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Satellite Symposium on

Dryland Agrobiodiversity for Adaptation to Climate Change

Indana Palace Hotel, Jodhpur, India
February 13, 2019

Proceedings and Recommendations

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of the

Satellite Symposium on
Dryland Agrobiodiversity for Adaptation to Climate Change

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Co-organized by

Indian Society for Plant Genetic Resources (ISPGR), New Delhi, India
Bioversity International (BI), New Delhi, India
Asia-Pacific Association of Agricultural Research Institutes (APAARI), Bangkok, Thailand

with support from

United Nations Environment Programme (UNEP) and
Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB)

during the

13th International Conference on Development of Drylands
(13th ICDD 2019), Jodhpur, Rajasthan, India

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Citation :

Agrawal A., S. Rajkumar, J.C. Rana, R.K. Tyagi, O.P. Yadav, K. Singh and R.S. Paroda (Eds.) (2019) *Proceedings and Recommendations of the Satellite Symposium on 'Dryland Agrobiodiversity for Adaptation to Climate Change'*. Indian Society of Plant Genetic Resources, New Delhi, Bioversity International, New Delhi, Asia-Pacific Association of Agricultural Research Institutes, Bangkok, held at Jodhpur, Rajasthan, India, February 13, 2019, 87 p.

Cover photos courtesy :

Director, ICAR-CAZRI, Jodphur, India

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http://nbpgr.ernet.in/ispgr

Printed at :

Malhotra Publishing House
B-6, DSIDC Complex, Kirti Nagar, New Delhi - 110 015
Mobile : 011-41420246
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PREFACE

A satellite symposium on 'Dryland Agrobiodiversity for Adaptation to Climate Change', was held at Jodhpur, India, on February 13, 2019. The meeting was co-hosted by the Indian Society of Plant Genetic Resources (ISPGR), Bioversity International, New Delhi, India and Asia-Pacific Association of Agricultural Research Institutes (APAARI), Bangkok, Thailand with support from United Nations Environment Programme (UNEP) and Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB). The symposium was organized during the 13th International Conference on 'Development of Drylands: Converting Dryland Areas from Grey into Green' (13th ICDD) at Jodhpur, from February 11-14, 2019. The 13th ICDD was jointly organized by the Arid Zone Research Association of India (AZRAI) and the International Dryland Development Commission (IDDC) on the occasion of Diamond Jubilee year of the Central Arid Zone Research Institute (CAZRI), Jodhpur and co-organized by Indian Council of Agricultural Research (ICAR), New Delhi; Trust for Advancement of Agricultural Sciences (TAAS), New Delhi and National Academy of Agricultural Sciences (NAAS), New Delhi. The objectives were to evaluate the current threats to dryland agrobiodiversity especially due to climate change, assess the agrobiodiversity in the Indian, Central and West Asian and North African dryland regions and deliberate on the required policy interventions to overcome the threats and challenges. This document provides the dialogues of the meeting and major recommendations emanating from them.

The organizers are very grateful to Dr R.S. Paroda, President, ISPGR and Chairman, TAAS, for conceiving as well as Chairing the symposium, and providing the necessary guidance. Dr Ashok Dalwai, Chief Executive Officer (CEO) of the National Rainfed Area Authority (NRAA), Delhi, is sincerely thanked for Co-Chairing the session and steering the deliberations effectively. The success of the meeting was also due to enormous support provided by distinguished speakers from India and abroad, each of whom is gratefully acknowledged. Special thanks are accorded to members of the organizing committee of the satellite symposium as well as the 13ICDD, especially Dr Kuldeep Singh, Director, ICAR-NBPGR, New Delhi; Dr Anuradha Agrawal, General Secretary, ISPGR; Dr J.C. Rana, National Coordinator, UNEP-GEF Project, Bioversity International, New Delhi; Dr R.K. Tyagi, Coordinator, APCoAB, Bangkok; Dr O.P. Yadav, Director, ICAR-CAZRI, Jodhpur; Dr Nav Rattan Panwar, Principal Scientist, CAZRI, Jodhpur and Member Secretary, Local

Organizing Committee, 13th ICDD; and Dr Anurag Saxena, General Secretray, AZRAI, Jodhpur. Dr S. Rajkumar, Senior Scientist, ICAR-NBPGR, Delhi is thanked for ably capturing the essence of the delibrations as Rapporteur. Financial support from ISPGR, Bioversity International/UNEP and APAARI/APCoAB is gratefully acknowledged.

We thank all the members of the organizing committee and support of participants from ICAR-NBPGR for their help in smooth conduct of the event. Mention to be made of support extended by Dr Pratibha Brahmi, Officer-in-Charge (OIC), Germplasm Exchange and Policy Unit, ICAR-NBPGR, New Delhi; Dr Om Vir Singh, OIC, ICAR-NBPGR, Regional Station (RS), Jodhpur; Dr Kartar Singh, Scientist, ICAR-NBPGR, RS, Jodhpur & Councillor (WZ), ISPGR; Dr Neelam Shekhawat, Scientist, ICAR-NBPGR, RS, Jodhpur and Dr M. Latha, Principal Scientist, ICAR-NBPGR, RS, Thrissur. Support provided by staff of ICAR-NBPGR, ICAR-CAZRI, ISPGR and TAAS in technical and logistic matters is sincerely appreciated. Finally, we thank all dignitaries and delegates who participated in the symposium.

Hopefully, this document would help in developing future programs and projects on agrobiodiversity of dryland areas, and would serve as a reference document by various stakeholders for shaping the policy, guidelines and procedures related to its management.

Editors

ACRONYMS AND ABBREVIATIONS

13th ICDD	13th International Conference on Development of Dryland : Converting Dryland Areas from Grey into Green
ADG	Assistant Director General
APAARI	Asia-Pacific Association of Agricultural Research Institutes
APCoAB	Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources
AZRAI	Arid Zone Research Association of India
CAZRI	Central Arid Zone Research Institute
CBD	Convention on Biological Diversity
CEO	Chief Executive Officer
CGIAR	Consortium of International Agricultural Research Centers
CIAT	International Center for Tropical Agriculture
CWR	Crop wild relatives
FAO	Food and Agriculture Organization of the United Nations
FIGS	Focused Identification of Germplasm Strategy
GEF	Global Environment Facility
GoI	Government of India
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Centre for Research in Semi-Arid Tropics
IDDC	International Dryland Development Commission
IISR	Indian Institute of Spices Research
ISPGR	Indian Society of Plant Genetic Resources
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
NAAS	National Academy of Agricultural Sciences
NBPGR	National Bureau of Plant Genetic Resources

NP-ABS	Nagoya Protocol on Access and Benefit Sharing
NRAA	National Rainfed Area Authority
NRCSS	National Research Centre on Seed Spices
PGR	Plant Genetic Resources
PPV&FRA	Protection of Plant Varieties and Farmers' Rights Authority
PS	Principal Scientist
RS	Regional Station
SDGs	Sustainable Development Goals
TAAS	Trust for Advancement of Agricultural Science
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

CONTEXT OF SATELLITE SYMPOSIUM

Drylands, which encompass deserts, semi-deserts, grasslands and rangelands, occupy 41.3% of the land surface on Earth, but are among the lesser-researched ecologies with respect to agriculture and somewhat over-looked by decision- and policy-makers. Considering the fact that drylands are home to about 44% of area of all the world's cultivated systems and 50% of the world's livestock and habitats for wildlife, it is imperative to give focussed attention on the role of agrobiodiversity in these regions to address the issues of food, nutrition and livelihood security of the nearly 2.1 billion people inhabiting these terrains, especially in the context of climate change threats.

Amongst the total 34 global hotspots, 9 are in the drylands and about 0.5% of the plant species are endemic to the region. In terms of agriculture, plant species endemic to the drylands make up 30% of the plants under cultivation today, including many ancestors and crop wild relatives (CWRs). However, exact status of species in the drylands remains unknown, as no comprehensive assessment has been collated.

The main occupation of humans who inhabit drylands are agriculture and animal husbandry. Local inhabitants use the agrobiodiversity in drylands for multiple purposes like food, feed, wool production, dairy, medicines and transport. However, due to the fragile natural resource base, achieving food security in drylands has been a great challenge. With the threat of climate change looming large and additional threat of massive out-migration, the livelihoods of people who live in these areas, will be further at considerable risk.

Species and ecosystems in drylands are a result of distinctive evolutionary process, developing strategies to cope with environmental constraints such as water scarcity, extreme hot and cold temperatures, and unpredictable long drought periods with sporadic rainfall. In plants, these manifest into features such as short growth cycles, long roots, water storage in roots and trunks, and dormancy during dry seasons. Livestock species and breeds have adapted by optimizing the use of scarce vegetation and water, minimizing their water loss, being able to walk long distances over rough terrain, and other characteristics. Paradoxically, agricultural genetic resources are of fundamental importance for adaptation to climate change, and also become a casualty under certain extreme edapho-climatic changes.

Many dryland areas, especially mountain regions, which are the centres of origin and/ or diversity of domesticated plants and animals (including their wild relatives) are under threat. Domestication of plants and animals in these regions is the outcome of efforts of farmers and herders who bred and selected the innumerable varieties/breeds specifically adapted to these niche areas. These farmers and herders are the most extraordinary innovators and conservers of agrobiodiversity, as they managed to develop unique and highly technological agriculture and pastoral management systems – many of them still in use – adapted to very adverse and changing environments. Empowering local communities and combining farmers' and external knowledge have been identified as some of the strategies for meeting the challenges in such ecologies. There is urgent need to understand the link between agrobiodiversity and climate change resilience, using a trans-disciplinary approach.

With respect to use of plant genetic resources (PGR) to address challenges in drylands, efforts are required on the development of varieties that are tolerant to higher temperatures and more frequent droughts. In this context, landraces and CWRs that are still found within the prevailing traditional farming systems in the drylands are potential sources of useful genes for plant breeding, especially to overcome adverse effects of climate change, which must be conserved. Unfortunately, many of the remaining hotspots of dryland biodiversity which have potential to contribute to climate change solutions are under rapid erosion, due to the combined effects of over-exploitation, destruction of natural habitats, and modernization of traditional farming systems. Hence, an important aspect of food security within the context of climate change will be to take measures to secure the genetic resources of agricultural drylands.

The problems of dryland degradation, climate change and agrobiodiversity loss, along with issues such as resource depletion, pollution, and urban expansion into productive farmland are symptomatic of lack of understanding of natural processes by society in general. Global changes in drylands will not only affect the local inhabitants, but also the livelihoods and welfare of a considerable portion of human population. Land management systems that protect top soil, conserve and recycle nutrients, conserve and concentrate water are those that will maintain productivity in the drylands. Agrobiodiversity contributes to resilience through a number of, often combined, strategies: the protection and restoration of ecosystems, the sustainable use of soil and water resources, agroforestry, diversification of farming systems, various adjustments in cultivation practices and the use of stress-tolerant crops and crop improvement.

Sharing of knowledge, capacity building of all stakeholders and partnerships, to research and adopt new technological options is imminently required for meeting the future demand of managing agrobiodiversity of dry areas to optimize adaptive mechanism and risk aversion. Increased and targeted use of genetic resources, for new varieties and breeds through fast track utilization of germplasm is needed to cope with changed production environments.

Agrobiodiversity management in drylands also requires functional convergence of global policy and regulatory frameworks that deal with biodiversity, food and agriculture, desertification and climate change. Specifically, they relate to the Earth Summit (1992) in Rio de Janeiro, which led to the establishment of the three sister conventions: Convention on Biological Diversity (CBD, 1993), United Nations Framework Convention on Climate Change (UNFCCC, 1994) and United Nations Convention to Combat Desertification (UNCCD, 1994). Other instruments are the FAO's International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001), Nagoya Protocol on Access and Benefit Sharing (NP-ABS, 2010) and Aichi Targets (2011-2020). Global commitment for greater coordination in legal, policy and management issues shall pave the path for sustainable livelihood security in drylands and in converting dryland areas from grey to green.

In light of the above, the Indian Society of Plant Genetic Resources (ISPGR), New Delhi, Bioversity International, New Delhi and Asia-Pacific Association of Agricultural Research Institutes (APAARI), with support from United Nations Environment Programme (UNEP) and Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB) co-organized a Satellite Symposium on 'Dryland Agrobiodiversity for Adaptation to Climate Change' during the 13th Interntional Conference on Dryand Development (13th ICDD) at Jodhpur, India. Issues were addressed through in-depth deliberations among researchers, intellectuals, policy makers, executives and other stakeholders on a common platform. The idea was to enhance awareness about the importance of agrobiodiversity of drylands, share the knowledge, experience and on-going research activities among the diverse stakeholders, to provide an effective platform for networking, and discussing policy implications related to dryland agrobiodiversity, with reference to efficient conservation and sustainable use of agrobiodiversity to ensure food and livelihood security in the drylands, in the changing climate change scenario.

Objectives

- To examine the current threats to dryland agrobiodiversity, deliberate upon the opportunities and challenges due to climate change, and the required policy interventions to overcome the threats and challenges.
- To take stock of agrobiodiversity in the Indian, Central and West Asian, and North African dryland regions and management strategies of their genetic resources.
- To Identify the possible role of regional and international organizations in management of dryland agro-ecosystems through research and development, in partnership mode for harnessing agrobiodiversity to address the global challenges being faced by dryland communities.

KEYNOTE AND INVITED LECTURES

During this session, one keynote lecture and six invited lectures were presented. Details are given hereunder.

Welcome of Dignitories and Delegates

At the outset Convenor of the Satellite Symposium Dr Kuldeep Singh, Director, ICAR-NBPGR & Vice-President, ISPGR, invited Dr R.S. Paroda, Chairman, TAAS & President, ISPGR, and Dr Ashok Dalwai, CEO, NRAA, to Chair and Co-Chair the session, respectively. He also invited representatives from the co-sponsoring organizations *viz.* Dr R.K. Tyagi, Co-ordinator, APCoAB, APAARI and Dr J.C. Rana, National Coordinator, GEF Project, Bioversity International and Dr Anuradha Agrawal, General Secreatry, ISPGR, to the dais. He welcomed all the delegates and introduced the Co-Chairs to the audience. While outlining the need for conservation of agrobiodiversity, he urged the invited speakers and panelists to suggest species required for in situ on-farm conservation, specifically for drylands.

Dignitaries on the dais – Drs Kuldeep Singh, Ashok Dalwai, R.S. Paroda, J.C. Rana, R.K. Tyagi, Anuradha Agrawal (right to left)

View of the audience

Keynote Lecture

Speaker : **Dr R.S. Paroda**, Chairman, TAAS & President, ISPGR, New Delhi, India

Topic : **'Current threats to dryland agrobiodiversity and strategies for adaptation to climate change'**

The tone of the symposium was set by Dr R.S. Paroda during his keynote address. He exalted the important role of agro-biodiversity in withstanding the adverse effects due to change in climate. He pointed out the human civilization settlement started around banks of river in the arid regions of Nile Valley and Indus Valley. He cited some examples of plants from arid regions which flourish well even in adverse conditions and provide economic returns to the farmers of these regions. For instance, the *Prosopis cineraria* tree (known locally in Rajasthan as 'Khejri'), is native to Western Asia and Indian subcontinent. Found in the arid and semi-arid regions of India, all the parts of the tree are useful, including for food, fodder and fuel. Likewise, crops such as millet and mothbean have great impact on the livelihood of farmers in the arid regions. Due to adverse conditions, plant species growing in these regions are always source for some important traits like salinity, heat and drought stress. The wheat variety 'Kharchia' is salinity-tolerant and grows very well in arid regions, and an important parent for development of other saline-tolerant varieties. However, over the years, most of these unique species are facing threat of genetic erosion.

Dr Paroda pointed out that the knowledge of traditional conservation is also getting eroded from these regions. In the past farmers used mixed cropping systems, which sustains both food for humans and fodder for livestocks, a practice which is has been discontnued in recent times. This lacuna

Dr R.S. Paroda presenting the keynote lecture

needs to be addressed to prioritize the action plan to restore the lost plant germplasm or related knowledge. The adverse conditions in arid regions provide variability in germplasm to be utilized effectively to tailor new crops. Dr Paroda emphasized that there is urgent need to strategize how to utilize available genetic variability, and this needs to be done immediately, before they are lost. He advised that databases of available variability and *ex situ* or community driven conservation efforts for dryland agrobiodiversity be given high priority, to prepare for climate adaptation. Intensive research efforts are required in this direction and also incentives and reward system for environmental services by the communities working towards protecting them need to be put in place. He opined that management of drylands agrobiodiversity would require formulation and implemention of right policies and a mission-mode approach to collect, evaluate, conserve and use the most important agrobiodiversity, including those which are threatened.

Invited Lectures

Speaker 1 : **Dr O.P. Yadav**, Director, ICAR-CAZRI, Jodhpur, India

Topic : **'Managing agrobiodiversity of Indian drylands for climate adaptation'**

Dr Yadav emphasized on three important points namely, (i) what are drylands

Dr O.P. Yadav speaking on 'Managing agrobiodiversity of Indian drylands for climate adaptation' and why conserving dryland diversity is important; (ii) what are the issues that are important from the agrobiodiversity point of view in drylands and (iii) what are the major threats to drylands. He elaborated on the importance of inter- and intra-species farm biodiversity. Plant genetic resources (PGR) from arid region are good source of genes for abiotic stress as they have in-built tolerance to abiotic stress, acquired naurally over a periods of time and also nurtured by the farmers. He provided numerous example of success stories where crops have been established and provided a list of crops which can be explored with research input, for utilization. Though the PGR from arid region are quite rich, it has to be channeled and harvested with the adequate research input. He concluded his speech by stating that although much has been accomplished in has arid agrobiodiversity management, but gaps exist which have to be monitored and filled using new age tools. Today biodiversity of drylands has become important not only for their ecosystems, but also other environments because germplasm pool for the adapted genes is a coomon requirement.

