trees on the basis of their kernel size and taste, thin pericarp and oil content according to sought after characteristics (Nevenimo *et al*., 2007; Thomson and Evans, 2006). A survey conducted in East New Britain Province of PNG where galip nut is a traditional crop showed that on average household owned 11 galip nut trees (Leakey, 2006). At present only very few small galip plantations (<50 ha) have been established primarily for timber production as the galip tree is also a valuable tropical hardwood species. There is no information of total production of galip nuts in the country. Estimates on kernel yield is 1.5-7 t/ha/year (Orwa *et al*., 2009b; Thomson and Evans, 2006).

Significant Achievements

Taro

Germplasm management: PNG is considered a secondary centre of diversity for taro with domestication of the crop from wild sources existing in the region rather than dispersal as a domesticate (Lebot and Aradhya, 1991; Lebot *et al*., 2004; Taylor *et al*., 2010). PNG was part of two major initiatives in the region to collect, characterize, document and rationalize taro collections. The first of those initiatives was the Taro Network for South-East Asia and Oceania (TANSAO) that characterized more than 2,000 taro accessions preserved in seven national germplasm collections (Vietnam, Thailand, Malaysia, Philippines, Indonesia, Papua New Guinea, Vanuatu) and identified core samples that were shared across participating countries (Lebot *et al*., 2004; Quero-Garcia *et al*., 2004). The second initiative was Taro Genetic Resources: Conservation and Utilization (TAROGEN) project that focused on Pacific Island Countries. The need for this work arose from the devastating impact of the incursion of *Phytopthora colocasiae* into Samoa that more or less destroyed taro production and exports from that country as all existing varieties had high susceptibility to the fungus (Hunter *et al*., 1998). Achievements of this project comprised collecting missions and the establishment of *ex situ* collections in PNG (859 accessions in 2005, currently 458 accessions) and other PIC and the characterization of taro morphological and genetic diversity using minimum descriptor lists (NARI, 2016) and genetic markers (Mace *et al*., 2006; Okpul *et al*., 2004). The core collection representing the top 20 per cent of the morphologically and genetically diverse taro is now conserved at the Centre for Pacific Plants and Trees (Pacific Community) in Fiji (Taylor *et al*., 2010).

Variety development: TAROGEN also helped with the development of taro breeding programmes in PNG and Samoa with the release of a number of taro leaf blight resistant hybrid taro varieties (Okpul *et al*., 2002; Singh *et al*., 2009). A summary of the achievements for PNG was published as an APAARI success story by Yalu *et al*. (2009).

Disease and pest management: Aside from the achievements in releasing varieties with a high level of resistance to *Taro Leaf Blight* mentioned in the previous section, a lot of work was done on developing effective management practices for taro beetle (*Papuana* spp.) control, which is considered a major pest in taro production in PNG. Various approaches were looked at including biological control using *Metarhizium anisopliae* and the Oryctes virus but while both can cause significant mortality in the beetles, especially in the case of *Metarhizium,* the lag time to death of the beetle as too long and damage still occurred, while Oryctes virus showed low persistence in the field. The current recommendation for effective control includes the use of imidacloprid or Bifenthrin in combination with cultural control methods (Lal *et al*., 2008).

Aibika and Other Traditional Leafy Vegetables

Germplasm management: Despite the importance of the leafy traditional vegetables in PNG, only for aibika germplasm collection was established and accessions morphologically characterized using a minimum descriptor list (Kambuou *et al*., 2003). In 2004, the *ex situ* collection still had 112 accessions, unfortunately this number has now dropped to 42 accessions. A recent project supported by the French Pacific Fund established a core collection of 20 accessions representing the diversity of aibika from the five participating Melanesian countries (Vanuatu, Solomon Islands, Fiji, PNG, New Caledonia) which are now preserved *in vitro* in the CePaCT in Fiji (Tuia *et al*., 2015). A second phase of the project will now be implemented and includes agronomic evaluation of national collections, exchange of germplasm and initiation of breeding activities for aibika.

NARI has also started to expand its PGR activities for leafy vegetables to include *Amaranthus* spp. (18 accessions, 5 different species viz. *A. blitium, A. caudatus, A. cruentus, A. dubius, A. hypochondriacus*) and black berried nightshade (*Solanum nigrum,* 3 accessions). This includes accessions from PNG as well as accessions imported from the World Vegetable Centre. The accessions have been morphologically characterized and are currently evaluated for agronomic traits. Incidence of pest and diseases is monitored as well (Solberg *et al*., 2016). Other work by Rubiang-Yalambing *et al*. (2016) screened 23 aibika accessions for variability in micronutrient and folate profiles and found that aibika has high levels of minerals and folate but this is significantly affected by environmental factors and further studies need to determine the best growing conditions for achieving consistently high levels of the nutrients.

Disease and pest management: Little is known about the pest and disease status of most leafy traditional vegetables. Again aibika is the best researched and Preston (1998) provides a comprehensive overview of pest and diseases recorded for this crop. In PNG aside from a number of insect pests (aibika jassid – *Amrasca devastans*, leaf roller – *Sylepta derogata*, shot-hole beetle – *Nisotrabasselae*), aibika collar complex is the most serious disease affecting aibika in PNG. The most important disease agent in this complex is *Phytophthora nicotianae* var. *nicotianae*. A recent survey in Morobe province, PNG confirmed the widespread occurrence of collar rot with farmers having little knowledge on the nature of this disease or how to manage it (Rauka and Shigaki, 2015).

Galip Nut

Germplasm management: A genetic resource exploration has been carried out in the main galip nut growing provinces in PNG (Fig. 4) and a collection of 224 open-pollinated families from 8 locations in three provinces (Madang, Autonomous Region of Bougainville, West New Britain) and 223 clones from East New Britain was established at the NARI Islands Regional Centre in East New Britain. Nuts collecting from the different locations were also assessed for characteristics and variation between locations and individual trees. Subsequently, genotypes with superior nut characteristics especially a high kernel to shell ratio were selected (Randall *et al*., 2016).

