Plant Biosecurity in Asia-Pacific – Status and Challenges

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ABSTRACT

After the recent emergence of Covid -19 and its impact on human life and economy the subject of plant biosecurity assumed greater importance for also ensuring agricultural biosecurity worldwide. The Asia-Pacific comprising 46 countries is seeing frequent outbreaks and spread of devastating pests such as rice brown plant hopper, wheat rust, late blight of potato, fruit flies, etc. threatening food security and livelihood and also impacting the agricultural trade. Efforts are being made to apply control measures and to undertake surveillance programmes for important pests. The Regional Plant Protection Organization viz., Asia-Pacific Plant Protection Commission and Pacific Plant Protection Organization are playing important roles in conjunction with National Plant Protection Organizations to minimize the pest threat in the region, though new pests such as race 4 of *Fusarium oxysporum* f. sp. *cubense* on banana, *Tuta absoluta* on tomatoes, *Magnaporthe oryzae* on wheat, etc. continue to emerge and spread in certain countries. Pests such as South American Leaf Blight, devastating on rubber in Latin America has high potential to be introduced and spread in the region. The challenges in managing transboundary pests in the Asia-pacific region stems from the very fact that the member countries fall under different categories of development i.e. developed, developing and the least developed. This has a direct bearing on their resources and capacity and hence the operational quality in dealing with the problem. This poses a huge challenge in harmonising the quarantine norms to combat the transboundary movement of pests in the Asia-pacific region. Monitoring of emerging pests through surveillance and implementation of Standards for compliance to Sanitary and Phytosanitary Agreement of WTO, stricter quarantine measures and capacity building on various aspects including emergency measures to tackle outbreaks are the key challenges for ensuring biosecurity in the region. The Regional Organizations like Asia Pacific Association of Agricultural Research Institutions and many national and international research, development and donor agencies are engaged in working towards various aspects of Plant Biosecurity in the region.

Key Words: Biosecurity, Quarantine, Pest, Asia Pacific

INTRODUCTION

Biosecurity is a strategic and integrated approach that encompasses a policy and regulatory framework to analyse and manage risks associated with food safety, plant and animal health and the environment. It covers the introduction of plant and animal pests and diseases, and zoonosis; the introduction and management of invasive alien species and genotypes; and the introduction and release of genetically modified organisms (GMOs) and their products (http://www.fao.org). Thus, biosecurity is a holistic approach to the sustainability of agriculture, food safety, and the protection of the environment, including biodiversity. Plant biosecurity encompasses the policy and regulatory framework to analyse and manage risks in the sectors of plant life and health, and related environmental concerns (Khetarpal and Gupta 2007; Waage and Mumford 2008; Khetarpalet al. 2009).

The Asia-Pacific region comprises all of Asia and Australasia as well as small/medium/large Pacific island nations. It has countries experiencing vast differences in topography, climates, livelihood systems and economic development. Agriculture forms the backbone of the rural livelihoods and national economy in most of the Asia-Pacific countries. The dynamic growth in agriculture trade in the Asia-Pacific region since last few years has shifted the world economy's centre of gravity from the Atlantic to the Pacific basin. The major crops of the region such as rice, wheat, maize, cassava, coffee, coconut, banana, cotton, tea, papaya, mango and others are attacked by a number of destructive pests threatening local or regional food security. The global threat to plant biosecurity in present day is further exacerbated with over 1 billion international travellers world-wide per year moving through airports and 18 million containers making over 200 million trips through sea-ports as part of the trade across the world every year (Sharma and Wightman 2015).

The use of the term pest in the article is as per International Standards of Phytosanitary Measures (ISPM) No 5 which defines pest as any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products https://www.ippc.int/largefiles/adopted.../en/ISPM_05_2007_En_2007-07-26.pdf)/(https://www.ippc.int/largefiles/adopted_ISPMs_previousversions/en/ISPM_05_2007_En_2007-07-26.pdf) thus including all pathogens, insects, mites and even weeds.

The present review deals strictly with status of plant biosecurity in Asia- reference to pestoutbreaks and spread in agricultural and commodity crops, the role of National and International organizations in dealing with such pests and the challenges encountered in ensuring plant biosecurity in the light of emerging pests. The article does not deal with (i) invasive alien weeds which are also classified as pests in ISPM 5 and have ecological, economic and social impact, (ii) the plant pests used as bio-weapons and (iii) the biosafety issues that relates to genetically modified crops developed through recombinant DNA technology.