Speaker 3: **Dr Ahmed Amri**, ICARDA, Morocco

Topic : **Efficient conservation and use of genetic resources of cereals and legumes**

The role of crop wild relatives (CWR) for ushering the next green revolution was the central theme of the presentation made by Dr Ahmad Amri. He stressed upon importance of focused germplasm collection strategy which is based on natural evolution, and allows collecting of germplasm with adapted traits based on the relationship of environment and trait itself. He said that the same analysis will also help us to protect the area and possible site for *in situ* conservation. The genebank of the International Center for Agricultural Research in the Dry Areas (ICARDA) has 157,000 accessions, of which unique collections, comprising 65-85% landraces and 5-12% CWR, are of significance from drylands. He mentioned that characterization of germplasm based on Focused Identification of Germplasm Strategy (FIGS) uses the relationship between the environmental

Dr Ahmad Amri speaking on 'Efficient conservation and use of genetic resources of cereals and legumes conditions of collecting sites and the traits requested by users. With advent of high throughput genotyping and the possibility of development of varities through wide hybridization, the management of germplasm is being strategized by adapting pre-breeding in the standrad operating procedures of germplasm characterization. The next important aspect is *in situ* on-farm conservation complementing *ex situ* conservation and providing benefits to farmers who maintain landraces and wild varieties that are useful for breeding programs. He concluded by stating that Latin America is center of origin for major crops and it is hoped that people will realize the dependence of all the countries in terms of exchanging the germplasm.

Speaker 4: **Ms Muhabbat Turdieva,** Bioversity Internation, Uzbekistan

Topic : **Agrobiodiversity of fruits and nuts to adapt to climate change in central Asia**

Ms Muhabbat Turdieva informed that as per World Bank report, the central Asian land-locked region is undergoing tremendous changes in climate, and has become highly vulnerable. Increasing average temperature, meagre rainfall is leading to land degradation of mountains in these regions. This sensitive area is endowed with numerous varieties of fruit and tree species, and among them traditional varieties constitute maximum numbers. This rich diversity possess wide range of functional traits which helps

Ms Muhabbat Turdieva making presentation on Agrobiodiversity of fruits and nuts to adapt to climate change in central Asia

them to perform well in very severe conditions in dry areas, in areas affected by salinity, heat and frost. Orchid diversity is also great range in this region. However, commercialization of these orchid species could not be done due to lack of quality plant materials. She said that there was need to improve ecosystem services and create healthy and safe environment, by using local agrobiodiversity to improve the livelihood of local people to restore the degraded landscapes. Committes to strengthen national policies to support establishment of orchid and tree plantations has resulted in the establishment of 10,000 ha of almond and pistachio plantations areas, by Government of Uzbekistan and Kyrgyzstan. She also provide suggestions to carry out conservation of agrobiodiversity for central Asia regions, especially by cooperation and partnership between scientists and farmers for mutual benefit. Increasing the benefits of farmers who are conserving and maintaining diversity is also required. She urged that initiatives to promote neglected underutilized species for restoration of the degraded lands was need of the hour, as also socio-economic evaluation of fruit and tree diversity and their improvement. It is very important to promote topics of international conventions, treaties on agrobiodiversity in curriculum of universities and colleges. She concluded by emphasizing on the need to establish south-south cooperation between regions and between countries on conservation technologies to maintain the agrobiodiversity. Samples of dried fruits (apricots, prunes etc.) brought by Ms Turdieva were relished by all the delegates.

Dr R.K.Tyagi speaking on role of regional organizations

Speaker 5: **Dr R.K. Tyagi**, Coordinator, APCoAB, APAARI, Bangkok, Thailand

Topic : **Dryland agrobiodiversity for adaptation to climate change: Role of Regional Organizations**

Dr R.K. Tyagi presented the objectives and functioning of APAARI, a membership-based, apolitical, multi-stakeholder, and inter-governmental regional organization. In the area of agrobiodiversity, APAARI is involved in policy making by organizing high-level dialogues and formulating recommendations by partnership and collaboration with governments, national and international agricultural research organizations, regional and global fora, non-governmental and farmers' organizations, private sector, and international development organizations. In the recent past, it had held an expert consultation on underutilized crops, wherein it was proposed to have center of excellence for capacity development. APAARI helps in mapping the existing capacities and the need of capacity development as per the needs of countries in the Asia-Pacific region, besides development of policy and advocacy required for strengthening agri-food research and innovation systems through collective actions, including agrobiodiversity management.

Speaker 6: **Dr J.C. Rana**, National Coordinator, UNEP-GEF Project, Bioversity International, New Delhi, India

Topic : **Mainstreaming the agrobiodiversity of drylands - Role of Bioversity International**

The importance of arid ecosystems and the challenges to be faced to mainstream

Dr J.C. Rana speaking on the role of Bioversity International in mainstreaming agrobiodiversity of drylands

the agrobiodiversity was discussed by Dr J.C. Rana. Traditional knowledge and traditional PGR are important aspect in mainstreaming agrobiodiversity, which is gradually getting eroded. Bioversity International has programs to mainstream the conservation and use of biodiversity for resilient agriculture and sustainable production systems and linking it to livelihood and benefit sharing. Main aim of these programs is to enhance crop and farming biodiversity. At farmers level, efforts are being made to provide access to diversity and primary seeds, so as to increase livelihood options and incomes through value-addition and marketing. Attempts are also being made to develop models for community seed bank or seed conservation which can be linked to farmers livelihood. In order to develop model for sustainability in this ecosystem, there is need to adopt 'system farming' rather than 'intensive farming' which is of more demand to resources.

PANEL DISCUSSION

The next session comprised a panel discussion on 'Issues and way forward for agrobiodiversity for adaptation to climate change'. During this session, seven panelists discussed various aspects on agrobiodiverity of specific crop groups relevant to drylands, besides view points were shared by two speakers on overall PGR and plant variety protection aspects. Brief outline of presentations follow hereunder.

Arid Horticulture

Dr P.L. Saroj, Director, ICAR-CIAH, Bikaner, gave an overview on the horticultural crop diversity in arid regions of India. He expressed concern about the varieties released for this region, which are required to be climate resilient and also specific to this arid region. He emphasized on the need for establishment of a network for systematic conservation of under-utilized fruit and vegetable of arid region, since it is being replaced by exotic vegetables which demand higher input of resources. Artificial regeneration and crop conservation must be initiated for those crops for which it has been established. He urged that there should be shift in the breeding programs from productivity and quality, to climate resilience traits.

Dr P.L.Saroj

Millets

Dr S.K. Gupta, Principal Scientist, ICRISAT, Patancheru, India spoke on the status of millets. He informed that millet production in arid regions has remained almost constant for a long time, with only marginal (3%) increase. Strong pre-breeding activities need to be initiated to bring variation into millet germplasm. Characterization of wild germplasm for the climate resilence and other attributes need to be characterized with modern tools like phenomics and high throughput genotyping.

Arid Legumes

Dr D. Kumar, Ex Principal Scientist, ICAR-CAZRI, Jodhpur, discussed about arid legumes which are the typical crops that are multi-utility, economically valuable, and convinient in terms of crop management techniques. If grown with cereals they increase the volume and nutrition and also take care of soil organic content. But the most important aspect is that they are highly drought and heat tolerant, therefore good candidate species to withstand global warming.

Dr D.K. Yadava

Arid Oilseeds

Dr D.K. Yadava, ADG (Seed), Crop Science Division, ICAR, New Delhi, expressed concern about underutilization of germplasm for crop improvement programs. He said that we have not used germplasm efficiently and no systematic efforts are made to identify the donors for abiotic stresses and very few genetic resources identified based on the natural screening conditions. In order to withstand severe climate change, new genetic stocks are required that have high degree of tolerance to high temperatures during sowing as well as the time of maturity. The screening methods also should use modern methodologies like large-scale genotyping for tagging genes and facilities like phenomics and phytotron for proper phenotyping. Like other major crops, oilseed nurseries from the global platform need to be brought to India for efficient use of germplasm. Farmers who are conserving the germplasm in the arid region should be recognized and provided incentives.

Seed Spices

Dr Gopal Lal, Director, ICAR-NRCSS, Ajmer, informed that germplasm collection of seed spices of arid region

Gopal Lal

are meagre compared to other regions. Existence of most of the germplasm in the form of traditional and local varieties due to natural selection of local adaptation has lead to formation of complex gene mixtures. Hence, proper sampling and regeneration is essential to recover and maintain full range of genetic variability. The desirable germplasm need to be identified from collections regarding, oil, oleoresin content, frost/drought tolerance and insect/disease resistance, which needs networking with other disciplines.

Forages

Dr R.K. Bhatt, Head & Principal Scientist, ICAR-CAZRI, Jodhpur, said that the cultivated fodder play significant role as a food resource for the livestocks, and we know that in the dry areas the farming communities' livelihood security is livestock centric. Apart from the cultivated fodder the grazing land, pasture land and mainly the grasses which grow in these dry areas, have the significant role in providing the green and dry fodder to the livestock. The dry regions with rich diversity of underutilized plants also have fodder value. The farming communities should be given incentive and rewards as they continue to conserve PGR of fodder value over the years. There is need of public support and education campaign for sustainability challenges and issues like climate change and biodiversity conservation.

Underutilized and Medicinal Plants

Dr Suresh Kumar, Ex Principal Scientist, ICAR-CAZRI, Jodhpur opined that the desert region provides high variability in the underutilized and medicinal species and have different adaptive mechanism to withstand the adverse conditions. However, the main threat to their conservation management is fragmentation of land and invasive species. He said that efforts should be made for their domestication, value addition and inclusion in cropping systems for diversification.

Arid PGR

Dr Om Vir Singh, Officer-in-Charge, NBPGR, Regional Station, Jodhpur said that genetic resources in the arid region are eroding very fast as landraces are being replaced by the farmers with modern high yielding varieties and hybrids. Moreover, natural habitats of wild relatives of cultivated species are being destroyed rapidly, due to natural calamities, land conversion, mechanization of agriculture, deforestation, developmental activities, and environmental pollution. Many landraces and primitive cultivars have already vanished and some are on the verge of it, and the remaining ones are genetically deteriorating gradually due to hybridization, selection or genetic drift and global warming. As climate change brings new pest and diseases, new source of resistance will be required by crop varieties. Genetic diversity that is

Dr Om Vir Singh receiving memonto from Dr Ashok Dalwai

currently underutilized may become more useful in times to come.

Protection of Plant Varieties and Farmers Right Act

Dr K.V. Prabhu, Chairperson, PPV&FRA, New Delhi, said that an important aspect

Dr K.V. Prabhu sharing his views

for agrobiodiversity management is not only tackling the climate change problem but making farmers/stakeholders who conserve this, understand the value of it. The point is to associate value in terms of the genes enhancing the value of the variety of crop species and protection of the same through law enforcement. The germplasm from farmers collection having some kind of economic turnover that related to genotype that has to be protected and then based on that facility that material can give, we can convert it into economic value as a variety.

CONCLUDING SESSION

Remarks by Co-Chair

Dr **Ashok Dalwai**, CEO, NRAA, New Delhi, appreciated inputs provided by the plenary speakers and the panelists for improvement and strategies suggested for dryland agrobiodiversity conservation and utilization. He emphasized that the importance of biodiversity in arid regions is not exclusive to crops, but includes other components like domesticated animals. He said that seasonal crops escape the adverse effect caused by climate change. However, perennials like livestocks and horticulture plantations have to survive through the adverse conditions. He said that green revolution had been more of a food revolution in selected crops, based on intensive use of inputs and confined to some richly endowed areas, which brought monoculture and has led to biodiversity loss. It was a timely and much required reaction when the world was suffering from food insufficiency. The burden of food security was brought to agriculture and then the farmer, it is possible to bring about the ecological burden to the farmers. Today the world's purchasing power is much more and many governments have great economic powers. Hence, they should be able to compensate any kind of loss that the farmers face due to the ecological burden and to promote crop alignment. We need to promote circular bio-economy in agriculture which is based on reduced use of inputs, recycling, reutilization so that we are going to have actually a sustainable mode or a renewal form of economy. In order to gain importance, we need to promote agro-processing parallel to food processing, especially for medicinal, aromatic and fiber yielding plants. The biodiversity component in agrobiodiversity is not only related to farm but also covers trees of catchment area and common properties. The climate change pressure is more on common properties than farm land. Agricultural systems comprising research laboratories, consumers, traders and farmers need to be reassessed in terms of value systems, such that every segment, including farmer gets the benefit. The technologies used for large farm land cannot be imitated to marginal farmers in our country. Integrated farming that is technologically advanced and market linked is required. We need to increase subsides for the marginal farmers compared to large land holding farmers. There is need to bring income revolution for farmers and that would require a green revolution that is demand driven (consumer-centric) than production-centric.

Remarks by Chair

Dr R. S. Paroda, Chairman, TAAS & President, ISPGR, said that the knowledge on available variability in the arid region is relatively better but the research relating to collection, evaluation, conservation and use, especially under the changing climate, is lacking considerably. Hence, efforts on research, documentation and conservation, including their protection under the existing laws, are required to be addressed on priority. Our existing genetic diversity for crops, grasses, shrubs and trees is unique and more adapted to climate change. In order to conserve existing biodiversity of the arid region, we need to prioritise the species first. To ensure this, we need to have a Red Data Book for the arid region agrobiodiversity so as to prioritise those needing immediate attention or are on the verge of extinction. For this, proper public awareness and policy advocacy is required. Special attention needs to be given to identify climate resilient germplasm for effective use in crop improvement programs. Reward system for the farmers to remain engaged in conservation of agrobiodiversity through much needed incentives for the environmental services by smallholder farmers is also justified. Dr Paroda highlighted the importance of networking and partnership among the institutes and countries in the region to make grey areas green.

Vote of Thanks

Dr Anuradha Agrawal, General Secretary, ISPGR & Principal Scientist, ICAR-NBPGR, New Delhi, proposed the vote of thanks on behalf of the organizers. She said that the

Dr Anuradha Agrawal, Co-Convenor, proposing the vote of thanks

Presentation of memento to Dr R.S. Paroda, Session Chair by Dr Kuldeep Singh, Session Convenor

symposium had catalysed excellent sharing of on-going research activities, information and experiences on agrobiodiversity of drylands among the diverse stakeholders, enhancing awareness about their importance, conservation and utilization. She thanked Chair, Co-Chair, Speakers, Panelists and Delegates for contributing towards the successful conduct of the Satellite Session. The organizers of the 13th ICDD, staff of ISPGR, ICAR-NBPGR and ICAR-CAZRI were duly acknowledged for the logistic and technical support. As a token of appreciation, mementoes were presented to the speakers, panelists, Co-Chair and Chair of the session.

RECOMMENDATIONS

- It is imperative that a clear Road Map is developed and implemented for the efficient conservation and sustainable use of dryland agrobiodiversity, to ensure food and livelihood security in the drylands specially in the changing climate scenario.
- Agrobiodiversity conservation and use should be comprehensive, not limited to crops on farm land, but include other components of dryland ecosystem, especially trees, shrubs, grasses and animal biodiversity.
- For mitigation of climate change in dryland ecosystems, research on the distribution, collecting, documentation, conservation and legal protection of agrobiodiversity requires to be intensified. Development of a Red Data Book for dryland diversity would be an important requirement to determine conservation priorities and minimise genetic erosion.
- Collection, characterization and evaluation animal and crop diversity of arid region that already withstand abiotic and biotic stresses must be undertaken on priority. Use of new tools and techniques like phenomics, genomics, space and robotic technologies should facilitate identification of valuable traits and genotypes better adapted in the drylands despite climate change scenario.
- There is need to promote and strengthen mixed cropping and agroforestry as well as silvi-pastoral systems (horticultural trees, multi-purpose perennials, bushes, grasses and livestock) to reduce the risk and stabilize income support to resource poor farmers, despite adverse conditions on account of climate change.
- Precision water management technologies (such as conservation agriculture, precision land levelling, micro-irrigation including sub-surface drip and field bunding) should be popularized and promoted through appropriate policy and programs. The list of crops suitable for growing in drylands need to be reviewed especially with respect to water requirement.
- Primary agro-processing units need to be established in rural and peri-urban areas to minimise the losses of farm produce and fetching better prices to farmers. Entrepreneurship involving

youth and women at local level need to be created and supported.

- Models to incentivise farmers need to be developed for facing ecological burden, in order to promote agro-ecology based cropping/farming and other agriculture systems. Also, environmental services for *in situ* and on-farm conservation of biodiversity and agrobiodiversity in the dryland ecosystems should be indexed and both incentives and reward systems be developed to support farmers promoting these sustainable practices.. Crops and varieties adapted to local environments need to be mainstreamed to harness the benefits of their resilience to climate change and nutritional significance.
- Circular bio-economy needs to be promoted, which is based on reduced use of inputs, recycling and reutilization for sustainable mode of renewal form of economy. Modification of the traditional integrated farming system and introduction of modern technologies need to be reassessed for small and marginal farmers in developing countries, by increasing subsides or other means of compensation.
- A more balanced approach in terms of policy is required for increased public funding/support to dryland farming and farmers, laying greater focus on research and development, production and marketing, on par with crops in the irrigated region.
- The need to develop effective cooperation and partnership through either a consortium or a network was also recognized for knowledge and germplasm sharing as well as for capacity building and sustainable use. For this, the role of international centers like Bioversity International and APAARI was recognized.

Extended Summaries*

**Reproduced from:*
Burman U., A. Saxena and N.R. Panwar (eds) 2019. Program and Abstracts of Satellite Symposium 3 on 'Dryland Agrobiodiversity for Adaptation to Climate Change', during '13th International Conference on Development of Drylands : Converting Dryland Areas from Grey to Green', Feb. 11-14, 2019. Arid Zone Research Association of India, Jodhpur, India, pp. 19-57.

Current Threats to Dryland Agrobiodiversity and Strategies for Adaptation to Climate Change

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Over millions of years, the available agrobiodiversity has evolved through the process of natural selection, mutation as well as genetic adaptation using specific traits such as short duration, deep root system, waxy leaves, water storage capacity in roots and trunks, dormancy during the drought, hot seasons etc. Similarly, the livestock species and breeds got adapted to scant vegetation and water, minimizing water loss, ability to walk long distances over rough terrain, etc. Hence, the adaptive traits of dryland agrobiodiversity fortunately offer significant opportunities for coping with adverse impacts of climate change.

Traditionally, drylands are home to native people with unique agrarian culture, selecting and maintaining since ages the significant levels of diversity of crops and livestock breeds suiting to their niche-specific cropping and pastoral systems. Hence, broader the agrobiodiversity, greater will be the chances for wider adaptation to changes in environmental (including climate) stresses like drought, insects and diseases, high temperatures, off-season rains etc. and to improve their genetic yield potential.

Despite severe stresses, it is rather a strange that drylands globally had been the centres of origin of most important food crops and large number of breeds of cattle, buffaloes, goats, sheep, equines and camels. Specific examples of crops originating in dryland regions are maize in Mexico, beans in Peru, tomato in Bolivia, potatoes in Chile, millets in Africa and India, and wheat in West Asia and North Africa (WANA) region etc.