Galip nut is a dioecious tree with male and female flowers developing on separate trees. Substantial variation has been found in nut characteristics between different trees (Thomson and Evans, 2006). Therefore, it is important to develop vegetative propagation techniques. Marcotting and approach grafting have been identified as suitable and effective techniques (up to 100% success rate) for capturing phenotypically superior individuals in the field but is not suitable for mass-propagation technique. Protocols for effective propagation from juvenile stem cuttings with strike rates of more than 90 per cent have also been developed. However, propagation techniques effective for mass propagation in the related species *Canarium ovatum* (pili nut) (Coronel, 1996) have shown to be unsuccessful in galip nut and an effective and efficient method especially to propagate from mature cuttings is still elusive requiring further research including *in vitro* techniques (Cornelius *et al*., 2012). That would also help to produce fruit closer to the ground and may develop a crown-like, rounded form, without passing through a period of juvenile habit.

Processing, value addition and product development: Substantial work has been done into development of post-harvest and processing protocols starting from harvest, depulping of the mesocarp, drying of the nut to 1per cent, cracking and the development of various products. A major achievement was the establishment of a pilot galip processing factory at the NARI Islands Regional Centre at Keravat, East New Britain which boosted the efforts of the Institute as a lead agency for galip research for development in PNG and the region. The factory is now producing various product lines including roasted kernel, sugar-salt cured and roasted, roasted kernel without testa. Those products are now sold to various local supermarkets in East New Britain. Aspects of food safety were also addressed with the development of a HACCP plan as well as information on storage and shelf-life of products (Wallace *et al*., 2016, 2012; Walton *et al*., 2016). Other areas of current research for development include the exploration of other domestic and export markets, financial feasibility and profitability in the value chain, development of partnerships and capacity building especially of women producers and small-scale processors.

Challenges and opportunities

Taro

As was mentioned above, taro is a crop in PNG that is not fully utilized to the extent of commercialization, export potential, downstream processing or added value and alternative uses (Quartermain, 2006). There are generally opportunities to increase productivity with application of improved varieties and agronomic practices. For example, NARI released taro resistant hybrids that can yield at least twice as much (12-15 t/ha) as common landraces (5-7 t/ha) in low input systems and even higher yields with improved practices. There is an unsatisfied demand in domestic urban markets for PNG as well as opportunities for export (Manner and Taylor, 2011).

There are also little explored opportunities for processing and value addition as well as promotion in the health food market. Taro starch grains are small making them highly digestible and of interest for processing into various food products, good dietary carbohydrate alternative especially for diabetic people, infant food or people allergic to cereal (Simsek and El, 2015). There are also varieties with high flavonoids and antioxidant content (Lebot and Legendre, 2014) and the crop can be considered as valuable sources of starch and minerals, especially potassium, calcium, phosphorus and magnesium in the human diet (Mergedus *et al.*, 2015) and bioactive proteins as immune stimulators (Pereira *et al.* 2015).

Aibika and Other Traditional Leafy Vegetables

Leafy traditional vegetables are not well researched in PNG. In general, most of the species used as leafy vegetable are relatively easy to grow and do not require much input at the subsistence level. Often they are still collected from the wild as needed (NARI, 2009). The nutritional value of this type of vegetables and its potential in improving nutritional outcomes and addressing persistent malnutrition in the country is well documented (French, 1986; Preston, 1998; Rubiang-Yalambing *et al.*, 2014) (Fig. 3).

However, a recent survey in PNG found that there is a decline in the consumption of leafy traditional vegetables relating to increasing urbanization and land pressure such as: physical access to land to grow or collect indigenous vegetables, cultural perceptions, loss of knowledge in growing and cooking indigenous vegetables, changes in life style, introduction of new vegetables, and the loss of natural habitats containing wild food resources especially amongst middle- to high income households although for poor urban households they are still the main type of vegetable consumed

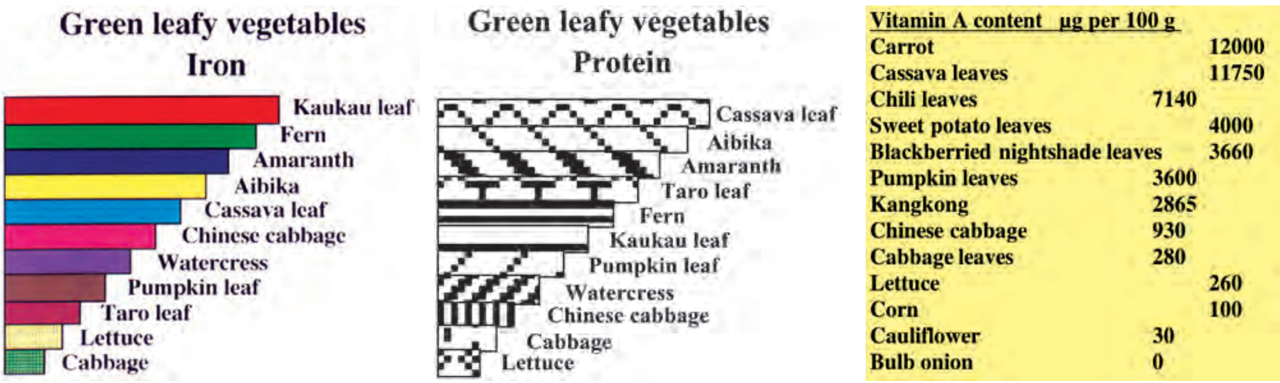

Fig. 3. *Comparison of vegetable crops for iron, Vit A and protein content (French, 1986)*