The Thar Desert in India is rather unique among the deserts of the world as it not only sustains the highest human and livestock population per sq km, but has also unique and rich flora and fauna, generally not found elsewhere. To mention a few, these are: pearl millet (*Pennisetum glaucum*) barley (*Hordeum vulagre*),'moth' bean (*Vigna aconitifolia*), cluster bean (*Cyamopsis tetragonoloba*), cumin (*Cuminum cyminum*), castor (*Ricinus communis*), fenugreek (*Trigonella foenum-graecum*), 'isabgol' (*Plantago ovata*), 'ber' (*Ziziphus mauritiana*), 'ker' (*Capparis decidua*), 'gonda' (*Cordia dichotoma*), 'sewan'grass (*Lasiurus scindicus*),'dhaman' grass (*Cenchrus ciliaris*), 'phog' (*Calligonum polygonoides*), 'khejri' (*Prosopis cineraria*), 'rohida' (*Tecomella undulata*), Salvadora spp.,'neem' (*Azadirachta indica*), 'babool' (*Vachellia nilotica*) etc. Unfortunately, some of these are now facing extinction on account of desertification, lack of attention and climate change.

The foremost threat to dryland biodiversity is the degradation of ecosystems and habitats caused by: (i) rapid urbanization, industrialization and developmental activities (e.g. housing, mining operations, dams, roads etc.); (ii) overcutting of trees and shrubs for fuel and building material; (iii) large scale irrigation and expansion of agricultural fields. "Micro hotspots" of dryland biodiversity found in wetlands, oases and groves, are particularly vulnerable. Further, out of the total number of species known in the world (~1.47 million), the exact number of species costing in the drylands and the degree of threat, including extinction, is not documented. Hence, it is difficult to establish any correlation between the rate of degradation of drylands (estimated as 60%) and the rate of extinction of species because of the lack of authentic data particularly on endemic species, including their distribution and numbers. With reference to threats to agrobiodiversity, many old crop varieties and even valuable rare species are gradually disappearing, as farmers and consumers crave for more uniformity in their food products. This, in turn, affects less obvious elements, such as insects that play a role in pollinating plants or controlling pests and the soil organisms that help plants extract nutrients from the soil.

Dryland agriculture has a significant component in the Indian agrarian economy, as nearly 55 per cent of the total net cultivable area (140 m ha) falls under drylands. Further, 50 per cent of the total rural work force and 60 per cent of livestock are concentrated in the dry regions of India. Fortunately, the farmers in drylands maintain their tradition of nurturing agrobiodiversity. For instance, in the North-western states of Rajasthan, Haryana and Punjab, the 'Bishnoi' community lives with a philosophy which absolutely forbids any harm to live forms of both trees and fauna, as they believe that the souls of their ancestors reside in plants and animals, particularly the 'khejri' tree (*Prosopis cineraria*) and the black buck being the classical examples. The 'khejri' tree is multi-purpose as it provides food, fodder, fuel and building materials. It also adds nitrogen to the soil and does not smoother the crops underneath. There is conscious conservation of valued trees and shrubs such as 'khejri' in crop fields, for sustained cropping, without any fallow land during the entire growing period. During years of drought, when annual crops fail, farmers rely heavily on the products of trees and shrubs as well as animals for their survival. Such eco-consciousness by communities helps in conserving the agrobiodiversity and ensures eco-friendly and healthy environment for the people of the region as well as for our future generations.

The physical processes of land degradation, biodiversity evolution or extinction, and climate change are quite inter-twined, especially in drylands. In the context of climate change, dryland agrobiodiversity would not only be a victim of climate change, but would be of vital importance for adaptation to this change. Hence, existence of wide genetic diversity be seen as an opportunity rather than concern. Climate warming will cause, *inter alia*, higher evaporation rates and lower rainfall both of which are major determinants of dryland ecological processes.

The international treaties (ITGRFA), conventions (CBD, UNCCD) and existing regulations on agrobiodiversity need to be implemented at the national and global level by enacting appropriate *sui genesis* systems/laws, policies and implementation plans. With respect to dryland agrobiodiversity, conservation and sustainable use needs to be given high priority, including increased funding, for their effective implementation. Also an effective adaptation and mitigation plan for climate change, as envisaged in the United Nations Framework Convention on Climate Change (UNFCCC), would be highly desirable. Practically, this requires coordination and convergence among the various actors dealing with environment, agriculture, trade and health.

Further, it must be recognised that rich agrobiodiversity alone is not sufficient. It needs to be supported well by an enabling policy environment and efficient institutional infrastructure. Moreover, proper management of drylands is a pre-requisite for effective management of agrobiodiversity through conservation and use. Also needed support to gene saviour communities though equitable access and benefit sharing will go a long way to ensure climate smart agriculture that is based on using rich agrobiodiversity. Relatively low awareness about the importance of drylands *vis-à-vis* agrobiodiversity and livelihoods is another reason why importance of rich genetic diversity has received inadequate attention of researchers, donors and the policy makers.

Considering above concerns, time is ripe to either revisit or devise needed action plan for conservation and sustainable use of dryland agrobiodiversity with a time targeted approach. In the past, conservation efforts had been focused typically on (i) *ex situ* conservation of major crop genetic resources and (ii) *in situ* conservation of natural systems mainly in protected areas. Although tangible results have been achieved through both these approaches, but still considerable gaps and omissions exist. Hence, much needed reorientation of policies, which can help in accelerating the processes for conservation and use of available rich genetic diversity, is a must under present scenario. It is, therefore, necessary to focus urgently on the following road map:

(i) **Building of Database:** There is an urgent need for a global initiative to document available dryland agrobiodiversity and maintain reliable database, especially on threatened/endangered species. This would require collation of existing information and the outcome of on-going research, though meagre, on various species. Such database will help in increased awareness and projection of potential danger to dryland agrobiodiversity so as to attract much needed attention of scientists, donors and policy makers.

(ii) **Capacity Development**: There is definite need for building both human and institutional capacity to mitigate the threats to dryland ecosystems and the agrobiodiversity, while addressing the adverse effects of climate change. Awareness and exchange between various dryland regions of genetic materials, cooperation for research and training, and sharing of information, technologies would be most desirable.

(iii) **Germplasm Improvement and Management**: Strengthening of research for evaluation, characterisation, identification and use of desired genes/genotypes for improved tolerance to biotic and abiotic stresses in most important crops/plants and tree species of dryland, will required in diverse edapho-climatic conditions and landscapes. Also, an *ex situ* conservation initiative, especially of crop wild relatives, would be necessary to maintain available diversity of species, populations and varieties, including those genotypes that are well adapted to climate change.

(iv) **Research Prioritisation**: Many species of high value in drylands have remained inadequately researched both for biotic and abiotic stresses, which needs to be addressed through allocation of adequate resources and higher number of researchers. Also, there is need to prioritise and have time targeted outcomes defined to achieve desired results. Greater involvement of farmers as well as farming communities in crop improvement programs, through participatory plant breeding, would yield faster outcomes.

(v) **Incentives and Reward System:** Dryland agrobiodiversity conservation strategies must focus on people, the end-users of genetic resources, whether for present or future generations. Models for sustainable *in situ* and on-farm conservation are, therefore, required to be developed, linked with proper incentives and rewards, including the effective provisions of access and benefit sharing (ABS).

In conclusion, the management of drylands agrobiodiversity would require collective action to formulate and implement right policies. This would entail allocating more funds for research and development (at least double), and undertaking a mission-mode approach to collect, evaluate, conserve and use the most important crop species diversity, including those that are threatened. In this context, support for multiplication of seeds/seedling/quality planting materials on large scale is needed. It is only through an effective and efficient conservation and use of available agrobiodiversity, we shall be able to address successfully the adverse effects of climate change, being an important Sustainable Development Goal.

Managing Agrobiodiversity of Indian Drylands For Climate Adaptation

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The drylands in India occupy about 80 million ha and are spread over arid, semi-arid and sub-humid climatic zones presenting nearly 56% of the net cultivated area. The drylands are characterized by low precipitation, highly variable rainfall patterns, high evapotranspiration rates, inadequate available nutrients in native soils, poor quality of ground water, severe land degradation, short growing period and low crop yields.

Despite these bio-physical constraints, the drylands support high human and livestock population, which mostly depend on agriculture and allied activities with limited natural resources resulting in over-exploitation of the resources. Presently degradation of natural resources (land, water and biodiversity), decreasing farm profitability and environmental pollution (soil, water) are threatening the sustainability of agricultural production in the drylands. Moreover, drylands are more vulnerable to global warming-mediated climate change reflected in form of more intense drought, sudden rainfall burst, high ambient temperature and appearance of new unforeseen diseases and pests. In addition to other technological interventions, the management of agro-biodiversity in drylands is expected to be a key factor for sustainability, food and fodder security and for improving livelihood in drylands.

Majority of coarse cereals (pearl millet, barley, sorghum, maize and finger millet), legumes (chickpea, mungbean, mothbean, clusterbean) and oilseeds (Indian mustard, groundnut, soybean) are grown in drylands. In addition, a large number of horticultural crops, grasses, fodder crops, bushes, medicinal plants, multi-purpose trees, underutilized potential crops and seed spices are part of dryland farming. Genetic resources of dryland species include landraces, improved elite material, traditional cultivars, genetic stocks and wild relatives that are potential sources of specific phenotypic traits, resistance to diseases and insect-pests; and tolerance to various abiotic stresses like drought and high temperature.

A large number of germplasm accessions of exotic and indigenous nature are conserved at the ICAR-National Bureau of Plant Genetic Resources (NPBGR), New Delhi either in National Gene Bank or Field Gene Banks across country. Characterization of genetic resources using prescribed descriptors has largely indicated existence of large variation for phenotypic, phenological, nutritional and stress-adaptation traits among available germplasm. However, only a very small fraction of these accessions has been utilized so far because of operational difficulties in dealing with huge number of germplasm accessions. The development of core and mini-core in recent past is expected to improve this situation. Formation of trait-specific gene pools is also likely to enhance the utilization of genetic resources to a greater degree.

The genetic resources from drylands hold a unique advantage as they have evolved over centuries by natural and human selection under drought, high temperature or saline conditions. They are better adapted to the local conditions and would contribute in enhancing the resilience at the farm level. These resources could be of immense importance especially as sources of native genes conditioning resistance to various biotic and abiotic stresses and also make unique study material to understand mechanism of adaptation to abiotic stresses. They could also serve as excellent genomic resource for isolation of candidate genes responsible for tolerance to climatic and edaphic stresses for accelerating further genetic improvement. Therefore, they would be of great relevance to both farming and scientific communities.

Agrobiodiversity faces multiple and complex challenges due to habitat destruction in drylands, high grazing/ browsing pressure, invasion of other species like *Prosopis juliflora*, dilution of customary conservation practices and unsustainable exploitation of natural resources.

Role of women farmers, sacred places and communities of drylands in biodiversity management is immensely important but is not properly documented and acknowledged. The maintenance of seeds of cross-pollinated crops like pearl millet, maize and sorghum by women farmers has been reported to increase introgression in a much larger population. *Orans* (sacred places) and *gochars* (common rangelands) in western Rajasthan are excellent examples of biodiversity conservation by communities but now are under threat due to poor maintenance.

The contribution of agrobiodiversity in eco-system services remains under-recognized. Critical assessment is needed for identifying geographical and trait-diversity gaps using GIS and other modern tools. Available germplasm should be searched for native variation in target traits. Additional explorations are needed in the regions where collection gaps have been indicated. *Ex situ* conservation of genetic resources from such regions and distribution of germplasm to the stakeholders on regular basis would remain very crucial especially in the present scenario of climate change. Developing *e*-resources with detailed information like passport data, characterization and evaluation data with respect to individual accessions would certainly help in enhancing the utilization of genetic resources in order to broaden the genetic base of crops which is very essential to reduce the chances of disease epidemics and to mitigate the effects of climate change.

Genetic variation is a bed-rock on which success of genetic improvement programmes depends. Plant genetic resources especially from drylands have to be conserved for their use in future in order to achieve sustainable development and to meet challenges in drylands. The present paper deals with the extent of variation among plant genetic resources of drylands and its significance in view of climate change to improve agricultural productivity and sustainability.

Efficient Conservation and Use of Genetic Resources of Cereals and Legumes

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Cereals (wheat and barley), food legumes (chickpea, faba bean and lentil), and temperate forage legumes (*Lathyrus*, *Medicago*, *Pisum*, *Trifolium* and *Vicia*) are important crops for the global food security and major components in sustaining the livelihoods of rural communities living in non-tropical drylands and beyond. In the light of the fast-growing population and the adverse effects associated with climate change, sustaining agricultural development and food security through crop improvement will require efficient conservation and use of plant genetic resources. Dryland agrobiodiversity, mainly landraces and crop wild relatives will be critical for ensuring continuous genetic gains under recurrent droughts, heat spells, increasing salinity stress, and changes in importance and virulence spectra of diseases and pests. The Mediterranean basin, West Asia, Central Asia, and Abyssinia encompass four major Vavilovian centers of diversity for species of global importance including cereals, food legumes, temperate forage and range species and dryland fruit trees. Landraces of these crops are still found in the traditional farming systems and their wild relatives in the remaining non-degraded natural habitats. However, these genetic resources are under alarming threats of over-exploitation, land reclamation, use of introduced species and newly released varieties, stressing the need for further judicious collecting to add novel diversity and using both *ex situ* and *in situ* conservation approaches to ensure continuous supply of needed diversity by the breeding programs and of adapted species for direct use in the rehabilitation of degraded systems.

The International Center for Agricultural Research in the Dry Areas (ICARDA), laying over the four major centers of diversity, plays a crucial role in promoting the conservation and use of non-tropical dryland agrobiodiversity. Its genebanks in Lebanon, Morocco and Syria hold in- trust important and unique collections of cereals and legumes totalling 157,000 accessions up-to date. The present contribution highlights the approaches developed and used to ensure efficient conservation and use of the genetic resources.

Adding novel diversity through different types of gap analysis

Crop conservation strategies were conducted for wheat, barley, grass pea, and food legumes in collaboration with sister CGIAR centers and other partners with the support from the Crop Trust, based on the holdings of major genebanks. Preliminary major gaps are identified, but, the conservation strategies need to be updated to include accessions held in unique and large collections held by countries laying within the major centers of diversity including those from China, India, Iran and Ethiopia. For landraces, mountainous and oasis areas require more collecting missions as only few accessions are available in the existing collections. Overall, several crop wild relative species are under-represented in the existing collections such as wild *Cicer*, wild *Lens* and specific *Aegilops* species. More efforts are needed to collect and conserve *Avena* species mainly in North Africa region and around the Mediterranean basin which include major centers of diversity. Based on the evaluation results, more collecting of landraces from central Asia and Afghanistan is needed to add novel diversity for diseases and insect pest resistance. Geographic gap analysis was conducted in collaboration with Birmingham University for wild relatives of cereals and temperate legumes using mainly DIVA-GIS (Hijmans et al., 2001) and MaxEnt packages (Phillips 2009). This approach allows to direct collecting missions to areas not sampled yet and to identify potential sites with high species richness of targeted taxa for the establishment of protected or well-managed areas. In this regard, the Mediterranean region and the Fertile Crescent in particular, include only very few protected natural habitats targeting the *in situ* conservation and management of wild relatives of cereals and legumes calling for more efforts to ensure dynamic conservation of remaining populations, including in diverse ecosystems and in transboundary areas. Recently, ICARDA in collaboration with CIAT is working on further development of approaches for landraces gap analysis including trait-based gap analysis. This later aims at targeting adaptive traits based on applying machine learning algorithms to link the distribution of adaptive sought trait to environmental attributes. The predictions from these models will identify eco-geographical gap with potential presence of specific adaptive traits.

Focused Identification of Germplasm Strategy (FIGS)

Distribution of genetic resources is a key and core genebank activities aiming at responding to requests from various users including breeders, researchers, farmers, etc. Most often, when the request does not specify the germplasm and traits sought, a random sample is selected and sent. Core collections were developed for major crops which include 10% of holdings representing the geographic- or characterization-based diversity. The Generation Challenge Program (GCP) developed reference sets representing 10% of the core collection selected based on molecular diversity. Mini-core collections (Upadhyaya *et al*., 2010) are also used to allow for minimizing the number of accessions to be evaluated. The Focused Identification of Germplasm Strategy (FIGS) developed by ICARDA in collaboration with Partners in Australia and Russia is basing the selection of manageable best-bet subsets based on the relationship between the environmental conditions of collecting sites and the traits requested by users (Mackay and Street, 2004). FIGS uses two approaches, the filtering approach which is based on knowledge of factors associated with traits, and the modelling approach based on finding mathematical relationship between the adaptive trait of interest and the long-term climatic and/or soil characteristics of collection sites through machine learning algorithm (Anglin, Kehel *et al*., 2018). The application of FIGS has allowed to send more 75 subsets so far, most of which confirmed the relevance of the approach in identifying sources of sought traits in relatively small subsets, which could also reduce the efforts undertaken by the genebanks in regenerating the accessions.

Evaluation and use of genetic resources in pre-breeding

Ensuring the continuum between the conservation and use of diversity requires strengthening the efforts to show the value of the genetic resources. This value is seen through the success of finding needed diversity for most traits sought by breeders including those related to new environmental challenges and to required quality and nutritional attributes. The genetic resources have also been used directly to select ecotypes for rehabilitation of pastoral lands in case of forages or to provide lost preferred landraces to local communities which experience harsh living conditions.

The evaluation using artificial inoculation with most virulent biotypes in case of diseases and insect pests and use of precision platforms for assessment of heat, drought and salinity effects have allowed to select landraces and wild relatives ideally suited to widen the genetic base of crops and as parental germplasm in breeding new adapted varieties. In the light of successes of introgressing useful genes from species in wild genepools in some crops, strengthening pre-breeding efforts is needed. Interspecific crosses in case of wheat has yielded elite germplasm combining high and stable yields along with resistance to major diseases and insects which allowed national agricultural research systems to release new varieties. In lentil, breeders at ICARDA have actively identified new and valuable traits in wild gene pools since, although varieties have not yet been released. wild relatives especially *Lens orientalis* and *L. ervoides* have been successfully utilized for shortening the crop duration, biofortifying the improved varieties with iron and zinc, and improving resistance to key diseases. Efforts are underway to test their performance in multi-environment yield trials under the Crop Trust project.