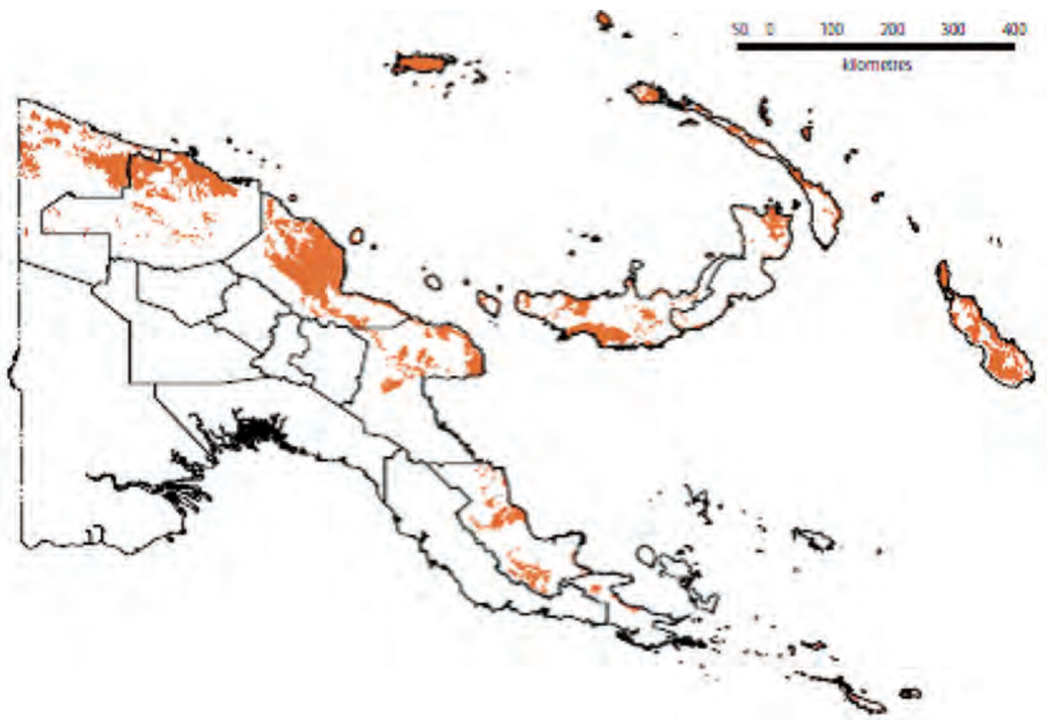

Fig. 4. *Distribution of galip nut as an important nut in PNG (Bourke and Harwood, 2009)*

(Paul *et al*., 2015). The study also found several opportunity points for the promotion of indigenous vegetables such as potential health benefits, cheaper prices, availability, and association with custom and tradition. Those opportunities are now being further explored in a current project implemented by NARI in partnership with Charles Darwin University funded by the Australian Centre for Agricultural Research (ACIAR) (http://traditionalvegetables.cdu.edu.au).

Galip Nut

The commercialization of galip nut is slowly progressing. There are still many areas to be addressed especially in the development of production systems, tree management, propagation, breeding etc. A potential threat to the progress of establishing galip plantings is the emergence of a serious pest, the galip weevil (*Ectatorhinus magicus)* that has devastated galip trees in some parts of East New Britain. The pest is endemic to PNG but only considered as a minor pest. Further work needs to be done to understand any linkages of the outbreak to factors such as varietal susceptibility, climatic factors and improved knowledge on the life cycle and population dynamics to derive appropriate management options (Cassis *et al*., 2017). There are opportunities to explore the use of by-products from the processing of galip kernel including the pulp (potential for composting or biogas), shell (charcoal, decorations for tourists), oil (from broken kernels), galip cake (remainder after oil extraction for livestock feed or inclusion in baking products). There are also opportunities to diversify products to also develop a value chain for galip oil, which is a high quality oil and can be used for skin and cosmetic products (Nevenimo *et al*., 2007).

Marketing, Commercialization and Trade

Taro, aibika, other leafy vegetables and also galip nut are almost exclusively marketed in local informal markets. There is no information available on volumes or total value marketed in country for those crops. Efforts on commercialization of galip products have been described already in previous sections of the paper.

Strategies to Harness their Potential

PNG is signatory to the Convention of Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). There are also current initiatives to accede to the Nagoya Protocol. NARI also has developed a PGR Strategy (Kambuou, 2005). In 2006 a workshop was conducted in PNG to analyze policies and strategies affecting the use of underutilized PGR with recommendations for the core elements of a strategic plan to enable effective conservation and sustainable use of currently underutilized crop species for food and agriculture (Quartermain, 2006). Some of the recommendations include:

- National agricultural development plans must adequately recognize the potential roles of currently underutilized species (UUS)
- Food security policies and strategies must give primary attention to food diversity and nutritional quality, as well as income earning potentials from (UUS)
- Strategies for improved nutrition must address the major problems of protein-energy malnutrition, nutritional anaemia, nutrition related diseases and iodine deficiency disorders, and improve access to traditional foods in urban and environmentally disadvantaged areas
- The bias against traditional or UUC in higher education teaching due to paucity of biological and economic information must be addressed through research and documentation.
- Strategies must promote the dissemination of information on UUS and the sharing of traditional knowledge.
- Documentation of existing knowledge
- Public and political awareness of the valuable attributes and potentials of traditional and currently UUS are crucial both for conservation of biodiversity and economic development through sustainable use

The development of a Strategic Plan of Action unfortunately did not eventuate in PNG following the workshop. While policies and to some extent strategies exist in the country, implementation has been poor. Underfunding of agricultural research for development (AR4D) by the Government of PNG is a major contributing factor. However, drawing the attention of the donor community to invest in the promotion and commercialization of underutilized crop species even with proven feasibility or potential and maintain support for a sufficiently long period to achieve long-term impacts has also proven difficult with the focus of donors to achieve development impacts at population level in short periods of time and reluctance to invest in AR4D.

The general underinvestment into AR4D is also hampering the development of necessary research capacities in all areas required for a facilitation of new value chains including PGR management, crop and tree management, postharvest and processing, product development, marketing and market development, economic modelling and facilitation of public-private partnership.

Major Focus Areas

Current major focus areas include work on taro, traditional leafy vegetables and galip nut and have been covered in above sections.

Infrastructure, Capacity Building and Financial Investment

All past and current work on the taro, leafy vegetable and galip nut have been supported with external grants from various donors. The TAROGEN and TANSAO project were implemented across the Pacific and APR, respectively. As part of both projects, capacity was built in the region and Papua New Guinea in genetic resources management, taro breeding approaches, taro characterization using morphological and genetic markers and virus indexing. Total investment for the TAROGEN project was A$4.3 million.

The work on traditional leafy vegetables has only recently started with a support from ACIAR with a total investment of A$1.2 million. Capacity is built in NARI on characterization of leafy vegetable genetic resources, seed management and market research.

The development of a galip nut industry can at this point be viewed as a success story given the progress made and the support received over the past 15 years from donors and an investment of around PGK 12 million (approx. USD 3.8 million). However, 15 years is a short period and USD 3.8 million a small amount in terms of industry development of a tree crop, e.g. it took more than 25 years for the Australian Macademia Industry to reach a level that made an impact in domestic and international markets. While significant progress has been made, much more investment is required to put this infant industry on a solid footing and ensure its longer-term sustainability. At this point the private sector is also reluctant to invest due to uncertainties around feasibilities and profitability in this new value chain.

Future Thrusts and Other Opportunities

Breadfruit

There are many more opportunities to better utilize the rich agro-biodiversity in PNG. Breadfruit is a tree crop that has so far been overlooked in with investment into increasing production, downstream processing and alternative uses. PNG has a rich diversity of breadfruit genetic resources that need to be better utilized for economic development in the country and to support food security in the face of growing effects of climate change.

NARI has identified breadfruit (*Artocarpus* spp.) as a priority in it's 4-year medium-term Implementation Plan 2017-2020. Breadfruit has been cultivated in the Pacific for over 3,000 years. The island of New Guinea is considered part of the centre of origin of this tree crop but breadfruit is now grown throughout the tropics including the Caribbean, Central and South America and parts of Africa (Ragone, 1997). In PNG they play an important role in the diets of many lowland coastal and island communities but the tree can grow up to 1250 m altitude. Breadfruit produces abundant nutritious fruit high in carbohydrates and a good source of fibre, vitamins and minerals and the nuts are high in protein, relatively low in fat and also a good source of vitamins and minerals. Both the flesh and nut are eaten (Bourke and Harwood, 2009; Jones *et al*., 2011a).

Breadfruit has gained considerable attention in the past 20 years as a valuable tree crop that can make a substantial contribution to alleviate hunger in tropical areas and stem the tide of non-communicable diseases afflicting many Pacific Islands (Jones *et al*., 2011b; Turi*et al*., 2015). Establishment of breadfruit orchards are also viewed as a potential strategy for Climate Change adaptation due to the relative tolerance to drought of the tree crop and the ability of some varieties to grow on poor coral soils (McGregor *et al*., 2016; Ragone, 2011). Commercial production of breadfruit is well established in the Caribbean and also other Pacific Islands such as Samoa are moving towards increasing production and promotion of value addition (Ragone, 2011).

Other Potential Focus Areas

There are a number of other indigenous fruit and nut species that are underutilized and have the potential for domestication and commercial production. Table 6 shows some of the tree crop species.

Table 6. PNG indigenous fruit and nut species with potential for commercialization

Name	Scientific name	Remarks
Okari nut	*Terminalia kaernbachii*	Nut species, high quality nut and good potential for processing and marketing; some localized efforts to improve on marketing of the nuts
Pao	*Barringtonia procera*	Nut species, considerable potential for commercialization; already markets developed in Vanuatu
Karuka	*Pandanus julianettii*	Nut species, widely grown in PNG and high domestic demand
Marita	*Pandanus conoideus*	Fruit species, widely grown; needs to be processed; potential as novel food product (sauce) or its medicinal properties
Ton	*Pometia pinnata*	Fruit species; considered to have excellent potential for commercialization

Source: Bourke (2010a, 2010b); Hougthon (1996); Jorim et al. (2012); Olson (1996)

Conclusions

In PNG, many crops which are considered as major staples such as taro or sweet potato, remain underutilized in terms of commercialization, export potential, downstream processing or added value and alternative uses. There are a range of UUC indigenous to PNG and the Pacific with potential to contribute addressing arising issue of lifestyle diseases, climate change, population pressures and to help in economic and socio-economic advancement of people. It will require a harmonization of policies and strategies at international, regional and national levels to prioritize investment in the development of UUC and a long-term commitment by international donors and national governments to allocate sufficient resources to unlock the potential of those crops.

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Country Status Report - Samoa

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Introduction

Samoa island groups is situated between latitude 13-15°S and longitude 170-173°W in the South Pacific. The group consist of two big islands and several other small uninhabited islets. Upolu and Savaii are the two main islands and have a population of more than 186,000 people with about 70 per cent of the population living in Upolu and 30 per cent in Savaii (Government of Samoa, 2009; 2014). About 25 per cent of the population are now dwelling in Apia urban area, and the centre of trade, commerce and communication linkage to the outside world. The rest of the population lives in villages along the coastal and several inland areas of the two main islands and two small islets, Manono and Apolima.

According to statistics of FAO (1991), land area of Upolu is about 1,115 km^2 with a population density of more than 100 people per km^2 and Savaii, the biggest island with land area of 1,814 km^2 with a population density of 25 people per km^2.

The soil of Samoa belongs to the soil taxonomy Order Inceptisols, with parent materials mainly classified as andesite basalt, with lots of weathered rocks fragments (Wright, 1963). Lowland and foothills soils range from very shallow sandy gravels to deep dark reddish-brown clays, while the uplands soil can be classified from very shallow to deep peaty silt loams. The physical nature of the soil is excellent for agriculture but due to its porosity and shallowness, is very susceptible to water and minerals leaching under frequent rain conditions.