In durum wheat, nearly all the elite material currently distributed by ICARDA includes a landrace (38% of the germplasm) and/or a wild relative (62%) in their pedigree. In particular, *T. ararticum* has proven particularly advantageous to ensure resistance to a damaging pest of the Mediterranean Basin: Hessian fly. Wild emmer instead has proven very effective to increase drought tolerance via deeper and better root system. *Aegilops speltoides* has resulted in very high level of spike fertility, ideal to tolerate heat stress. *T. boeticum* instead has been shown to significantly increase the tillering capacity and hence the yield potential of the elite lines that included it. Still, this is nothing but a short list of the great potential of crop wild relatives (CWR) in breeding. Zaim et al. (2017) could demonstrate the disease resistance, yield, stability and even industrial quality superiority of several CWR-derived elites when tested against commercial cultivars across sites in the Mediterranean region. Since 2018, ICARDA has partnered with NORAD and the Global Crop Trust to try to deliver these superior CWR-derived cultivars to smallholder farmers of Africa.

Importance of genotyping in conservation and use of genetic resources

Substantial efforts have been undertaken to genotype a large portion of the ICARDA genebank collections. Over 27,000 accessions of wheat, 3,000 of barley, and 1,000 of chickpea were genotyped using mainly DArtseq technology (Sansaloni, 2011). The information derived has been used to study the genetic diversity of the existing collection and to identify duplicates and miss-classified species. Interestingly, these same studies have been used to confirm the center of origins and diversification of durum wheat and define a map of global allelic diversity. Association mapping studies and marker by environment interactions have also allowed the identification of major adaptation genes and helped in their exploitation through breeding. Finally, this genomic information shall be integrated with climate model to further refine the effectiveness of the FIGS approach and make predictive characterization for quantitative traits using genomic prediction, and even predict regions that due to climate change are most likely to lose and/or gain important diversity.

References

Anglin N.L., Amri A., Kehel Z. and Ellis D. (2018) A case of need: Linking traits to genebank accessions. Biopreserv. Biobank 16(5): 337-349.

Hijmans R.J., Guarino L., Cruz M. and Rojas E. (2001) Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS. Plant Genetic Resources Newsletter (127): 15–19.

Mackay M.C. and Street K. (2004) Focused identification of germplasm strategy-FIGS. In: Black C.K., Panozzo J.F. and Rebetzke G.J. (eds.) Cereals 2004, Proc. 54th Australian Cereal Chemistry Conference and the 11th Wheat Breeders' Assembly Cereal Chemistry Division. Royal Australian Chemical Institute, Melbourne, pp. 138–141.

Phillips S.J. (2009) A Brief Tutorial on Maxent. Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History. Lessons in Conservation, Vol. 3, pp. 108-135.

Sansaloni C., Petroli C., Jaccoud D., Carling J., Detering F. et al. (2011) Diversity Arrays Technology (DArT) and next-generation sequencing combined: genome-wide, high-throughput, highly informative genotyping for molecular breeding of Eucalyptus. BMC Proceedings 5 (Suppl 7): 54p.

Upadhyaya H.D., Yadav D., Dronavalli N., Gowda C.L.L. and Singh S. (2010) Mini core germplasm collections for infusing genetic diversity in plant breeding programs. Electronic Journal of Plant Breeding 1(4): 1294-1309.

Zaim M., El Hassouni K., Gamba F., et al. (2017) Wide crosses of durum wheat (*Triticum durum* Desf.) reveal good disease resistance, yield stability, and industrial quality across Mediterranean sites. Field Crops Research 214: 219-227.

Agrobiodiversity of Fruits and Nuts to Adapt to Climate Change in Central Asia

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Central Asia covers a vast region from the Caspian Sea in the west to the Tian-Shan mountain ranges in the east and includes the territory of five independent countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Being located in the center of Eurasian continent, far from oceans, with extensive areas of deserts and mountain ranges the region of Central Asia has arid climate and possess richness of landscape diversity with more than 20 different ecosystems. Due to its geographic location and diverse climatic conditions, Central Asia is likely to face severe problems caused by climate change. It is reported that in the second half of the 20th century, the area of glaciers has decreased by almost one third in Tajikistan, and more than 1,000 glaciers have melted over the past four decades in Kyrgyzstan. The shortage of water, which is an important driver of agricultural development in the region, would be a major challenge in future. Lack of water and frequent droughts are becoming important stress factors for agricultural development in Central Asia. Four out of five countries in Central Asia have been identified as most vulnerable to climate change, according to studies of World Bank conducted in 2009 in 28 countries of Europe, Caucasus and Central Asia.

On the contrary, the region has great potential to cope with problems likely to be caused by climate change. It is a "hot spot" of agrobiodiversity. Central Asia is home to 8,300 vascular plants, of which around 10% are endemic. N.I. Vavilov had identified Central Asia as one of the eight world centers of origin and domestication of crops. The region possesses rich genetic variability of crop wild relatives, traditional and improved crop varieties. Species and intra-species diversity of fruit and nut trees of Central Asia plays an important role for the livelihoods of local people. More than 300 species of fruit and nut trees, including almond, pistachio, walnut, apricot, apple, pear, cherry plum, pomegranate, fig, peach, persimmon, quince and others are being cultivated for centuries in Central Asia.

Local people have selected from the crop wild relatives and domesticated hundreds of fruit and nut tree varieties, highly adapted to a wide range of diverse climate and soil conditions in mountain slopes and lowland valleys. Surveys in Central Asian countries - Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan showed that many of them are still grown in home orchards and smallholder farms. Local people do maintain the rich genetic diversity of traditional fruits and nut trees and have passed on to the next generation. During the surveys, 160 local varieties of grape, 145 of apple, 103 of apricot, 40 of walnut, 32 of pears, and 26 of pomegranate have been found.

It is noteworthy that forests in Central Asia are the home of wild fruit and nut tree species including walnut (*Juglans regia* L.), almond (*Amygdalu s*sp.), pistachio (*Pistacia vera* L.), apple (*Malus* sp.), pear (*Pyrus* sp.), grape (*Vitis* sp.) and serve as natural landscape for their continued evolution and adaptation to changes in environment, including the climate. Sixty eight genotypes with economically valuable traits likely to be useful for breeding new varieties have been distinguished in wild populations of pistachio, currant, sea buckthorn, almond, apple and cherry plum.

This local diversity has several valuable traits, such as early ripening, resistance to spring frosts, salinity and drought tolerance, absence of fruit bearing alternation, which can be used in the improvement of fruits and nut trees. The local fruit and nut tree varieties are highly valued for their excellent taste, aroma, long shelf life of fruits, and good quality of dried products (dried apricots, raisins). Recent scientific publications do indicate that germplasm of Central Asian fruit trees is widely used outside the region to improve quality of fruits especially the flavor and sugar content (Ledbetter, 2009). In addition, local diversity of fruit trees in Central Asia demonstrates "the excellent fruit-growing characteristics such as ability of trees to retain fruits longer in areas with high air temperature, which shows their inherent potential to adapt to areas with a long growing season" (Horticultural Reviews, 2003).

Local fruit and nut tree diversity plays an important role for improving the livelihoods of local people. Fresh, dried, canned fruits and nuts are an important part of diet of local people in Central Asia as well as a source of income for most farmers. Local people harvest walnut, pistachio and almond nuts in wild stands of these species. Being highly drought tolerant, almond and pistachio trees are used for restoration of degraded lands in dry areas where no other crop can be grown.

Hence, the rich genetic diversity of fruit and nut tree in Central Asia offers great opportunity for yet better adaptation to climate change, provided exploited effectively through scientific evaluation, characterization, breeding and conservation so as to ensure faster agricultural development and food security in the region despite climate change. This paper would highlight strategy for better adaptation in fruit and nut trees to climate change.

Dryland Agrobiodiversity for Adaptation to Climate Change: Role of Regional Organizations

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It is well-known that drylands comprise one of the world's major ecosystems, typically characterized by scarcity of moisture for all or part of the year, and soils which are in most parts infertile. In terms of global distribution, drylands occur in every continent, being most extensive in Africa. Dryland ecosystems contain a variety of agrobiodiversity of plant, animal and microbial species that have developed special strategies to cope with the low and sporadic rainfall, and extreme variability in temperatures. Such adaptive traits of agrobiodiversity have global importance, especially in the context of predicted climate change. At the international level, concerns for climate change adaptation led to adoption of the United Nations Framework Convention on Climate Change (UNFCCC) along with the Convention of Biological Diversity (CBD) during the Earth Summit at Rio-de-Janeiro in 1992. Both the conventions have been instrumental in triggering local, regional and global initiatives for sustainable management and use of agrobiodiversity for combating and mitigating climate change.

Value of and threats to dryland agrobiodiversity

Traditional dryland systems and their agrobiodiversity including traditional crops and their varieties, tress and local breeds of livestock have contributed enormously to food and nutritional security to millions of farmers and large number of traditional communities in drylands. In some areas, traditional plant varieties and livestock can be the only sustainable option for food production and proven to be life-savers during adverse climatic conditions. Agrobiodiversity in drylands is under various kinds of threats – (i) increasing pressure on scarce water, less trees and cultivable land, due to ever-increasing population, (ii) decreasing level of water tables, monocultures, soil erosion, due to inappropriate farming techniques, (iii) land-use change from grazing to cropping, deforestation and afforestation with inappropriate species, (iv) lack of systematic conservation efforts, (v) loss of traditional management system by traditional communities and documentation of indigenous knowledge, (vi) impacts of climate change leading to harsh natural vagaries. It has become imperative to combat these threats for mitigating the adverse impacts due to climate change by conserving and sustainably using dryland agrobiodiversity for improving the livelihoods of small and marginal farmers and traditional dryland communities.

Supporting research areas for conservation of dryland agrobiodiversity include: (i) assessing the value of dryland resources and the services communities provide, (ii) cultivation and processing of dryland plants and animals, (iii) optimization of traditional resource use and management, and (iii) interaction of the different agrobiodiversity components with each other, their environment and climate (www.giz.de/expertise/downloads/giz2011-en-agrobiodiversity-in-drylands.pdf)

Sustainable Development Goals (SDGs)

The SDGs are the blueprint to achieve a better and more sustainable future for all. SDGs, which are important with relevant targets for this discussion and need regional cooperation, are mentioned below:

SDG 13: Take urgent action to combat climate change and its impacts

(i) To strengthen resilience and adaptive capacity to climate-related hazards and natural disasters.

(ii) Integrate climate change measures into national policies, strategies and planning.

(iii) Improve education, awareness-raising and human and institutional capacity on climate change mitigation.

SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

(i) Ensure the conservation of mountain ecosystems (including cold dry regions), including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development

(ii) Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, protect and prevent the extinction of threatened species

(iii) Integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies.

SDG 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development

(i) To enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation.

(ii) Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources and

(iii) Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.

Role of regional organizations in policy, capacity building and networks

Agrobiodiversity management in drylands also requires functional convergence of global policy and regulatory frameworks that deal with agrobiodiversity, food and agriculture, desertification and climate change. Regional initiatives need to bring neighbouring countries together to address the common issues in management of dryland agrobiodiversity. Regional organizations can play significant role for management of agrobiodiversity in drylands, as mentioned below:

1. Prioritization of research

a. High level policy dialogues

b. Expert consultations

c. Workshops/ Seminars/Symposia

2. Capacity development

a. Mapping the existing capacity and need of capacity development

b. Technical and soft skill trainings

c. To create robust impact pathways, prepare logical frameworks, measure indicators, from research to extension, policy, and impact on farmers' livelihoods

d. Functional capacity development to build awareness among policy makers, media and the public

3. Public awareness

a. Public awareness by sharing of experiences, and best practices

b. Indigenous knowledge

c. Success stories across various communities, regions and countries.

4. Policy advocacy

a. Creation of supportive policy environments including legal frameworks at both national and international levels

b. Policy briefs

c. Development of the value chain and exploration of markets at local, national and international levels

d. Prioritization of investment

5. Partnership development

a. Increased cooperation at, regional and international levels

b. Develop synergies in the region to build partnerships and networking of groups and institutions

c. Mechanisms for partnerships by greater involvement of private sector and brokering of partnerships

The Asia-Pacific Association of Agricultural Research Institutions (APAARI), 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. Currently, it focusses on realising sustainable development goals in Asia and the Pacific. This is carried out by coordinating between ministries, research organizations (especially the national agricultural research institutes), universities across the region, and development partners. Major approach comprises upgrading the knowledge base, improving knowledge sharing, and closing the gap between science and development practice in order to make best use of technology and to foster sustainable management. For dryland agrobiodiversity management, APAARI can facilitate in (i) understanding and assessing of dryland ecosystems; (ii) development of a cadre of scientists with core competencies, information and skills in science and technologies for dryland agrobiodiversity management and use, post-harvest processing and value addition; (iii) policy interventions at national and regional level (iii) promoting public and private investments; (iii) support institutional changes to strengthen R&D and overall capacity development.

Mainstreaming the Agrobiodiversity of Drylands in the Context of Climate Change – Role of Bioversity International

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In today's complex and interconnected world, what we eat and how we produce it are inextricably bound together. With the global population expected to touch 9.7 billion by 2050, there will be increasing pressure on our limited natural resources to produce more food, almost 50% more food, feed and bio-fuel than it did in 2012. Recent FAO report warns that the projected growth in world population is likely to be concentrated in sub-Saharan Africa and South Asia, with major concentration in India. This will pose immense problems, as expanding agriculture in India will be difficult because of scarcity of land and water resources. At present, there are worrying signs that yield growth is leveling off for major crops. Hence, high-input, resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production.

The Sustainable Development Goals recognize that these challenges are interconnected and multidimensional. Under these challenges, achieving food security in drylands is especially challenging. Drylands cover 41% of the earth's land area and are home to 38% of the world's population, the majority of whom live in poverty. With changing climates threatening fragile ecosystems and high migration levels, the livelihoods of more than 2 billion people are at risk.

The latest report on Land Degradation and Restoration recognizes that combatting land degradation, which is a pervasive, systemic phenomenon occurring in all parts of the world, is an urgent priority in order to protect the biodiversity and ecosystem services that are vital to all life on Earth and to ensure human well-being. Land degradation negatively impacts 3.2 billion people and represents an economic loss in the order of 10% of annual global gross product. Each year, the world is losing 12 million hectares of land, and thus the opportunity to grow 20 million tonnes of grain. Moreover, 24 billion tonnes of fertile soil disappear each year. The precariousness of the situation becomes more pronounced when we know that 2.6 billion people depend directly on agriculture and 52 per cent of the land used for agriculture is either moderately or severely affected by soil degradation. About 400 million hectares of degraded lands have been reported in southern and eastern Asia. The Report concludes that avoiding land degradation and restoring degraded lands makes sound economic sense, resulting in, inter-alia, increased food and water security, increased employment, improved gender equality, and avoidance of conflict and migration. Avoiding land degradation and restoring degraded lands are also essential for meeting the Sustainable Development Goals.

Farm households and rural communities around the world, including in dryland systems, have long since used agricultural and tree biodiversity to diversify their diets and their production systems, to manage pests, diseases and weather-related stress. The evidence shows that biodiversity-based approaches intensify production while reducing pressures on the environment, for example, by improving soil quality. At the same time, a diversified diet is essential for human health.

Climate change is expected to have major impacts on smallholder farmers in the developing world. It is well-documented that agriculture is the second largest contributor to carbon emissions after the energy sector. At the same time, climate change is affecting our ability to grow food as many crops that currently grow well in a certain location may no longer do so as time goes on. The IPCC predicts that yields of major crops will reduce by 2% while demand increases by 14% every decade until 2050. Up to 40% of the world's land could develop novel climates often with new crop pests and diseases.

Healthy dryland ecosystems and agrobiodiversity are essential for dryland communities to overcome their poverty. A major challenge is how to facilitate agricultural growth without endangering the resource base. About 800 million farmers in drylands depend on cereals and legumes. When food supplies are scarce, traditional plant varieties are often lifesavers as they are well adapted to drought, variable rainfall and harsh environments. The adaptive traits of dryland organisms are of growing importance for coping with the impacts of climate change and using traditional varieties in production systems can increase the capacity of the system to adapt to unexpected or changing climate events, as they harbour higher levels of genetic diversity, and so are more able to respond to variation in their environment.

Rajasthan where Bioversity International is working is the largest state of India covering nearly 10.4% of total geographical area of the country. Agriculture in Rajasthan is primarily rainfed. Groundwater is getting depleted as well as polluted. In general, every third year is a drought year in most of the districts of Rajasthan. Rajasthan is well known for its traditional biodiversity comprising both plants and animals, which are of global significance. It possesses some unique medicinal and aromatic plants as well as seed species and food legumes. Desert trees and shrubs like *Khejadi*, *rohida*, *phog*, *ker*, *ber*, etc. are indigenous to Rajasthan. Hence, there is need to capitalize on available potential of Rajasthan agriculture that remain untapped. Production of rapeseed and mustard, coriander, cumin, fenugreek, guar and moth are highest in the country. Nevertheless, increasing the productivity and profitability from these crops needed for improving the livelihood of farmers from this region of India.

Seeds for Needs, an initiative led by Bioversity International and partners, is linking farmers to the seeds they need to face changing climatic conditions. This approach puts farmers in the role of citizen scientists, testing, observing and comparing different varieties, trying new farming techniques, and experimenting with different crop rotations to see what works for them. They evaluate different qualities of each variety such as yield, resilience, nutrition, taste and resistance to pests and diseases. The idea is to stimulate farmers to experiment with different landraces and varieties, while linking to geographical tools to make these efforts more targeted and more efficient

In India, 10,000 farmers across five states participated in 25,000 crowdsourcing trials assessing different varieties of rice and wheat on their farms. Linking to local genebanks, scientists and farmers evaluated a broad selection of crop diversity, including traditional varieties, modern varieties and obsolete varieties. Trials resulted in the adoption of many more released varieties of rice and wheat along with the prevalent ones. Thereby, contributed to broadening of genetic base. As a result, their agricultural systems should be more resilient to climate change and rural communities are now better able to use adapted genetic materials through an improved local seed system network. Going forward, farmers are better able to identify suitable genetic material that will help them adapt to the changing climate and make better choices according to local conditions.