Farming Systems

Farming practices in the country are described as either subsistence or commercial plantation mainly in the lowland and extending up to the higher elevation (Paulson, 1993). Lands around the coastal areas where people dwell are classified as coconut mixed cropping zone with varieties of food crops like breadfruit *(Artocarpus altilis)*, banana *(Musa* spp.), yams *(Dioscorea* spp.), edible aroids *(Colocasia esculenta, Alocasia macrorrhiza* and *Xanthosoma* spp.).

Extending inland and upland are large commercial plantation zones dominated by coconut (*Cocos nucifera)* and cocoa (*Theobroma cacao)* plantations. Upland are mainly taro *(Colocasia esculenta)* planted as either cash or food crop on a large commercial scale for export. These areas extending up to forest are classified as taro fallow zones and pasture for cattle farms.

Generally, Samoa is a small country with limited natural resources including food crops, medicinal plants and forest species. For many decades now, the government and the private sector, with assistance of donor agencies and international organizations, has carried out a number of research

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and seed supply systems to support planting material distribution and encourage farmers in planting schemes for sustainable food production and income security. Table 1 provides some of these Donor Funded Projects.

Table 1. Donor funded R&D projects on agriculture executed in Samoa

Donor	Name of Project	Activity / objective
World Bank	Samoa Agricultural Competitiveness Enhance Project (SACEP)	Technical and financial assistance for fruit and vegetable production in Samoa
	The China Agricultural Technical Cooperation Project	
UNDP	Pilot Programme for Climate Change: Enhancing the Climate Resilience of Coastal Resources and Communities Project	Technical and financial assistance for coconut replanting scheme
UK and Bioversity International	Darwin Initiative Coconut Project	
NWAID Agency	New Zealand Aid Programmes	Assistance to cocoa industry
Australian Aid	Pacific Horticultural Agricultural Market Access (PHAMA)	Assists for fresh and frozen agricultural produce market access
ACIAR	Soil Management, Nutrient Recycling and Soil Portal Project and the IPM/ICM Pest Control in the Pacific	Soil health and pest integrated management
ITPGRFA - Access Benefit Sharing Fund	Project on Access Benefit Sharing Fund	Technical and financial assistance for fruits and vegetable, aroids and other roots and tubers R&D

Area, Production and Productivity

The total land area of Samoa as recorded by Wright (1963) is about 2,841 km^2 and only 21 per cent of the total land mass is reported to be suitable for agricultural activities. In the 2009 Agriculture Census, the total land area use for crops cultivation was only 38,000 hectares, which was only 57 per cent of agriculturally suitable land. Coconut is by far the most important crop which covers almost 66 per cent of all agricultural land; other crops planted in large acreage of land for food and cash purposes are taro, cocoa, other edible aroids like alocasia and xanthosoma, banana and breadfruit. These crops cover more than 80 per cent of land under crops cultivation and employs around 70 per cent of agriculture dependent households in the rural areas (Government of Samoa, 2009).

Crops of major importance to the economy of Samoa are coconuts, cocoa, taro banana, breadfruit and kava (Table 2). These crops are given high priority to be fully utilized for their potential in value adding and marketing through research in crop improvement and development of seed supply systems for sustainable supply of quality planting material. The government, together with donor funded projects, provide technical and financial assistance to support research and development to explore the full potential of these crops in primary production and market access.

Underutilized Crops (UUC) of Nutritional and Health Value

There are many food plants including vegetables, root and tuber crops fruit trees and spices that grow naturally either in the bush or in cultivation by few farmers, mostly in backyard gardening. These plants received little attention, neglected or overlooked but are still maintained, for vegetables or medicinal uses. Very little attention has been given to these underutilized plants, not much is known about their value and mostly neglected due to low preferences in terms of food, medicinal, herbal drinks and commercial potential.

Most of these species were generally believed to be introduced during the time when Missionaries arrived; some are recent introductions through agriculture programmes, but lack promotion on their nutritional value and health benefits. These plants are now widespread and are thriving well in the

Table 2. List of economically important crops fully utilized for their potential in Samoa

Scientific name	Family	English name	Local name	Important part(s)
Cocos nucifera	Arecaceae	Coconut	*Niu*	Nuts (cream, water)
Theobroma cacao	Malvaceae	Cocoa	*Koko*	Seeds
Colocasia esculenta	Araceae	Taro	*Talo*	Corm and leaves
Alocasia macrorrhiza	Araceae	Giant taro	*Taamu*	Corm
Musa spp.	Musaceae	Banana	*Fa'i*	Matured and ripe fruit
Artocarpus altilis	Moraceae	Breadfruit	*Ulu*	Fruit
Dioscorea spp.	Dioscoreaceae	Yam	*Ufi*	Tubers
Xanthosoma sagittifolium	Araceae	Xanthosoma	*Talopalagi*	Tubers and mini corms
Piper methysticum	Piperaceae	Kava	*Ava*	Roots
Morinda citrifolia	Rubiaceae	Noni	*Nonu*	Fruit
Vanilla planifolia	Orchidaceae	Vanilla	*Vanilla*	Fruit
Carica papaya	Caricaceae	Pawpaw	*Esi*	Fruit
Persea americana	Lauraceae	Avocado	*Avoka*	Fruit
Citrus latifolia	Rutaceae	Tahitian lime	*Tipolo Tahiti*	Fruit
Ananas comosus	Bromeliaceae	Pineapple	*Falaai*	Fruit
Brassica spp.	Brassicaceae	Chinese cabbage	*Kapisisaina*	Leaves
Brassica oleracea	Brassicaceae	Head or English cabbage	*Kapisilapotopoto*	Head
Cucurbita spp.	Cucurbitaceae	Pumpkin	*Maukeni*	Fruit
Solanum lycopersicum	Solanaceae	Tomato	Tomato	Fruit

landscape of Samoa. Some of these plants were identified, selected and are highly recommended by nutritionists working in the health sector, to be promoted as nutritionally rich vegetables for home gardening and have great potential commercially.

The Ministry of Health in partnership with the Ministry of Agriculture and Fisheries (MoAF) and the Ministry of Education Sports and Culture are working together in promoting healthy eating programmes for elementary and high schools in the country, as part of school curriculum and activities to create awareness about importance of eating locally produced fruits and vegetables for health. This programme is the initiative of the Ministry of Health to combat the high level of obesity, overweight, high blood pressure and diabetes which is on the rise in an alarming rate. The programme is now starting with school targeting young children and youth, teaching them on know how to grow, cook and understand the nutritional values and benefits of these highly nutritious vegetable crops that can be easily grown in home gardens at very low cost and are excellent food for health. The MoAF has been given the role of supplying planting materials and seeds of locally available vegetables and fruit trees that are nutritiously rich in phytochemicals and are beneficial for health to supply school and rural communities gardening programmes. Table 3 gives the list of underutilized food plants that are considered important for health benefits and commercially.

Production of Quality Seeds and Planting Materials

Most of the seed supply will be met by the support from donor funded projects, and supply of planting materials for vegetative crops will be met from field genebank collection and *in vitro* mass propagation for distribution. Breeding programme will be explored in search of high quality improved

Table 3. List of underutilized vegetables and fruits recommended for school garden communities programme

English name	Scientific name	Family name	Samoan name	Plant part used
Sweet potato	*Ipomea batatas*	Convolvulaceae	*Umala*	Tuber, shoots
Hibiscus spinach	*Abelmoschus manihot*	Malvaceae	*Pele*	Leaves
Okra	*Abelmoschus esculenta*	Malvaceae	Not known	Fruit
Drumstick	*Moringa oleifera*	Moraceae	*Tamaligiai*	Leaves, pods
Bitter gourd	*Momordica charantia*	Cucurbitaceae	Not known	Fruit, shoots
Basil	*Ocimum basilicum*	Lamiaceae	*Basili*	Leaves and seed
Ginger	*Zingiber officinale*	Zingiberaceae	*Fiu*	Tuber/rhizome
Turmeric	*Curcuma longa*	Zingiberaceae	*Ano*	Tuber/rhizome
Fruit Trees				
Soursop	*Annona muricata*	Annonaceae	*Sasalapa*	Fruit/leaves
Pomelo	*Citrus maxima*	Rutaceae	*Pomelo*	Fruit
Grapefruit	*Citrus x paradisi*	Rutaceae	*Moliaisuka*	Fruit
Oranges	*Citrus sinensis*	Rutaceae	*Molisuamalie*	Fruit

varieties, improving or increasing the level of phytochemical contents or quality of a particular bio-active molecular or groups of chemicals, like flavonoids and phenols.

Disease and Pest Management

Only sweet potato, in the list of promoted UUC, is vulnerable to tuber and stem weevils, scab moth is also found to cause shoot curling in some varieties. Varietal selection through breeding programme and collection of seeds from genebank, field collection will be carried out to select new genotypes for resistance build up and yield improvements. No major problems (disease and pests) are known to be associated to the other crops in the list (Table 3).

Challenges and Opportunities

Some of these underutilized plants have been recognized as important crops for human health benefits, but there are some constraints that are limiting the production of these crops.

Challenges/Constraints

- These crops are new to the farming communities and little is known of their market potential. Farmers are reluctant to accept cultivation of these crops, as the risk of failure is perceived to be high.
- Lack of market information to farmers always put farmers in the risk position when they look for local traders.
- Lack of technical knowledge in cultivation, production, processing, marketing and problems in maintaining of quality planting materials supply.
- Lack of awareness programmes on the importance of UUC and their beneficial values, as people are not easily convinced of any new product promoted.
- Inadequate supply and production of quality seed of UUC, being limited or absent altogether.
- Lack of facilities for processing to add value to the produce.
- Technical capacity of staff is very limited, lack of research initiative and researchers are not interested or show no interest

- Lack of technical and financial assistance from donor agencies to support research and genebank conservation, characterization, seeds and planting materials supply systems, processing and market value chain of un-recognized underutilized plants.

Opportunities

- Partnerships between government ministries, private and public sectors can play a vital role in solving most of the constraints described above.
- Beneficial effects of these UUC to be fully explained to people together with fact sheets and other relevant information available and must be more convincing to the farmers and customers.
- Encourage private sector in building infrastructure needed for processing and distribution for marketing.
- Work together to strengthen ties between farmers, exporters, consumers and business people for the efficiency, consistency of the value chain of product and to create trust between producers, processors and market.
- The MoAF Crops Division to ensure sufficient and consistent supply of quality seeds and planting materials network.
- Strengthen and sustain crops division adaptive research capacity to trial and develop sustainable productivity and seed supply of highly nutritional underutilized plants.
- Strengthen capacity to prepare and deliver extension/advisory information and messages through media and information communication technology (ICT) application.
- Use agriculture as a vehicle for delivery of messaging on plant nutrition value knowledge and practices.

Strategies for Emerging Challenges

At present, UUC species in Samoa are unfortunately neglected. The Ministry should prepare and include a policy intent to strengthen and promote high nutritious-medicinal value food plant in the Agriculture Sector Plan in the next five year, for their significant contribution in the country's economy with the aim of promoting healthy living and improving income earning of farmers through the use of UUC. Following are some of the approaches to address the emerging challenges:

- The Government through the MoAF to strengthen and promote cultivation, *in situ* and *ex situ* conservation of UUC.
- Strengthen and support research and development on reproduction, cultivation, breeding and evaluation of UUC.
- To promote health awareness programmes for schools and general public.
- To coordinate and strengthen public and private partnership collaboration for utilization, value addition, export and marketing of UUC.
- To provide and facilitate training and workshops for growers.
- The Government to provide support for infrastructure for marketing. Most of these crops will be marketed locally, as there is a potential local market with high price. The Ministry will work together with some private sector players in the processing and trading industries, first at local then international level.