In another programme named "Improving Nutritional Security of Rural Population through Biodiversity" multipurpose tree-based Horticulture production system was found effective for improving productivity, employment opportunities, economic condition and nutritional security. The tree such as gunda (*Cordia mixa*), anar (*Punica granatum*), amla (*Embilca offcinalis*), ber (*Ziziphus mauritiana*) lemon (*Citrus Limonum*) karonda (*Carissa carandas*), drumstick (*Moringa oleifera*), jamun (*Syzygium cumini*), sapota (*Achras zapota*), date palm (*Phoenix dactylifera)* and imali (*Tamarindus indica*) have been found suitable for this area. Besides, cluster been (*Cyamopsis tetragonoloba*), moth bean (*Vigna aconitifolia*) and cowpea (*Vigna unguiculata*) were found suitable for horticulture-based farming system. The agri-horticulture with RWH model has led to increased availability of water for protective irrigation of horticulture plants, drinking and goat rearing. It has helped poor farmers to save cost and time expended to procure water, saving hours of hard labour mostly put in by women.

Bioversity International is also implementing UN Environment GEF project on 'Mainstreaming Agricultural Biodiversity Conservation and Utilization in Agricultural Sector to Ensure Ecosystem Services and Reduce Vulnerability in India' and drylands Jodhpur, Badmer and Jaisalmer of Rajasthan are part of this project. The project focus on strengthening local seed supply systems and the establishment of community genebanks, seed fairs, field evaluation trials and demonstrations, crowd sourcing (putting landraces/ farmers varieties and modern varieties together and allow need based participatory selection), diversity fora and other adaptive technologies that enable farmers to benefit from diversity rich solutions. The will help mainstream crop diversity through working with farmers to use diversity to address challenges posed by climate change. This also includes identification of suitable crop diversity to address such challenges, improved awareness and information on varietal adaptation based on scientifically sound evidence and its validation by farmers and communities. Income and other livelihood improvement actions will also support mainstreaming.

Millets: Issues and Way Forward for Agrobiodiversity for Adaptation to Climate Change

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Millet family includes pearl millet, sorghum and many other minor types of millet. They have advantage over wheat, rice or maize for having higher adaptation potential to a range of marginal growing conditions, for able to withstand higher levels of climatic stresses and for their capacity to be cultivated in variety of soils. Also, they possess range of micronutrients, including calcium, iron, zinc, dietary fibres, balanced amino acids, and are therefore more usable protein than many other fine cereal crops. Global neglect of the millets and increasing emphasis on few elite food crop species are narrowing the food security basket. The most disadvantaged by this food production policy are the poorest of the poor. The shrinking number of food crops in the regional and global food basket is restricting the opportunity of farmers in difficult regions to use their land resources, environment and traditional knowledge. This note primarily focusses on agrobiodiversity related issues related to pearl millet, most prevalent global millet crop, and most of this discussion can apply to other millets also.

Climate shocks will have an overall negative effect on agricultural production across the regions, and this could lead to food and nutritional insecurity (IPCC, 2014). Semi-arid and arid tropics are known to be particularly vulnerable to climate change due to high climate variability, high reliance on rain-fed agriculture, and limited economic and institutional capacity to respond to climate variability and change. Pearl millet and sorghum are most important millet crops for food security and nutrition in these regions. These stresses will become more severe in near future and require identification of genotypes tolerant to abiotic stresses and relevant traits useful in breeding programs for improving adaptation, production and/or nutrition quality of these crops.

Pearl millet is cultivated on about 18 m ha in Sub-Sahelian Africa. The Sahel will be the most adversely affected in sub-Saharan Africa due to extreme variation in climate change as a result of frequent droughts of varying intensity and duration. For instance, pearl millet in Niger is the main staple crop, and farmers grow this crop in 65% of the cultivated area for producing more than 80% of the entire caloric intake in the country. The impact of drought has been estimated on germplasm by comparing the ancestors with their descendants, which revealed that drought caused many changes in life-history traits, including a shift to earlier flowering, reduced peak flowering, and greater skew of the flowering schedule in pearl millet. The present day pearl millet cultivars have thinner stems and fewer leaf nodes at the time of flowering than ancestors. Hence, in this quickly changing climate there is continuing need to assemble and screen germplasm strategically and discover new sources of variation that will enable developing new crop cultivars adapted to adverse climate and its variability.

Crop Wild Relatives (CWR) have contributed many agronomically beneficial traits in shaping the modern cultivars and they will continue to provide useful genetic variation for climate-change adaptation, and also enable breeders select plants that will be well-suited for the future environmental conditions. **Core and mini-core collections** have been suggested as a gateway to enhance the utilization of germplasm in crop breeding. These subsets are available in pearl millet, sorghum, finger millet, foxtail millet, and proso millet.

In view of climate change and rising temperatures, tolerance of crops to high temperature during their reproductive stage has recently assumed high significance. The high temperatures have relevance at both seedling and reproductive stages of crop in pearl millet. A few genotypes have been identified from Rajasthan for better survival under high soil surface temperatures during initial stage of development. Large genetic variation for tolerance to heat at reproductive stage among pearl millet breeding lines and populations has also been observed, and heat-tolerant lines have been identified. Breeding lines, populations and germplasm accessions have been identified as heat tolerant (high seed set at air temperatures of > 42°C), which can be further utilized for diversifying the genetic base of heat tolerant materials in pearl millet to enhance cultivar diversity in summer cultivated pearl millet crop in North-Western India, and in several African and Central Asian countries where ambient temperatures are quite high in different crop seasons.

Soil fertility will be greatly impacted by increase in both atmospheric CO_2 concentration and temperature. While increase in CO_2 concentration will mean opportunity for enhanced photosynthetic rate, the growing plants will not be able to take advantage of this unless the photo-synthesis-driven increased nutrient requirement is met through balanced and integrated nutrient management strategy. In pearl millet, low P (LP) stress induces significant delay in heading and flowering dates. A flowering delay in pearl millet would increase the risk of the plant encountering water deficient conditions leading to decrease in biomass and panicle weight due to LP stress. There is need to explore genetic diversity to address such soil fertility linked traits in climate change scenario.

India, major grower of pearl millet (about 8 m ha) in Asian region, cultivates millets in diverse agro-ecologies having 150-600 mm annum rainfall. During the cultivar development process, Indian pearl millet landraces have mainly contributed for earliness, high tillering, high harvest index and local adaptation, whereas African material has been a good source of bigger panicles, large seed size, and disease resistance. Systematic evaluation and screening of germplasm has led to the identification of specific sources of better grain quality, resistance to diseases and adaptation to diverse agro-ecologies. Indian pearl millet cultivation is dominated by hybrids which occupy about 4-5 m ha area, with about 80-90 diverse hybrids on farmers field at any point of time. Recent investigations revealed that trait specific breeding followed in Indian hybrid breeding program led to differentiation of breeding materials into clear cut heterotic pools, separately for seed and restorer parents. Most of the seed parents have been bred using germplasm from African *Togo* region, while restorer parents are bred using Indian germplasm with local adaptation. Now moving further, highly heterotic B- (seed parent) and R- (restorer parent) heterotic groups have been identified from Asian and African origin populations to further elevate genetic gains in pearl millet. The time has come to broaden the pearl millet cultivar diversity of West African countries, which have been growing OPVs till date, to shift towards hybrid technology to enhance productivity in the region.

Following broad guidelines can be followed to enhance adaptation potential of millets to mitigate effects of climate change:

New cultivars and breeding populations will need to be continually developed to help withstand climatic extremes and maintain or even increase productivity in the face of increased climatic variability.

- ICRISAT and NBPGR has collection of >20,000 pearl millet accessions in their gene banks, along with huge germplasm for other millets also. There is need to encourage utilization of these valuable resources in active breeding programs.

- The use of exotic germplasm in breeding is a long-drawn process, often associated with undesirable traits; and shedding these negative linkage drags will require careful planning and execution of germplasm enhancement steps in such a way that the co-adapted gene complexes, while introgressing new genes into improved genetic background, are not lost.
- As there was large amount of genetic variability available in pearl millet landraces for useful traits, use of wild relatives in crop improvement was negligible. Crop wild relatives (CWR) contain higher levels of resistance for both biotic and abiotic stresses and are promising for some agronomic and nutritional traits. Therefore, these will continue to play a vital role in crop improvement programmes, more so under conditions of climate change. Also, there are still large gaps, more specifically in crop wild relatives and landraces, in ex situ gene bank collections preserved across the globe. There is need to assemble and screen germplasm strategically and discover new sources of variation that will enable developing new crop cultivars adapted to adverse climate and its variability.
- Modern tools such as those from applied genomics must support conventional breeding to accelerate development of improved open pollinated or inbred cultivars and hybrids in such a way that it increases the available genetic diversity to improve food and nutritional security
- Precise phenotyping is the key to finding gene(s) and its allelic variants, analyse their expression, and thereafter for introducing these agronomically beneficial alleles into crop cultivars to enhance adaptation and meet new challenges to agricultural production.
- Gene pools can be developed to provide researcher with the widest variability in germplasm accessions to sustain continual improvement over a longer period of time.

A multi-disciplinary effort and long-term consortium-based approach involving conservationists, geneticists, plant breeders, and molecular biologists will be required to harness the wealth of available millet agrobiodiversity to address agriculturally important problems, more so in this time of climate change.

Issues and Way Forward for Agro Biodiversity for Adaptation to Climate Change

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Arid legumes, particularly guar, moth bean, cowpea and horse gram, are known for elasticity in adjusting with any companion crop or biological system; and adapting in abrupt growing environments. Due to inherent specific virtues, these legumes are characterized for biological means of taming and thwarting global warming, thereby appeared to me, as the future crops. These so called minor legumes, are multi-utility loaded, economic backup, and have simplicity in plantings. These regional and pocket crops, are the most crucial components of system diversity in fragile and orphan agro-eco system like drought, heat, planting dates, soil types, management cares in varied regions and seasons.

First issue for commencing crop diversity is abrupt dry and warm situations. The two recent most examples provide solutions. During *kharif* 2018, in Badmer and Bikaner Thar districts rainfall was touching 100 mm, interval between dry spells was 35-45 days, temperature ranged 35-42 degree C, and soil is 90% sandy. In Kau Khera (Badmer) village, Mr Ganga Ram, a farmer, obtained grain yield of moth bean (CZM-2) and moong bean (IPM-2-13) 300 and 90 kg/acre, respectively. The net benefit from moth bean was Rs 10,090/acre. In Hamera village (Bikaner), Mr Tolaram farmer laid out 20 acres of guar demonstration and harvested grain yield @ 195 kg/acre, the normal yields in abnormal situations. Thus, guar and moth bean appeared to be the prime crops for adding to diversity, where all crops fail due to extreme situations.

Second issue is mono cropping and its sequences in different regions in India. Guar is supplementing cotton in Vidharbha region, peanuts on red soils in Rayalsema region, local crops in Raichur and Gulbarga dry regions and has been successfully introduced in Madurai regions, only 50-70 km of sea. Horse gram is the source of diversity in rice-rice sequence in Kerala and in tribal regions from dietary habits and cultivation potential. Similarly, cowpea is good example as a source of diversity after harvest of wheat in northern India. Cowpea and horsegram for want of varied utilities can be adjusted as legume for adding to diversity in 250-800 mm rainfall situations of semi-arid and arid conditions.

Third issue is soil type and its texture. Guar and horsegram are the arid legumes can be accommodated in any soil (sandy, loamy, sandy loam, clay, even in black soils to some extent) provided water logging conditions are completely managed. In fact these crops do not mind soil barriers if standing water is tackled judiciously.

Fourth issue is planting dates. These are the crops that can be planted in July, August, September, December and February-March, in rainy, winter and summer seasons almost throughout country. Diversity on farm lands would only find easy acceptance if addressing issues related of the concerned crops; for instance, adding to farm economy, stability, having multi uses with convenient cultivation strategies. Guar and moth bean are most stable in market price and productivity, simple to be cultivated; and guar has hundreds of commercial uses. Organic moth bean grains are exported to western world @ 0.5 million US $ per annum. Horsegram a source of curing certain human diseases, like stone formation in kidneys, cold, cough etc. Horsegram grain produce is also exported.

Future strategies: Guar gum being exported @ Rs 9.05 thousand crore in quantity of 3.5 MT annually from India. This is used and exported as food grade and industrial grade guar powder, with viscosity values of 1,000-5,000 and 5,000-10,000 cP, respectively Thus, we need breeding for industries by developing cultivars of low and high viscosities. Similarly, guar gum is not directly used for more than 70 industries but as per product based derivatives are developed in USA and same are again imported back to India. Thus, in case we develop varieties with desired viscosities and manufacture derivatives in India, it will increase demands and would augment guar in newer regions. Also guar gum powder due to adding to stiffness, if used in road and building constructions would further its diversity. There is scope of developing guar based hydrogel for rain-fed areas. There is need of popularizing guar meal and guar Korma, guar gum industry bi-products. Same are very rich source of crude protein (45-50% CP), as a cheap source of animal cake. Still there are some issues related to improvement in quality of guar gum bi-products.

There is need to curtail growth period of guar from 90 days to 70-75 days to fit it successfully in rainfall situations of 50-60 days, which is common in guar areas. Moth bean needs more attention on enhancing its export potential by developing small-sized grain with smooth outer layer for using in daily snacks. If more heat tolerant genes are accumulated in moth bean by shuttle evaluation in warm and warmer regions, it would be able to tolerate heat up to 45-47°C. Developing dual purpose varieties of horsegram and cowpea would enhance their uses as diversified crops for grain and fodder in constraint situations.

Genetic Resources of Oilseed Crops Adaptable to Climate Change: Issues and Way Forward

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Oilseeds in India occupied an area of 24.64 million ha with total production of 31.30 million tonnes with an average seed yield of 1,270 kg/ha during 2017-18. Total nine oilseed crops *viz*., soybean (*Glycine max* Merr.), groundnut (*Arachis hypogaea* L.), rapeseed mustard (*Brassica* spp.), sunflower (*Helianthus annus* L.), safflower (*Carthamus tinctorius* L.), sesame (*Sesamum indicum* L.), niger (*Guizotia abyssinica* Cass.), linseed (*Linum usitatissimum* L.) and castor (*Ricinus cummunis* L.) are being grown in India. There have been increasing trends in area, production and productivity since 1950-51 and a significant boost was received after implementation of Technology Mission on Oilseeds by Government of India. Launch of Technology Mission on Oilseeds in 1986 led to 37% increase in area, 45% increase in productivity which enhanced the production to almost double (99% increase) during 1990-91 over 1980-81. Major contribution towards this enhancement was due to improved varieties and their seed availability and production and protection technologies.

It is well-known fact that oilseeds are grown on marginal lands under rain-fed conditions with no or very less availability of irrigation water. Area falling under arid zone in different states occupies a significant acreage under oilseed crops. The hot arid zone covers around 32 mha area comprising states of Rajasthan, Punjab, Haryana, Gujarat, Maharashtra, Andhra Pradesh and Karnataka, where 89.6% area falls under arid regions of Rajasthan, Gujarat, Punjab and Haryana together which constitute the great Indian Thar desert. Jammu and Kashmir falls under cold arid zone comprising of about 7 mha area. Almost all the oilseed crops are being grown in arid regions of these states which encounters recurrent drought, heat, salinity and cold. Though number of varieties of different oilseed crops have been developed for these areas but systematic efforts need to be intensified for breeding varieties for the various biotic and abiotic stresses encountered due to climate change.

Exploitation of available genetic resources is key to success of any crop improvement program. In case oilseeds, it has been observed that very limited germplasm has been used in crop improvement till date. National Gene Bank (NGB) at NBPGR holds 62,709 accessions of oilseeds germplasm which represents 52 species, the details of which are given in table below:

Crops	Accessions Conserved in Gene Bank	Genetic Stock Registered
Oilseed Brassica	12,673	64
Groundnut	13,834	49
Sesame	9,840	04
Safflower	7,365	04
Soybean	4,082	10
Linseed	2,903	04
Sunflower	1,409	04
Others (Castor, Niger, Perilla, Jatropha, Garden Cress, Sandalwood etc.)	10,603	53
Total	**62,709**	**192**

Systematic efforts to identify and utilize the trait specific germplasm for various biotic and abiotic stresses have not been made in oilseed crops which is evident from the fluctuations in area, production and productivity of these crops over years. During past one decade efforts have been initiated to identify trait-specific germplasm in some of the oilseed crops which has been summarized as under:

Rapeseed mustard

Salt tolerant lines/varieties: CS-52, CS-54, CS-234-2-2, CS-56, RH-8814 (IC-401570), CS-58, CS-1100-1-2-3-5-1, CS-1500-1-2-2-2-1, BPR-540-6

Drought tolerant lines/varieties: RH-781, RH-819, RH-406, RB-50, RH-725, RVM-2, Pant Rai-20, RGN-298, Aravali, Geeta, Shivani, DRM-541-44

Heat tolerance lines/varieties: Pusa Vijay (NPJ-93), Pusa Mustard 25 (NPJ-112), Pusa Mustard 27 (EJ-17), Pusa Mustard 28 (NPJ-124), BPR-540, BPR-541-4, BPR-543-2, BPR-549-9, Pant Rai-18, RH-406, RGN-229, RGN-236, RGN-298

Frost tolerant lines/varieties: RH-819, RGN-48

Groundnut

Low and high temperature tolerant lines: NRCGs 14480, 14324, 14367, 14414, 14333, 14492, 14454 and released groundnut varieties viz., ALR 2, ALR 3, GJG 9, GG 13, Somnath, KRG 1, JGN 3, LGN

1, TAG 24, JL 220, Narayini, ICGV 00350, ICGV 87846, TG 1, TG 17.

Drought tolerant lines: Two germplasm NRCGs 14390, 14395 and 10 released groundnut varieties viz., BG 2, ICGV 86590, Kadiri 3, M 197, DRG 12, BG 3, Kadiri 2, TG 1, DSG 1, GAUG 10.

Soybean

Drought tolerant lines: JS 97-52, EC 538828, NRC 7, EC 602288, JS 71-05

Water logging tolerant lines: JS 97-52, PK 472, JS 20-38

Heat tolerant lines: JS 97-52, EC 538828, NRC 7

Photo-insensitive lines: MACS 330, EC 325097, EC 33897, EC 34101, EC 325197, EC 390977

Long Juvenile: AGS 25

Sunflower

Drought tolerant lines: AKSF-42-1, M-1026, 298-R, GMU-351 and hybrids; Laxmi-225, CO-2, CSFH-12205, DRSH-1, KBSH-44

Castor

Drought tolerant lines: RG298, RG1437, RG1826

To fully utilize the available genetic resources of various oilseed crops, large scale screening is required under arid zones to identify the potential lines for using them in breeding programs, as has been done in case of wheat. The promising lines of various traits identified under field screening should further be characterized under controlled stress conditions (phenomics/phytotronics) and the molecular markers linked to traits of interest should be identified for using them in precision breeding for introgression of these traits. More systematic efforts are required to collect, conserve and regenerate the germplasm, local landraces and wild relatives from the arid zones.

Biodiversity of Seed Spices: Status and Opportunities under Changing Climatic Scenario

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Genetic diversity is an essential resource for crop breeding and reservoirs of identified and unidentified genes. The primary and secondary centres of origin are the source for germplasm due to the natural hybridization and flow of genes throughout their existence. Detailed study on germplasm gives us the source material for resistance to biotic and abiotic stresses which can be further used in the improvement aspect. India is the land of spices and is the primary or secondary centre of origin to major spices. Among spices, seed spices contents of 300 genera in with 3000 spices virtually all are perennial biennial or annual herbs. The important seed spices relevant in Indian context are coriander, cumin, fennel and fenugreek. Most of the seed spices cultivated in India are of Mediterranean origin. In none of the seed spices, wild relatives which could contribute by way of hybridization to cultivated forms are known to exist in India. Most of the germplasm, therefore, exist in the form of traditional varieties. A total 109 spices are listed by ISO and 63 spices are grown in India and out of which 20 are being classified as seed spices. Out of 20 seed spices, ICAR-NRCSS, Ajmer is working in 10 most important seed spices namely cumin, coriander, fennel, fenugreek, ajwain, anise, caraway, celery, dill and nigella. According to National Horticulture Board, third advance estimate of year 2017-18, the seed spices occupied an area of 1826 (000 ha) and produce 1866 (000 MT) with an average productivity of 1.02 t/ha. Significant increase in productivity was observed in total seed spices during the period of 2008 (0.79 t/ha) to 2017 (1.02 t/ha) (Gopal, 2018).

Importance in national economy

Seed spices play a significant role in our national economy because of its large domestic consumption and growing demand for export. India is exporting about 14 per cent of its production annually and fulfills nearly 50 per cent of world demand. The total export of seed spice crops is Rs 3,738 crores, out of which cumin alone contributes Rs 2,418 crores annually (Spice Board India, 2017-18) (Gopal, 2018). The world demand of seed spices is increasing at the rate of 8 to 10 per cent annually.

Importance of biodiversity under changing climatic scenario

Crop biodiversity includes all components of biological diversity of relevance to food and agriculture. It includes plants' genetic resources: crops, wild plants harvested and managed for food, trees on farms, pastures and rangeland species, medicinal plants and ornamental plants of aesthetic value. Genetic variability is a prerequisite for any improvement in a crop. The success of any crop improvement program depends on the magnitude of genetic variability and extent to which the desirable characters are heritable. The ultimate goal of breeding program aims to improve the characteristic of plants so that they become more desirable. Evidence of rising temperatures, changing seasonal patterns and increasing frequency of extreme weather events is growing. The consensus is that climate change will affect agricultural productivity worldwide. Since seed spices are majorly grown under arid and semiarid climate so these crops shall be affected more due to climate vagaries. Therefore, adaptation technologies will be crucial to ensure national and global demand of seed spices in coming years.

Climate change is contributing to the loss of biodiversity, but the crop diversity that is safeguarded is expected to play a significant role both in mitigating the adverse effects of, and adapting to, climate change. A report by FAO places crop diversity at the forefront of adaptation solutions. A key to achieving adaptation is broadening the genetic base of crops. The continued availability and accessibility of both traditional and improved varieties is key to future improvements in crop productivity. For example, in seed spices coriander, fennel, fenugreek and cumin varieties already released by ICAR-NRCSS, Ajmer, which are able to grow in biotic and abiotic stress conditions.

Status of biodiversity in seed spices

India is bestowed with immensely rich landrace diversity in seed spices. Much of country biodiversity is in the custody of farming community who followed age old farming system. However, it is being lost from the natural habitat's due expansion of agriculture production in the frontier areas. Hence scientific management of these valuable resources has assumed prime importance today. At present about 7,000 germplasm/lines of seed spices conserved and maintained in India (with ICAR-NRCSS, Ajmer and AICRP centres). Being a national active germplasm site (NAGS) for seed spices, ICAR-NRCSS, Ajmer is repository of 2,167 germplasm lines (2017-18). In past two decades ICAR-NRCSS, Ajmer have developed 21 varieties (Coriander-3, Fenugreek-5, Fennel-2, Dill-1, Nigella-2, Ajwain-2, Anise-, Celery-2 and Caraway-1) of 10 seed spice crops and identified unique promising genotypes by non-traditional breeding methods having desirable traits. Some of the relative species of coriander, cumin, fennel and fenugreek is also reported by many researchers from different parts of world

Challenges and Opportunities

ICAR-NRCSS, Ajmer is striving hard for collection and conservation of the valuable gene pool on different seed spices as a national repository for further utilization in seed spice improvement programme. The following challenges and opportunities as derived from the past 20 years' experience of survey, collection, evaluation and conservation of seed spices at ICAR-NRCSS.

1. Because of existence of most germplasm in the form of traditional/ local varieties due to natural selection for local adaptation, leads to formation of complex gene mixture. Proper sampling as well as regeneration is essential to recover and maintain the full range of genetic variability.

2. Due to lack of genetic variability in available germplasm, strong and stable resistant sources are needed for biotic and abiotic stresses which are not yet available. The desirable germplasm must be identified from the collections regarding oil and oleoresins content, frost, drought tolerance and insect, pest and disease resistance. Need of more collaboration for explorations through ICAR-NBPGR, New Delhi from Mediterranean regions and adjoining parts, Iran, Iraq, Russia and Europe.

3. The seed spices are crops of arid and semi-arid regions and yet its biodiversity have been not exploited fully. The existing diversity of major and minor seed spice crops in remote and tribal pockets need to be revisited. There is tremendous scope for collection of valuable land races of seed spices crops.

4. Minor seed spices such as ajwain, dill, celery, nigella, aniseed and caraway yet not surveyed with full attention. The biodiversity related to these crops need to be collected, conserved and utilized as they are considered as underexploited crops.

5. Advanced biotechnological tools to be applied to prevent or counter any attempt of bio piracy of valuable germplasm of seed spices from India.

The inherent nature of slow germination of seed spices, lack of complete information on pollination behaviour, high biotic stresses and limited R&D on post-harvest techniques particularly storage methods for seed spices crops are the major problem in effective management of seed spice germplasm.

Reference

Gopal L. (2018) Scenario, Importance and Prospects of Seed Spices: A Review. Current Investigations in Agriculture and Current Research 4(2): 491-498. doi 10.32474/CIACR.2018.04.000181.

Forage Resources of Drylands of India

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The drylands of India comprise the hot arid and semi-arid regions. Indian arid zone covering an area of 3.2 lakh km^2 is lying in the states of Rajasthan, Gujarat, Haryana, Andhra Pradesh and Karnataka of which 62% lies in Rajasthan. About < 2% of net cropped area is used for cultivation of fodder crops and only 4% of the total land is under grazing lands ('oran', 'gochar' and pastures). Economy of the region is livestock centric which mainly depends upon the native rangelands, pasture grasses, cultivated fodder and roughages. The forage genetic resources occurring in this region assumes great significance in view of its adaptability to harsh environmental conditions forming a storehouse of genes of stress tolerance. Pearl millet, sorghum, lucerne, cowpea, range grasses and legumes, trees and shrubs are the major fodder resources in the region.

Fodder and feed resources

Pasture lands, community grazing lands, cultivated fodder crops, crop by-products and residues, non-conventional by-products of agro industrial processing and concentrate feeds comprise various stuff resources for livestock of drylands. As regards crops by-products, residues and stover such as straw of wheat, barley, pearl millet, sorghum, mung, moth, gaur, cowpea and other legumes comprise a major share (60-70%) of feed resources. Millet is most important dual purpose crop grown in large area in arid zone of Rajasthan. Its stover is comprehensively used to feed livestock and contributes about 30% of fodder availability from cultivated crop in arid region. Grasses and weeds from grazing land also contribute fodder to the livestock. Anjan grass (*Cenchrus ciliaris*), birdwood grass (*Cenchrus setigerus*), sewan (*Lasiurus sindicus*), burero (*Cymbopogon jwarancusa*), marvel grass (*Dichanthium annulatum*), gramna (*Panicum antidotale*) and murath (*Panicum turgidum*) are important perennial grass species of the region. Other associated community species are

Cenchrus biflorus, *Tragus roxburghii* and *Aristida funiculata*. Among low perennials two species *Dactyloctenium scindicum* and *Ochthochloa compressa* occur in diverse habitats are eagerly grazed by livestock.

Trees and shrubs also play significant role in providing fodder to the livestock in the lean period and dry spell. *Prosopis cineraria*, *Acacia senegal*, *Acacia nilotica*, *Tecomella undulata* etc. in low rainfall tract (200-250 mm), and shrubs like *Ziziphus nummularia*, *Capparis decidua*, *Calligonum polygonoides* and *Haloxylon salicornicum* serve as the top feed species on different situations and contribute significantly towards fodder supply in arid and semi-arid regions. Many other species of grasses, weeds, shrubs and trees are not dominated but also provides nutritious green forage grazing/browsing animals. Mixed/intercropping of cereals and legumes and silvopasture systems are the better options for providing the nutritive fodder to animals than sole cropping.

Diversity and improved varieties of forages

About 106 species of grasses are found in western Rajasthan. Sewan grasslands, spread in Jaisalmer, Barmer, Bikaner and Jodhpur districts of Rajasthan once remained as the major source of fodder supply are in highly deteriorating condition. Wide range of genetic variation was observed in the characteristics contributing to forage yield, forage quality and underground biomass for the pasture grasses. At the ICAR-CAZRI, Jodhpur, a sizable genetic stock of grasses, shrubs and trees are being maintained. Sorghum, pearl millet, cowpea guar and napier-bajra hybrid are the important cultivated fodder crops in the dry areas. Pearl millet is most important dual purpose crop grown in large areas of drylands. HYV of fodder crops have been evolved over the years to meet the demand of green and dry fodders (Table 1).

Table 1. Cultivated fodder crops and their improved varieties for drylands

Sorghum (*Sorghum bicolor)*	CSH-20-MF, CVS-15, Gujarat Forage Sorghum-1,3, 4, Harasona, Haryana Chari-136, 171, 260, 308, Haryana Jowar-513, Jawahar Chari-6, 69, JS – 263, JS- 20, JS- 29/1, K-7, Meethi Sudan 59-3 (SSG 59-3), MFSH-3, MP Chari, Pant Chari-3, 4, 5, Proagro Chari, Punjab Sudan x Chari-, Pusa Chari Hybrid (PCH)106, 109, Pusa Chari (PC)-1, 23, 6, 9, Rajasthan Chari-1, 2, Safed Moti, SPV-669, Pant Chari 7, 6, 8, CSH-24-MF, MFSH-4, MFSH-5, GK-905
Pearl millet (*Pennisetum glaucum*)	Anand Forage Bajra-3, APFB- 2, Avika Bajra Chari, BAIF Bajra-1 CO-8, Nandi-70, Nandi-72, NDFB-2, 3, 5, 11, Giant Bajra, Gujarat Forage Bajra-1, PAC-981, PCB-141, 164, Proagro No. 1 (FMH-3), Raj Bajra -1, Raj Bajra Chari-2, APFB-09-1, Moti Bajra
Cowpea (*Vigna unguiculata*)	Bundel Lobia-1 &2, Charodi, CL-74, 367, CO-5, EC-4216, Gujarat Forage Cowpea-1, 2, 3, 4, Hara Lobia (HFC-42-1), Haryana Lobia–88 (HC- 88), HCP 46, IL 1177, KBC-2, Kohinoor (S-450), Konka Fodder Cowpea-1 (DFC-1), MFC-08-14, MFC-09-1, Shweta, UPC-287, 4200, 5286, 5287, 607, 618, 621, 622, 625, 628, 8705, 9202, TNFC-0926, 0924, Aishwarya, Vijaya

Guar/clusterbean) (*Cyamopsis tetragonoloba*)	FS 277, HFG 119, HFG 156, Bundel Guar 1, Bundel Guar 2, Guar Kranti, HG-75, Bundel guar-2, Bundel guar-3, RGC-1031, RGC-986
Maize (Zea mays)	Pratap makka chari-6, J-1006, African tall
Lucerne (*Medicago sativa*)	Anand 2, Anand Lurcene 3, 4, RL 88, CO-, CO 2, GAU-L-2 (SS-627), LL Composite-3 (LLC-3), Composite-5 (LLC-5), Type-9 (T-9), TNLC-14 as CO-3
Oat (*Avena sativa*)	OL-125, Kent, UPO-212, OS-6, 7, Bundel Jai – 851, 2001-3, 822, 2004, 991, 992, Haryana Javi, Haryana Javi-8, UPO – 212, 94
Barley (*Hordeum vulgare*)	RD-2035, RD-2552, RD-2715 and Azad

Prominent grass, tree and shrubs

Sewan (*Lasiurus sindicus* Henr.) is one of the dominant species of *Dichanthium-Cenchrus–Lasiurus* type grass cover spread in western Rajasthan. The grass is extremely drought resistant and thrives even in very low rainfall regions receiving 100 mm to 300 mm annually. Buffel grass (*Cenchrus ciliaris* L.) has wider adaptability for a range of soil and climatic conditions and can be cultivated in semi-arid and arid drylands. It is very palatable at early stage of growth, and remains fairly palatable at maturity. Similarly, Bird Wood Grass (*C. setigerus* Vahl) tolerates heat and drought and grows in areas of annual rainfall as low as 200 mm, making it excellent for improvement of low rainfall grazing lands.

Karad (*Dichanthium annulatum* (Forsk) Stapf) is another important grass of Rajasthan, thriving in rainfall regions of $\geq$ 350 mm. Blue Panic (*Panicum antidotale* Retz.), often found on sand dunes is an excellent sand binder and drought resistant grass adapted to a variety of soils and climatic conditions. Murat (*P. turgidum* Forsk.) grows on sand dunes and sandy plains in open rangelands and cultivated fields of Thar Desert of Rajasthan and Gujarat. In pasture grasses and legumes high yielding varieties developed for cultivation (Table 2). Fodder Trees and shrubs are integral part of perennial fodder resources in the dry areas (Table 3).

Table 2. Improved varieties of grasses and legumes.

Anjan grass/Buffel grass (*Cenchrus ciliaris*)	Bundel Anjan-1, 3, Gujarat Anand Anjan Grass-1, Marwar Anjan (CAZRI-75), RCCB-2, RCC-10-6, CAZRI Anjan 2178, CAZRI Anjan 358, Gujarat Anand Anjan Grass-2
Dhaman ghas/ Birdwood grass (*Cenchrus setigerus*)	Marwar Dhaman (CAZRI-76)
Sewan grass (*Lasiurus sindicus*)	RLSB-11, CAZRI Sewan 1

Lampa ghas/Black Spear Grass (*Heteropogon contortus*)	Bundel Lampa ghas-1 (IGHC 03-4)
Marvel grass (*Dichanthium annulatum*)	Gujarat Marvel Grass-1 (GMG-1), Marvel-7, 8, 93, Marvel-09-4, Phule Govardhan, Phule Marvel-06-40
Rhodes grass (*Chloris gayana*)	Rhodes-10
Sen grass (*Sehima nervosum*)	Bundel Sen ghas-1 (IGS-9901)
Dinanath grass (*Pennisetum pedicellatum*)	Bundel Dinanath-2, Bundel-1, COD-1 (TNDN-1), Jawahar Pennisetum-12, Pusa Dinanath grass
Dhawalu grass (*Chrysopogon fulvus*)	Bundel Dhawalu grass-1, Dongari Gawat 2-4-11, GAU D-1
Signal Grass (*Brachiaria ruziziensis*)	Dharwad *Brachiaira ruziziensis* Selection-1(DBRS-1)
Guinea Grass (*Panicum maximum*)	Bundel Guinea-1, Bundel Guinea-2, CO-1, CO-2, CO-3 (GG), Hamil, Haritha, Harithasree, Makueni, PGG-101,14, 19, 518, 616, 9, Punjab Guinea Grass-1 (PGG-1), Riversdale, Dharwad Guinea Grass-1 (DGG-1)
Bajra Napier hybrid (Pennisetum *americanum L. Leek) × (P. purpureum Schum.)*	APBN-1, BNH-10, CO-1, 2, 3, CO (CN) 4, CO (BN) 5, Hybrid-3 Napier (Swetika-1), NB 21, NB-37, PBN-233, PBN-83, Phule Jaywant (RBN-13), Sampoorna (DHN-6), Suguna , Supriya, Yeshwant (RBN-9), PBN-342, Phule Gunwant
Range legumes	
Stylo	*Stylosanthes hamata, S. seabrana, Stylosanthes scabra*
Field bean (*Lablab purpureus*)	Bundel Sem-1 (JLP-4)
Aparajita/ Butterfly pea (*Clitoria ternatea*)	JGCT-2013-3
Herbaceous Legumes	*Indigofera argentea, I. cordifolia, I. hochstetteri, I. linifolia, I. sessiliflora, Tephrosia uniflora, Rhynchosia aurea, R. schimperi*

Table 3. Fodder trees and shrubs

Tree species	Khejri *(Prosopis cineraria)*, Anjan *(Hardwickia binata)*, Neem *(Azadirachta indica)*, Ardu *(Ailanthus excelsa)*, Nutan *(Dichrostachys nutans)*, Subabool *(Leucaena leucocephala)*, Israili Babool *(Acacia tortilis)*, Deshi Babool *(Acacia nilotica)*, Khajuri Babool *(Acacia nilotica var. cupresiformis)*, Kumat *(Acacia senegal)*, Dhav *(Anogessus latifolia)*, Siris *(Albizia lebbeck)*, Khara Jal *(Salvadora persica)*, Meetha Jal *(Salvadora oleoides)*, Gundi *(Cordia gharaf syn. C. rothii)*
Shrubs	Zhar beri *(Zizyphus nummularia)*, *Acacia jacquemontii, Calligonum polygonoides, Haloxylon salicornicum, Grewia tenax, Capparis decidua, Halophytes (Haloxylon recurvum, Salsola baryosma, Suaeda fruticosa*

Conclusions

Range grasses and legumes and other herbaceous species play vital role in providing the nutritious forages in the arid and semi-arid zone of India. They have intrinsic high water and light use efficiencies ensuring sustainable forage production to support livestock in the region. High yielding cultivars of forage crops are equally important forage resources in the dry areas under rainfed and also under limited irrigation. Tree and shrubs also play significant role as top feed resources in these areas. Restoration of degraded grazing lands and *in situ* conservation needs to be implemented as policy measure to protect the natural grasslands with its species diversity. People/community participation is important to conserve the precious resource base of these dry areas with incentivisation.