Future Thrust

- Increase awareness on the nutritional importance of these crops.
- Use every opportunity to bring together farmers, private sector, national and maybe regional stakeholders for consultation, meetings, workshops to meet and discuss benefits and market potential.

- Encourage media participation in promotion, awareness on health benefits, launching and marketing of UUC.
- Research, information sharing and promotion of commercialization.
- Use of annual agriculture show as a platform to encourage production and consumption of nutritious food and health related benefits.
- Provide training in production, processing, preservation together with business management and marketing support.
- Develop appropriate school (elementary and high) curriculum to focus on local food production and good nutritional and health.

Conclusions

It is expected that partnership and collaboration between the Government ministries (Ministry of Health, Ministry of Education, MoAF) together with local communities, private sector and school programmes, will help in developing and promoting the nutritional and marketing value of UUC for healthy living in the country.

Mass multiplication, cultivation, research and conservation (both in the field and *in vitro*) of planting materials for continuous supply for research and production should be mandated to the MoAF. This will ensure sustainable utilization, distribution and commercialization of promoted UUC to be recognized together with economically important major crops in the country. Farming nowadays is very challenging and become more and more competitive with farmers intention to maintain and secure income levels. The government need to look in ways to transform agriculture from more subsistence to higher value added production to generate more and new business for farmers.

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Appendix 1

Technical Programme

Day 1: Monday, 13 November 2017		
08:30-09:00	Registration	
	Opening Session	
09:00-09:07	Welcome Address	Ravi Khetarpal, APAARI, Thailand
09:07-09:14	Setting the Context	Raj Paroda, TAAS, India
09:14-09:21	Remarks	Vincent Lin, COA, Taiwan
09:21-09:28	Remarks	Suwit Chaikiattiyos, DOA, Thailand
09:28-09:35	Remarks	Fenton Beed, WorldVeg, Thailand
09:35-09:42	Remarks	Yusuf Zafar, APAARI, Thailand
09:42-10:00	Inaugural Address	Hiroyuki Konuma, Meiji University, Thailand
10:00-10:05	Vote of Thanks	Rishi Tyagi, APAARI, Thailand
10:05-10:30	***Tea/Coffee Break and Group Photograph***	

Technical Session I: Thematic Technical Presentations

Co-Chairs : N.K. Krishna Kumar, Bioversity International, India and K.S. Varaprasad, Ex ICAR, India
Rapporteur : Umesh Srivastava, Ex ICAR, India

10:30-10:50	Underutilized Crops for Food and Nutritional Security: Global Scenario	Benard Ngwene, Leibniz Institute, Germany
10:50-11:10	'Crops For the Future': Agricultural Diversification to 2017 and Beyond	Max Herriman, CFF, Malaysia
11:10-11:30	Underutilized Plant Diversity in Asia and the Pacific	Anjula Pandey, NBPGR, India
11:30-11:50	Grasspea: A neglected but Important Pulse Crop for Nutritional Security of Low-income People	A. Sarker, ICARDA, India
11:50-12:10	Nutritionally Rich Underutilized Vegetables	Ray-yu Yang, WorldVeg, Taiwan
12:10-12:30	Edible Wild Plants in Asia-Pacific: A Case Study with Bastar Tribal Pockets	Umesh Srivastava, Ex ICAR, India
12:30-12:50	Biofortification using Underutilized Crops	Binu Cherian, HarvestPlus, India
12:50-13:10	Knowledge Management Resources in CABI for Underutilized Crops	A. Sivapragasam, CABI, Malaysia
13:10-14:00	***Lunch at Iris Restaurant, Rama Gardens Hotel***	
14:00-14:20	Forecast Application for Risk Management in Agriculture: Case Study from Tamil Nadu, India	Anshul Agrawal, RIMES, Thailand
14:20- 14:40	***Discussion***	

Technical Session II: Strategies on Underutilized Crops for Food and Nutritional Security

Co-Chairs : Darab Hassani, AREEO, Iran and Ray-yu Yang, WorldVeg, Taiwan
Rapporteur : K.S. Varaprasad, Ex ICAR, India

14:40-14:55	Pseudocereals (grain amaranth, buckwheat, chenopods)	Kuldeep Singh, NBPGR, India
14:55-15:10	Underutilized Climate-smart Nutrient rich Small Millets for Food and Nutritional Security	H.D. Upadhyaya, ICRISAT, India
15:10-15:25	Underutilized Legumes: Global Status, Challenges and Opportunities for Harnessing Potential Benefits	J.C. Rana, Bioversity International, Central and South Asia Office, India
15:25-15:40	***Tea/Coffee Break***	
15:40-15:55	Importance of Tuber Crops for Food and Nutritional Security in Oceania	Arshni S. Shandil, SPC, Fiji
15:55-16:10	Underutilized Tropical and Sub-tropical Fruits for Nutrition and Health Security and Climate Resilience - A Bioversity International Initiative	N.K. Krishna Kumar, Bioversity International, Central and South Asia Office, India
16:10-16:25	Potential of Seabuckthorn (*Hippophae* L.) - A Multipurpose Under-utilized Crop of Dry Temperate Himalayas	Virendra Singh, CSKHPKV, India
16:25-16:45	***Discussion***	

Technical Session III: Country Status Reports on Underutilized Crops

Co-Chairs : Mohamad Roff, MARDI, Malyasia and A. Sarker, ICARDA, India
Rapporteur : Anjula Pandey, NBPGR, India

South Asia		
16:45-17:00	Bangladesh	Rina Rani Saha, Bangladesh
17:00-17:15	Bhutan	Kailash Pradhan, Bhutan
17:15-17:30	India	Kuldeep Singh, India
17:30-17:45	Iran	Darab Hassani, Iran
17:45-18:00	Sri Lanka	Hemantha Wijewardena, Sri Lanka
18:00-18:15	Nepal	Baidya Nath Mahto, Nepal
18:15-18:30	Pakistan	Abdul Ghafoor, Pakistan
18:30-18:50	***Discussion***	
19.00	***Reception Dinner at Iris Restaurant, Rama Gardens Hotel***	

Day 2: Tuesday, 14 November 2017

Special Session

Co-Chairs : Ravi Khetarpal, APAARI, Thailand and H. Wijewardena, SLCARP, Sri Lanka
Rapporteur : Anuradha Agrawal, NBPGR, India

09:00-9:20	Women Farmers as Driving Force	Eri Otsu, Heroines for Environment and Rural Support (HERS), Japan

Technical Session III: Country Status Reports on Underutilized Crops (contd.)

Co-Chairs : Fenton Beed, WorldVeg, Thailand and Reynaldo V. Ebora, PCAARRD, Philippines
Rapporteur : Kailash Pradhan, DOA, Bhutan

South-East Asia		
09:20-09:35	Lao PDR	Bounthong Bouahom, Lao PDR
09:35-09:50	Malaysia	Mohamad Roff Bin Mohd. Noor, Malaysia
09:50-10:05	Thailand	Suwit Chaikiattiyos, Thailand
10:05-10:20	Vietnam	Pham Hung Cuong, Vietnam
10:20-10:35	Philippines	Reynaldo V. Ebora, Philippines
10:35-10:50	Taiwan	Keng-Chang Chuang, Taiwan
10:50-11:10	***Discussion***	
11:10-11:30	***Tea/Coffee Break***	

Technical Session III: Country Status Reports on Underutilized Crops (contd.)

Co-Chairs : Bounthong Bouahom, NAFRI, Lao PDR and Kuldeep Singh, NBPGR, India
Rapporteur : Arshni Shandil, SPC, Fiji

The Pacific Countries		
11:30-11:45	Fiji	Savenaca Cuquma, Fiji
11:45-12:00	Papua New Guinea	Birte Komlong, PNG
12:00-12:15	Samoa	Moafanua Tolo Iosefa, Samoa
12:15-12:45	***Discussion***	
12:45-14:00	***Lunch at Iris Restaurant, Rama Gardens Hotel***	

Technical Session IV A: Working Group Discussion

14:00-16:00	Working Group 1 **Production: Conservation, Improvement and Crop Management** Chair : H.D. Upadhyaya, ICRISAT, India Facilitator : K.S. Varaprasad, Ex ICAR, India
	Working Group 2 **Utilization: Value addition, Marketing and Export** Chair : Dhrupad Choudhury, ICIMOD, Nepal Facilitator : J.C. Rana, Bioversity International, Central and South Asia Office, India
	Working Group 3 **Partnership and Capacity Building** Chair : Mohamad Roff Bin Mohd. Noor, Malaysia Facilitator : Anuradha Agrawal, NBPGR, India
	Working Group 4 **Biotechnology for Enhancing Utilization of Underutilized Crops** Chair : Rajeev Varshney, ICRISAT, India Facilitator : Rishi Tyagi, APAARI, Thailand

16:00-16:20	***Tea/Coffee Break***

Technical Session IV B: Working Group Recommendations

Co-Chairs : Birte Komlong, NARI, PNG and B.N. Mahto, NARC, Nepal
Rapporteur : Anjula Pandey, NBPGR, India

16:20-16:25	Working Group 1	H.D. Upadhyaya, ICRISAT
16:25-16:30	Working Group 2	Dhrupad Choudhury, ICIMOD, Nepal
16:30-16:40	Working Group 3	Anuradha Agrawal, NBPGR, India
16:40-16:45	Working Group 4	Rajeev Varshney, ICRISAT
16:45-17:00	***Discussion***	

Day 3: Wednesday, 15 November 2017

Technical Session V: Panel Discussion on Policy Support for Underutilized Crops to Achieve SDGs

Co-Chairs : Max Herrimen, CFF, Malyasia and Sergei Bang, NARI, PNG
Rapporteur : Anuradha Agrawal, NBPGR, India

09.00-11.00	Perception of Panellists (Max. 10 min. each)
	Yusuf Zafar, PARC, Pakistan
	Fenton Beed, WorldVeg, Taiwan
	Reynaldo V Ebora, PCAARRD, Philippines
	Kuldeep Singh, NBPGR, India
	Mohammed Roff Bin Mohd. Noor, MARDI, Malyasia
	Rajeev Varshney, ICRISAT, India
	K.S. Varaprasad, Ex-ICAR, India
	Benard Ngwene, Leibniz Institute, Germany
	Ravi Khetarpal, APAARI, Thailand
	Dhrupad Choudhary, ICIMOD, Nepal
11:00-11:20	***Tea/Coffee Break***

Plenary Session

Co-Chairs : Raj Paroda, TAAS, India and Fenton Beed, WorldVeg, Thailand
Rapporteur : Rishi Tyagi, APAARI, Thailand

11.20-12.20	Presentation of Recommendations of Technical Sessions/Working Groups	Umesh Srivastava; K.S. Varaprasad; Anjula Pandey; Arshni Shandil; Anuradha Agrawal
12.20-12.40	Brief Remarks by the Co-Organizers (~2-3 min., each)	Fenton Beed; H.D. Upadhyaya; Max Herriman; A. Sarker; N.K. Krishna Kumar; Ravi Khetarpal
12.40-12.55	Remarks by the Co-Chairs (7-8 min., each)	Fenton Beed Raj Paroda
12.55-13.00	Vote of thanks	Rishi Tyagi
13.00-14.00	***Lunch at Iris Restaurant, Rama Gardens Hotel***	

Departure

Appendix 2

Participants

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