Impact of Climate Change on Underutilized and Medicinal Plants in Indian Arid Zone

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Underutilized plants have limited current use compared to their immense possible use and hence have huge economic potential. Their abundance in stressed environments is a boon to local people for their survival and limited trade. Since these are not commercialised crops, systematic information on their biology, cropping, value addition, and economic benefits is much less known. Of the 682 species reported from Indian arid zone, many are important source of life support such as species proving vegetables (40), seeds (27), fruits (27), fibres (8), ropes (3), gums and resins (7), medicinal uses (131) (Kumar et al., 2004) and many provide fuel wood and forage. Most of these species show intra specific variability e.g. in *Aloe vera* (123 lines). Besides, 31 wild and weedy relatives of crop plants also occur here. Of all these species, 46 are threatened and vulnerable, many being medicinally important such as *Commiphora wightii*.

Climate change scenario in Indian arid zone

Climate change is expected to cause up to 30% reduction in rainfall in northern part of the desert regions of India while it may increase in its southern and eastern parts up to 15% and gradual rise in temperature by 4-5°C everywhere. The abnormal monsoon rains will be more common. Consequently, there will be more recurrence of cloud burst and floods in southern and south-eastern Rajasthan and southern Gujarat, and droughts in arid Rajasthan. Such a scenario would result in high wind and water erosion. Summer rainfall will decline up to 25%, resulting in more frequent and severe droughts, increased incidence of wind erosion and more frequent floods. Their impact will be compounded by increasing desertification, industrialization, mining, intensification of agriculture, irrigation, tourism and urbanization.

Impacts of climate change

Poor rains will accentuate moisture stress, that *inter-alia* will delay germination and poorer survival of germinated saplings. Lesser moisture in soil will shorten or telescope vegetative phase in annuals resulting in early flowering, less/poor seed set culminating in poor seed bank and decline in populations over time. Perennials may have more number of flowering event which may be small in duration and quantity. In fact, more off-season flowering in younger trees of *Prosopis cineraria* yielded seeds showing much less germination. Climate change mediated off-season flowering will expectedly yield less germinating seeds. Continuous prolonged occurrence of extreme events (high temperature, dryness) at seed formation and maturation level could result in abortive seeds and ultimately results in compositional change. Evidence exists on variable shifts in phenology under differential grazing pressure: more grazing pressure resulted in earliness of flowering in perennials while delay in annuals. Such shifts will be more frequent, affecting larger area under climate change scenarios. Extreme event of flood will submerge the seed bank ultimately killing them. Seeds will also be washed away and lost.

At landscape level favourable habitats will be left far and few, thus, increasing inhospitable niches, which ultimately result in poor or low germination, subnormal growth of saplings, low seed set and finally enhanced vulnerability. Consequently, shifts in their distributional range will cause compositional changes on major habitats, altering successional pathways ending up in changed climax. This will change competitive balance between species having different rooting depths, woodiness and associated below ground organisms and *inter alia* the grasslands and savannas will be the most affected. Such events would also cause a decline in biomass production/ yield of grazable species in the desert. Many species of economic and medicinal value will be insularised to become rarer. Vicariates, invasives and weedy species being immune to climate changes will become dominant replacing the existing climax of *Prosopis cineraria-Salvadora-Acacia* species amongst woody perennials and *Dicanthium-Lasiurus-Cenchrus* species among grasses. Highly dispersive species will fill all the spaces created by loss of vulnerable species due to climatic change but poor dispersive species will increasingly become smaller in size and locked up in smaller area of suitable conditions. Spread of *Prosopis juliflora* replacing *Acacia senegal* and *Commiphora wightii* in Bhuj and Jamnagar district is already evident. Secondary metabolites quantity and quality especially in medicinal plants will be adversely affected e.g., oleo-gum-resin yield of *C. wightii*, gum yield in *A. senegal*, lawson content in 'Mehnd'i and sennosides in senna. Even if desertic species are brought to favourable climate, its survival remains uncertain as found in *Caralluma edulis*, a threatened medicinal species and a typical commensel of *Lasiurus sindicus* and *Panicum turgidum*. Thus, any drastic change in the functional niche of threatened species due to climate change or any other reason would make them more endangered. The endangerment of species will increase with reduction in population size and extent of occurrence, decline in area of occupancy, reduction in mature individuals and finally increased probability of extinction in wild as seen in endemic perennial species, *Ziziphus truncata*. Slow rate of adaptive changes in response to climate changes, especially in perennial species due to their intrinsic physiology, longer life and poor dispersal mechanism make them more vulnerable to extinction.

Adaptive strategies

Rain mediated annual species will adapt by having staggered germination; already known in many species which germinate till next rain event. Prolonging dormancy to achieve germination at different intervals will make them have longer viability. Unfavourable environmental conditions are known to impose enforced dormancy which might prolong during continuous climatically changed scenario and for which seeds will need to develop longer duration viability. Seeds of members of Gramineae (*Cenchrus*, *Dactyloctenium*), Leguminoseae (*Indigofera*, *Lathyrus*), Boraginaceae (*Heliotropium*, *Arnebia*), Cucurbitaceae (*Citrullus*, *Miukia*) can remain viable for long periods varying from 1-15 years. Developing apomictic seeds bypassing pollination and fertilization can also be one strategy. Perennial species may retain seed bank on mother plant itself. Branches may dry/die and resurrects during favorable climate as is seen after frosts in *Calotropis procera* and *Prosopis juliflora*. Plasticity and polymorphism, common properties of desert plants along with leaf folding, shedding, changed leaf architecture, altered phylotaxy and developing hard seed coat could be other adaptive strategies. Widening ecological amplitudes so as to occupy newer niches will be ultimate strategy for survival. But a shift in distribution range requires matching dispersal strategy and that will be limited by natural barriers, fragmentation of area by land use changes and anthropogenic factors. These need to be validated specially in respect of endemic and threatened medicinal and underutilized species. Besides, the impact induced changes also need to be isolated from effects of biotic interaction and changed pest and disease scenario. Effective mitigation requires focused efforts for assessing their genetic diversity as well as *ex situ* and *in situ* conservation, including that in participatory mode. Domestication, value addition and inculcating them in cropping system for diversification in farming system are urgently needed to save this less researched plant wealth.

Plant Genetic Resources of Indian Hot-Arid Zone

Om Vir Singh*, Neelam Shekhawat and Kartar Singh

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The Indian hot arid zone covering an area of 3.2 lakhs km^2 is lying in the states of Rajasthan, Gujarat, Haryana, Andhra Pradesh and Karnatka of which 62% lies in Rajasthan. Food and Agriculture Organization of the United Nations (FAO) characterized drylands by a scarcity of water, which affects both natural and managed ecosystems and constrains the production of livestock as well as crops, wood, forage and other plants and affects the delivery of environmental services. For millennia, drylands have been shaped by a combination of low precipitation, droughts and heat waves, as well as human activities such as fire use, livestock grazing, the collection of wood and non-wood forest products, and soil cultivation. Dry land soils tend to be vulnerable to wind and water erosion, subject to intensive mineral weathering, and of low fertility (due to the low content of organic matter in the topsoil). Thus, growth and development of plants are handicapped by prolonged period without rain that threatens plant life with desiccation and complete destruction but several plant species including *Aerva persica*, *Calotropis procera*, *Capparis decidua*, *Crotalaria burhia*, *Leptadaenia pyrotechnica*, *Prosopis cineraria*, *Salvadora* spp. and *Tecomella undulata* still thrive well despite the inhospitable conditions. The plant diversity is intimately associated with the habitat diversity of the dry land. The perennial endemic shrubs like *Capparis decidua*, *Colligonum polygonoides*, *Haloxylon salicornicum*, *Calotropis procera* and *Ziziphus nummularia* and *grasses Cenchrus setigerus*, *Cenchrus ciliaris*, *Panicum antidotale*, *Lasiurus sindicus*, *Dicanthium annulatum* etc., tree species like *Tecomella undulate*, *Prosopis cineraria*, *Acacia nilotica*, *Acacia senegal*, *Salvadora oleoides* and *S. persica* are some of the economically important species of the Indian desert. The Indian desert has a large number of other perennial species such as *Acacia persica*, *Commiphora wightii*, *Crotalaria burhia*, *Leptadaenia pyrotechnica*, *Zizyphus* spp., *Salvadora* spp., *Solanum surattense*, *Withania somnifera* and many other useful plant species of immense medicinal values. The other various species of grasses of *Cenchrus*, *Aristida*, *Eleucine*, *Eragrostis*, *Digitaria*, and *Indigifera*, are found in desert. *Cymbopogon jwarancusa* an essential oil plant, *A. senegal*, *C. wightii*, *Euphoria caducifolia*, *Butea monosperma*, *Anogeissus pendula* and *E. caducifolia* are found on sand stones and gravelly habitats. Because of their immense use and over exploitation some of the threatened plants of Indian desert are 'bajradanti' (*Barleria prionitis*), *Cenchrus prieurii*, *Cleome gynandra*, *Commiphora wightii*, *Farsetia macrantha*, *Haloxylon salicornicum*, *Peganum harmala*, *Tephrosia falciformis*, *Tribulus rajasthanensis*, *Withania coagulan* and *Ziziphus truncate*. The important lessor known wild edible plants of drylands are *Cassia tora*, *Ceropegia bulbosa*, *Cordia gharaf*, *Grewia tenax*, *Rhus mysurensis*, *Caralluma edulis* and *Leptadenia reticulata*. Some of the important horticultural crops of the regions are *Ziziphus mauritiana*, *Phoenix dactylifera*, *Capparis decidua*, *Emblica officinalis*, *Aegle marmelos*, *Punica granatum*, *Annona squamosa*, *Cordia myxa*, and *Carissa carandas*.

Rich crop diversity is available in the Indian arid zone in terms of both number of species, genotypes and ecotypes. The genetic diversity occurring in this region assumes great significance in view of its adaptability and to harsh environmental conditions forming a store house of genes of stress tolerance. The Indian arid zone is the primary centre of origin of many plant species like mothbean (*Vigna acconitifolia*), horse gram (*Macrotyloma uniforum*), bael (*Aegle marmelos*), kundri (*Coccinia indica*), and guggal (*Commiphora wightii*) and secondary centre of origin of clusterbean (*Cyamopsis tetragonoloba*). Rich diversity of pearlmillet (*Pennisetum glaucum)* is also found in the region. Approximately 106 species of grasses are also found in the western Rajasthan and is also known as primary centre of genetic diversity of grasses. Western region of Rajasthan, Gujarat and Saurashtra regions possess rich agro-biodiversity of pearl millet, guar, mothbean, sesame, cowpea, mungbean, blackgram, sorghum, wheat (drought and salinity tolerant), brassicas, chillies, cucurbitaceous vegetables, fruits, citrus, grasses and spices (coriander, fenugreek, ajwain and garlic).

Genetic resources in the region are eroding very fast as landraces are being replaced by the farmer with modern high yielding varieties and hybrids, natural habitats of wild relatives of cultivated species are being destroyed, Natural calamities, land and crop conversation, mechanization of agriculture, deforestation, developmental activities, environmental pollutions are further aggravating the situation. Many of the landraces and primitive cultivars have already vanished and some are on the verge of it and the remaining ones are genetically deteriorating gradually due to by hybridization, selection or genetic drift and global warming. As climate change brings new pest and diseases, new source of resistance will be required by crop varieties. Genetic diversity that is currently underutilized may become more useful in times to come.

Institutes of Indian Council of Agriculture Research like National Bureau of Plant Genetic Resources (NBPGR), Central Arid Zone Research Institute (CAZRI) and Indian Institute of Seed Spices (IISS) have collected valuable germplasm of their mandate crops from the region. CAZRI has conserved in its botanical garden a large number of medicinal, ornamental, succulents, endangered and rare plant species of this region. Jodhpur Regional Centre of NBPGR has collected and conserved live plants of 453 accessions in the field gene bank, comprising Aegle marmelos, Agave americana, Aloe vera, Annona squamosa, Balanites aegyptiaca, Bauhinia racemosa, Bursera glabrifolia, Capparis decidua, C. rothii, Carissa carandas, Citrus limon, Commiphora wightii, Copernicia prunifera, Cordia myxa, Grewia asiatica, Malpighia emarginata, Mangifera indica, Moringa oleifera, Morus alba, Phoenix dactylifera, Phyllanthus emblica, Pithecellobium dulce, Psidium guajava, Punica granatum, Salvadora oleoides, Simmondsia chinensis, Syzygium cumini, Tamarindus indica, Tecomella undulata, Ziziphus mauritiana,and other plants of economic importance. Germplasm of field crops like pearlmillet (Pennisetum glaucum, 11,843 accessions), finger millet (Eleusine coracana, 88 acc.), barley (Hordeum vulgare, 114 acc.), paddy (Oryza sativa, 96 acc.), proso-millet (Panicum miliaceum, 48 acc.), kodomillet (Paspalum serobiculatum, 22 acc.), nightshade (Solanum surattense, 53 acc.), sorghum (Sorghum bicolor, 91 acc.), wheat (Triticum aestivum/T. durum, 1,256 acc.), maize (Zea mays, 323 acc.), little millet (Panicum sumatrense, 77 acc.), clusterbean (Cyamopsis tetragonoloba, 6,174 acc.), mungbean (Vigna radiata, 2,510 acc.), moth bean (Vigna aconitifolia , 3,422 acc.), cowpea (Vigna unguiculata, 3,796 acc.), other pulses (urad, chana, tuar, rajma, 374 acc.), castor (Ricinus communis, 612 acc.), sesame (Sesamum indicum, 3,867 acc.), other oil yielding plants (mustard, taramira, jatropha, 704 acc.), dhaman grass (Cenchrus ciliaris, 78 acc.), sewan grass (Lasiurus scindicus, 44 acc.), sheda grass (Dichanthium spp., 60 acc.), anjan grass (Cenchrus setigerus, 60 acc.), bhurut grass (Cenchrus preurii/biflorus, 27 acc.), nalta jute (Jew's mallow) (Corchorus olitorius, 59 acc.), jute (Corchorus pseudoplitorius, 24 acc.), wild jute (Corchorus tridens, 49 acc.), sunhemp(Crotalaria juncea 26 acc.), desi cotton (Gossypium arboretum, 34 acc.) and (Gossypium herbaceum, 64 acc.), cumin (Cuminum cyminum, 34 acc.), fenugeek/ methi (Trigonella foenum-graecum, 190 acc.) are being conserved in the gene bank at Jodhpur.

PROGRAM

February 13, 2019 (Wednesday); 14.00 – 17.00

Chair: **R.S. Paroda**, Chairman, TAAS ***Co Chair:*** **Ashok Dalwai**, CEO, NRAA

Convenor: **Kuldeep Singh**, Director, NBPGR ***Co-Convenor:*** **Anuradha Agrawal**, ISPGR

Rapporteur: **S. Rajkumar**, Senior Scientist, NBPGR

Time	Title	Speakers
	Keynote Lecture	
14.00-14.20	Current threats to dryland agrobiodiversity and strategies for adaptation to climate change	**R.S. Paroda** TAAS and ISPGR, India
	Invited Lectures	
14.20-14.35	Managing agrobiodiversity of Indian drylands for climate adaptation	**O.P. Yadav** CAZRI, India
14.35-14.50	Conservation and use of agrobiodiversity in CWANA drylands	**Ahmed Amri** ICARDA, Morocco
14.50 -15.05	Agrobiodiversity of fruits and nuts to adapt to climate change in Central Asia	**Muhabbat Turdieva** Bioversity International, Uzbekistan
15.05-15.20	Dryland agrobiodiversity for adaptation to climate change: Role of regional organizations	**R.K. Tyagi** APAARI, Thailand
15.20-15.35	Mainstreaming the agrobiodiversity of drylands - Role of Bioversity International	**J.C. Rana** Bioversity International, India

Panel Discussion : Issues and way forward for agrobiodiversity for adaptation to climate change		
Time	**Crop Group**	**Panelist**
15.35-16.35	Millets	**S.K. Gupta**, ICRISAT, India
	Arid legumes	**D. Kumar**, Ex CAZRI, Jodhpur
	Arid oilseeds	**D.K. Yadava**, ICAR, Delhi
	Arid horticultural crops	**P.L. Saroj**, CIAH, Bikaner
	Seed spices	**Gopal Lal**, NRCSS, Ajmer
	Forages	**R.K. Bhatt**, ICAZRI, Jodhpur
	Underutilized and medicinal plants	**Suresh Kumar**, Ex CAZRI, Jodhpur
	Dryland PGR	**Omvir Singh**, NBPGR, Jodhpur
16.35-16.55	***General Discussion on Way Forward***	
16.55-17.00	***Concluding Remarks***	**Chair and Co-Chair**

Core Organizing Committee

Chair: **R.S. Paroda** (Chairman TAAS) ***Co-Chair :*** **Kuldeep Singh** (Director, NBPGR)

Members : **J.C. Rana** (Bioversity International), **R.K. Tyagi** (APAARI), **O.P. Yadav** (CAZRI), **Sunil Archak, Rakesh Singh and Anuradha Agrawal** (ISPGR)

ABOUT SPEAKERS AND ORGANIZERS

Dr R.S. Paroda

Chair & Keynote Speaker

Dr Raj S. Paroda is the Chairman of the Trust for Advancement of Agricultural Sciences (TAAS) and President, Indian Society of Plant Genetic Resources. He is an accomplished plant breeder and geneticist by profession and an able research administrator, and has made significant contributions in the field of crop science research. He was former Director General, Indian Council of Agricultural Research (ICAR) & Secretary, Department of Agricultural Research and Education (DARE), Government of India (GoI). He is known for modernization and strengthening of the national agricultural research system in India as well as in Central Asia and the Caucasus. He has the unique distinction of being the main architect of one of the world's largest and most modern National Gene Bank in New Delhi. Dr Paroda had been the founder chairman of Global Forum on Agricultural Research (GFAR) based at FAO, Rome. He was also the President of Indian Science Congress in 2000-2001 and President of the NAAS, besides a dozen scientific societies in agriculture. He also served for more than two decades as Executive Secretary of APAARI, Bangkok. Till recently, Dr Paroda worked for the overall benefit of farmers as Chairman, Farmers Commission of Haryana, Chairman of Working Group on Agriculture and member of Rajasthan Planning Board. He has received numerous awards and recognitions, like Rafi Ahmad Kidwai Prize, ICAR Team Research Award, FICCI Award, Om Prakash Bhasin Award, BP Pal Gold Medal, Borlaug Award, Mahendra Shiromani Award and the prestigious Padma Bhushan awarded by the GoI in 1998.

Dr Ashok Dalwai
Co-Chair

Dr Ashok Dalwai, IAS (Orissa cadre, 1984), is the CEO of the National Rainfed Area Authority (NRAA), a post of Secretary for GoI. Born in farmer family from Belagavi District of Karnataka, he obtained B.Sc. and M.Sc. degree in Agriculture from Dharwad University, with a passion towards farming and a vision to contribute something worthy for farmers. He has had an illustrious career in Development Administration where he has implemented several reforms in the rural agrarian sector in the state of Odisha. In his capacity as the Collector of the District, both in the states of Odisha and, Karnataka, he has applied his deep knowledge of agricultural sector. Ashok has served under the Odisha Cadre as assistant commissioner at Gundpur, district collector at Talhandi District of Odisha. The then Chief minister of Odisha had specially chosen him to work for this district which had a bad name due to malnutrition. He also worked as divisional and Principal Secretary for Agriculture, Cooperation and various departments in Odisha. For central government he worked as Deputy Director General, Unique ID of Adhaar information authority, (UIDAI). Prior to joining NRAA, he was the Additional Secretary, Ministry of Agriculture Cooperation & Farmers Welfare, GoI, where in his capcity as Chairman, Committee for Doubling Farmers Income, he spearheaded the governments' mission to bring income revolution for the Indian farmers.

Dr Kuldeep Singh
Convenor

Dr Kuldeep Singh is Director, ICAR-NBPGR, New Delhi since August 11, 2016 and Vice-President, ISPGR (2019-21). His fields of competence are plant breeding, molecular breeding, molecular genetics, genomics and wide hybridization. He started his career as an Assistant Wheat Breeder at PAU, Ludhiana (1990-1999), and was associated with development and release of three wheat varieties and establishment of basic genetic material and protocols for development of wheat haploids through wheat x maize crosses and for hybrid wheat. He worked at the International Rice Research Institute (IRRI), Philippines, as a Post-Doctoral Fellow with the World Food Laureate, Dr G.S. Khush, wherein a complete series of secondary trisomics in rice were developed and used for mapping centromere positions in the classical and molecular linkage maps of rice, which laid foundation for generating correct physical map of rice and the rice genome sequence. Dr. Singh worked as Molecular Geneticist (1999-2007), Senior Molecular Geneticist (2007-2016) and Director (Nov 2010 – Jan 2015) at the School of Agricultural Biotechnology, PAU, Ludhiana and was involved in wide hybridization (wheat and rice, using wild varieties), gene identification and mapping and genome sequencing (led the country for sequencing of chromosomes 2A of wheat, published in Science in 2018). He has to his credit > 250 publication including 115 research papers in prestigious refereed journals. He was a dedicated teacher, who taught 13 different courses in Genetics, Plant Breeding and Molecular Genetics and Genomics at PAU, Ludhiana.

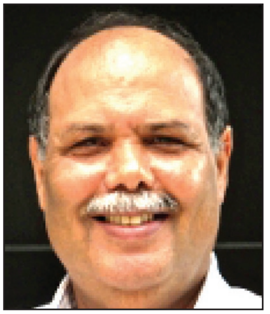
Dr O.P. Yadav

Invited Speaker

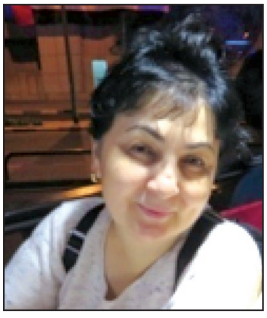
Dr O.P. Yadav is Director of the ICAR-Central Arid Zone Research Institute (CAZRI), since 2015. Prior to this he led the Indian Institute of Maize Research, and All India Project of Pearl Millet of the country. He has more than three decades of experience of research and management and his scientific work has helped in understanding of crop adaptation to drought stress environments and in evolving appropriate strategies for developing stress-adapted and nutritious crops and cultivars. His contribution has been recognized at the international level as seen by several quality publications (>200 including Nature) He has been trained at the Harvard School of Business, Massachusetts; Cornell University, Ithaca, New York and Institute and Grassland and Environmental Research, Aberystwyth, UK. He is Fellow of the National Academy of Agricultural Sciences. He has won Royal Society-INSA Fellowship, DBT Overseas Fellowship, Platinum Jubilee Award of Indian Science Congress and the Outstanding Achiever by Ministry of Agriculture. Under his dynamic leadership, CAZRI has been awarded the Sardar Patel Best Institute Award of ICAR for the Year-2017.

Dr Ahmed Amri

Invited Speaker



Dr Ahmed Amri is the Head of Genetic Resources Section and Deputy Director of Biodiversity and Integrated Gene Management (BIGM) at International Center for Agricultural Research in the Dry Areas (ICARDA), Morocco. Dr Amri's areas of research include breeding, pre-breeding, on-farm/in situ conservation of genetic resources and ex situ conservation. He worked as cereal breeder since 1980 at INRA-Morocco and released 18 barley varieties, 5 Triticales and contributed to the development of Hessian resistant varieties of bread wheat and durum wheat. He joined ICARDA as Regional Coordinator of a GEF Regional project on conservation and sustainable use of dryland agrobiodiversity (1999-2005), Regional coordinator for West Asia program of ICARDA (2000-2008), ICARDA country Manger in Iran (2005-2009). He has contributed to teaching at universities in Morocco and Jordan and advised 28 M.Sc. and Ph.D. students. He has published 132 papers including 72 in referred journals. He has participated in collecting missions and contributed to development of genebanks at ICARDA and provided technical backstopping and training on genebank management and genetic resources conservation and use in more than 17 countries.



Dr Muhabbat Turdieva

Invited Speaker

Dr Muhabbat Turdieva is the Regional Project Coordinator, Bioversity International, Tashkent, Uzbekistan. She joined Bioversity's office for Asia, Pacific and Oceania office in April, 1999 as a Forest Genetic Resources Scientist. Her main responsibility was providing support to Central Asian and Transcaucasian Network on Plant Genetic Resources (CATCN-PGR) including training of young scientists, development and implementation of collaborative projects on assessment of distribution and diversity level of local forest tree species, fruit crops, vegetables and melons in Central Asia. Since 2006 she has been coordinating a regional project 'In situ/on farm conservation and use of agrobiodiversity (horticultural crops and wild fruit species) in Central Asia' funded by UNEP-GEF. She also helps in facilitation of development of policy options for safeguarding local agrobiodiversity, integrating issues of access and benefit sharing and recognizing role of local communities and farmers as agrobiodiversity conservationists.

Dr Rishi Kumar Tyagi

Invited Speaker

Dr R.K. Tyagi is Coordinator, Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB) in Asia-Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, Thailand. His current work involves capacity development, knowledge sharing, policy advocacy in areas of agricultural biotechnology and its application for efficient conservation and sustainable use of bioresources the Asia-Pacific region. Prior to this, he has served as Head, Division of Germplasm Conservation (> 8 years) and managed, coordinated and monitored activities of the National Genebank (NGB) of the ICAR-NBPGR. The NGB scaled-up to second rank in the world from third position under his leadership. His most significant contribution has been the formulation and execution of the 'Consortium Research Platform on Agrobiodiversity' as Lead Centre Project Coordinator, genetic resources comprising plant, animal, aquatic, agriculturally important microbes and insects. He has successfully completed several inter-institutional and international projects and conducted many trainings on management of PGR. Dr Tyagi has also been the faculty of PG School, IARI, New Delhi and has over 350 publications to his credit.

Dr Jai Chand Rana

Invited Speaker

Dr J.C. Rana is the National Coordinator, GEF, Bioversity International, India. His research interests include plant genetic resources management; on-farm conservation and climate change. He joined the current position in 2017, prior to which he worked as Head, Division of Germplasm Evaluation, ICAR-NBPGR, (2014-17), as Principal Scientist/Senior Scientist at NBPGR, RS, Shimla (1993-2014). Dr Rana has developed 12 varieties of agri-horticultural crops. He has worked on *in situ* conservation in Western Himalayas and established 30 community seed banks. He has published 137 research papers in peer reviewed national and international journals. Dr Rana is recipient of awards and recognitions such as ICAR-MS Swaminathan National Award for outstanding Research on Hill Agriculture; Recognition Award, National Academy of Agriculture Science for biennium 2015-16, Dr B.R. Barwale Award for excellence in Plant Genetic Resources 2017; Dr R.B. Ekbote National Prize for use of PGR; Fellow, NAAS; Fellow, ISGPB; ISPGR; Post Doc Fellowship, SCAU, China etc.

Dr S.K. Gupta

Panelist

Dr S.K. Gupta is Principal Scientist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India. He heads ICRISAT's pearl millet breeding research. Since 2008, his focus has been on developing hybrid parents (both seed and restorer parents) of pearl millet with high productivity and abiotic and biotic stress tolerance. He has been instrumental in disseminating these to partners to enable them to develop high-yielding hybrids to suit different agro-ecologies. Earlier, while working as Plant Breeder at Punjab Agricultural University, Ludhiana (2001-2008), he developed about 10 promising varieties of chickpea, pigeonpea, green gram and black gram. He has extensive international collaborations with partners in more than 20 countries. He has mentored several PhD research scholars, published about 90 research papers and is an active member of many professional societies.

Dr D. Kumar

Panelist

Dr D. Kumar is Secretary, Indian Arid Legumes Society, Jodhpur. He was All India Project Coordinator (Arid Legumes) (2000-2010), Jodhpur, during which time he developed 8 national varieties of guar, 7 of mothbean and horsegram each, and 2 of cowpea. The arid legumes project was rated as the Outstanding Project in 2008 and was bestowed with Ch. Charan Singh Award at ICAR day. He gave the concept of summer cultivation of guar and extended it to whole country. As an Emeritus Scientist at CAZRI he has visited several times African countries for introduction of arid legumes. He has established the Indian Arid Legumes Society, and has been its Secretary.

Dr D.K. Yadava

Panelist

Dr D.K. Yadav is the Assistant Director General (Seed), Crop Science Division, ICAR, New Delhi & Head, Division of Seed Technology, Indian Agriculture Rresearch Institute, New Delhi. His research led to better understanding and targeted utilization of diverse germplasm, resulting in release of 19 varieties (mustard-16; pulses-3). Early maturing mustard varieties *viz*. Pusa Mustard-25,PM-27, PM-28, PM-26 and RGN-145 have provided greater choice to farmers under changing climatic scenario. He has bred five low erucic acid varieties *viz*., Pusa Mustard-21,22,24,29,30 and country's first Double Zero Indian Mustard variety Pusa Double Zero Mustard 31. Demand of IARI bred Indian mustard varieties has touched to more than 56 per cent. He has published 75 research papers and 125 other publications. Recipient of Rafi Ahmad Kidwai Award–2017, Dr. B.P. Pal Memorial Award-2012, NAAS Recognition Award-2018, Dr. P.R. Kumar Brassica Outstanding Scientist Award-2017 and Fellowship of NAAS.

Dr P.L. Saroj

Panelist

Dr P.L. Saroj is Director, ICAR-Central Institute for Arid Horticulture, (CIAH), Bikaner. Prior to this he was Director, ICAR-Directorate of Cashew Research, Puttur, Karnataka (2012) and Assitant Director General (Hort.-I) (2009), ICAR New Delhi, where he was facilitated coordination and monitoring of horticultural research in the country. He is involved in research, teaching, administration, extension, coordination and management for the last 27 years. Specialized in Pomology, standardized anatomical indices for predicting plant vigour in *Psidium* species, propagation techniques of fruits *viz*., aonla, ber, bael, guava, pomegranate, tamarind, lasoda, ker etc., suggested rootstocks and training systems for grapes, technology for utilization of degraded lands, developed various value added products from underutilized crops, suggested mango, guava, peach and ber based cropping systems and identified genetic stocks of cashew. Recently developed two jumbo nut size cashew hybrids. Published first report on peach phytoplasma.

Dr Gopal Lal

Panelist

Dr Gopal Lal is Director, ICAR-National Research Center on Seed Spices, Ajmer, Rajasthan. He has made outstanding contributions in the field of research, teaching and extension on different aspects of fruits, vegetables, seed spices and post harvest technology of horticultural crops. Nearly 60 technologies in horticultural crops including seed spices on various aspects have been developed by him for the benefit of different stake holders. He has published 115 research papers, 4 authored and 13 edited books, 60 book chapters, 140 popular articles, developed more than 20 value added products and filed six patents, which were already published. He is Fellow of many professional societies (HSI, ISS, ISSS and CHAI), and recipient of Best Research Worker Award of NRCSS, Ajmer and Dr. R.S. Paroda Award of CHAI, New Delhi. He also played a crucial role in Rajasthan Kisan Ayog in planning and formulating state policy for development of agriculture in Rajasthan state.

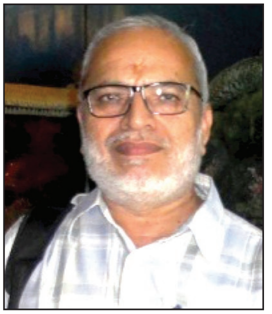
Dr R.K. Bhatt

Panelist

Dr R.K. Bhatt is Principal Scientist and Head, Division of Plant Improvement and Pest Management, ICAR-CAZRI, Jodhpur. He has made significant contributions on the selection of climate resilient genotypes for arid and semi-arid regions. Potential grass genotypes of *Cenchrus ciliaris*, *C. setigerous*, *Pennisetum pedicellatum* and *Stylosanthes* were selected for semi-arid and hot arid region of India. *Panicum maximum*, *Cenchrus ciliaris* and *Stylosanthes hamata* selected as climate resilient genotypes for maximum CO_2 assimilation and sequestration as grown under elevated CO_2. Large number genotypes of pasture grasses along with shrubs and tree germplasm conserved and maintained under field gene bank at CAZRI, Jodhpur in the hot arid climate.

Dr Suresh Kumar

Panelist



Dr Suresh Kumar is Ex Principal Scientist and Ex. Head of Division, CAZRI, Jodhpur. He has surveyed, documented and mapped vegetation of eight districts of western Rajasthan and two of arid Gujarat using satellite data and ground truthing. Vegetation dynamics under differential grazing pressures revealed importance of ephemerals. He has successful rehabilitated sand dunes (through aerial seeding), rocky habitats, and mine spoils of limestone, gypsum and lignite. He rescued and recovered 20 threatened species using *ex-situ* and *in-situ* conservation and their rehabilitation in nature using ecological niche modeling.

Dr Omvir Singh

Panelist

Dr Omvir Singh is the Principal Scientist and Officer-In-Charge, ICAR-NBPGR, Regional Station, Jodhpur. A plant breeder by training, Dr Singh has been involved in research, administration, and management of PGR activities of collecting, characterization, evaluation and pre-breeding of genetic resources in the drylands of Rajasthan and Gujarat. He has carried out exploration, charcaterization and evaluation of *Brassica* spp., castor, wheat and barley, guar, mungbean, mothbean and cowpea, sesame, pearl millet, finger millet and little millet Besides this collection and conservation of several horticultural crops and plants of economic importance are being conserved in FGB.

Dr Anuradha Agrawal

Co-Convenor

Dr Anuradha Agrawal is the General Secretary, ISPGR (2019-21) & Principal Scientist and Officer-In-Charge, Tissue Culture and Cryopreservation Unit at ICAR-NBPGR, New Delhi. Her areas of research interest include *ex situ* conservation of plant genetic resources, with special reference to *in vitro* conservation and cryopreservation. She is recipient of BOYSCAST (Better Opportunities for Young Scientists in Chosen Area of Science and Technology) Fellowship in Plant Genetic Resources (2000-2001), Under this she was a Visiting Professor at the Laboratory of Tropical Crop Improvement, Katholieke Universiteit of Leuven (KUL), Leuven, Belgium, for 6 months in 2001, where she specialized in the area of cryopreservation. She was awarded the 'Punjabrao Deshmukh Outstanding Woman Scientist Award 2011' by the ICAR in recognition of her work related to development and application of cost-effective *in vitro* conservation and cryopreservation protocols for medium- and long-term conservation of vegetatively propagated species. She has contributed immensely towards banana conservation, diversity and cryopreservation. She has more than 200 research publications including research papers in national and international journals of repute. She has actively contributed in organizing several national and international symposia and training programmes related to PGR.

Dr S. Rajkumar

Rapporteur

Dr Rajkumar is Senior Scientist, Division of Genomic Resources & Member, PME Cell, ICAR-NBPGR, New Delhi. He specializes in cytogenetics and molecular genetics. Prior to joining NBPGR he worked at CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow and CSIR-Institute of Himalayan Bioresources Technology (IHBT), Palampur on diversity analysis, biochemical content and population genetics of medicinal and aromatic plants, especially in the Himalayan region. At ICAR-NBPGR, he has generated molecular taxonomic tools to differentiate wild and cultivated species of important horticultural crops. He has also assessed temporal variation in diversity of long-term stored safflower germplasm for effective regeneration protocol. Presently he is working on molecular cytogenetics of pre-breeding material of agri-horticultural crops.

PHOTO GALLERY

Inaugural Session of the 13th ICDD 2019

Mr Gajendra Singh Shekhawat, the then Minister of State for Agriculture and Farmers' Welfare, addressing the gathering

Dr R.S. Paroda, Chairman TAAS and President ISPGR presenting his remarks

Dr O.P. Yadav, Director, ICAR-CAZRI , presenting an overview about the conference

View of the Participants

Satellite Symposium on Dryland Agrobiodiversity

Dignitaries on the dais

Presentation of Mementoes to Speakers and Panelists of the Satellite Symposium

Venue and Participants of Satellite Symposium

Hotel Indana Palace, Jodhpur

Participants tasting the dried fruits from Central Asia (courtesy Ms M. Turdieva)

View of participants in the Satellite Symposium

Refreshment time between various sessions of ICDD

Co-organized by

Indian Society for Plant Genetic Resources (ISPGR), New Delhi, India
Bioversity International (BI), New Delhi, India
Asia-Pacific Association of Agricultural Research Institutes (APAARI), Bangkok, Thailand

with support from

United Nations Environment Programme (UNEP) and
Asia-Pacific Consortium on Agricultural Biotechnology and Bioresources (APCoAB)

during the

13th International Conference on Development of Drylands
(13th ICDD 2019), Jodhpur, Rajasthan, India