STATUS OF PLANT PESTS AND BIOSECURITY IN ASIA – PACIFIC

The important crops of Asia-Pacific are host to a large number devastating pests inflicting severe losses to the tune of billions of dollars annually, though the exact figure is not available. A global estimate of 30–40% loss in developing countries annually from 'field-to-fork' are common (The Royal Society 2009; Flood 2010) and may be even higher when post-harvest loss is taken fully into account. Historically a number of economically important plant pests have also transgressed across the region either as migratory or quarantine pests. The fastest flying transboundary plant pest the desert locust (*Schistocera gregaria*) is the world's largest migratory insect travelling long distances. Among the pests of high economic importance Brown plant hoppers (BPH) of Rice, not considered a serious threat in tropical Asia till 1970s, suddenly emerged as significant pest of rice with grave outbreaks in tropical Asia-Pacific countries. Rice cultivation has grown up to 158 million ha out of which 90% production is being carried out in developing countries (Poolprasert and Jongjitvimol, 2014). The sudden emergence

of BPH as a major pest of rice has been linked to the advance of the Green Revolution in countries such as Bangladesh, Brunei, China, Fiji, Korea, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, Sri Lanka, Thailand and Vietnam (Heinrichs 1977; Dyck and Thomas, 1979). Serious outbreaks of this pest have been reported in different Asia-Pacific countries (Lim et al. 1978; Mochida 1979; Soejitno 1999; Asghar et al. 2013). In Vietnam alone the area affected increased from about 0.35 m ha in 2005 to 1.1 m ha in 2010. In China during 2008, when 7.5 million ha in several provinces were infested it resulted in a loss of 2.8 million t of paddy and the losses are now being compounded with 10.4 million ha reported to be infested in 2010 (Cheng, 2009). Wheat is an important food security crop in many countries of the region and extensively grown in Australia, China, India, Pakistan and Indonesia. The wheat rusts, stem rust (Ug99) and the yellow rust are perpetual threat to the countries which rely on wheat crop as source of their subsistence and livelihood. Since its detection, new variants of Ug99 have evolved with the result that over 80% of all commercially-grown wheat varieties are now highly susceptible to stem rust. It has subsequently spread from Uganda to Kenya (1999), to Ethiopia (2003); to Yemen and Sudan (2003); and to Iran (2008). Because of the susceptibility of 90% of the wheat varieties grown worldwide, the Ug99 group of races was recognized as a major threat to wheat production and food security. Its spread, either wind-mediated or human-aided, to other countries in Africa, Asia, and beyond is evident (Singh et al. 2011). Depending on wind movement and the presence of susceptible cultivars, countries in Central and South Asia are now exposed to high risk of the disease. Besides, the emergence and establishment of yellow rust races with virulence for Yr9 (a common resistance gene of high yield wheat v
arieties of the world) to stripe or yellow rust resulted in large-scale epidemics that completely eliminated the wheat crop. A region-wide breakdown of this gene was reported in South Asia during 2002–2004. In addition, since 2000 two new aggressive strains of yellow or stripe rust capable of adapting to warmer temperatures have been identified (Hodson, 2011). Another pest of high economic importance Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* established in Hawaii in 1959 and other Pacific Islands in the 1970s has now spread to many countries in South East Asia.(Williams 2004; Muniappan et al. 2011) and India (Shylesha and Joshi 2011; Mani et al. 2013).

Country-wise list of outbreaks of major pests

A detailed list of major pest outbreaks in different countries including their phytosanitary legislations is given in Table 1. Also listed in the Table 1 are pests for which surveillance and control measures are being taken.

Majority of the countries in Asia-Pacific are members of the WTO and are parties to the Agreement on Application of Sanitary and Phytosanitary Measures (known as SPS Agreement). This contributed for majority to amend their legislative measures or to append additional decrees to include key provisions of pest reporting, survey and surveillance, pest risk analysis prior to imports and identification of areas with low pest prevalence or pest-free areas as per International or Regional standards. However, the implementation of legislative provisions, leaving aside some developed countries appear to be far from satisfactory in the region due to economic and other reasons.

The Table 1 reveals that that during the last few years about 90 serious plant pest outbreaks have occurred in 36 countries of the region. Of this 25 outbreaks were in multiple countries of which outbreak of BPH on Rice alone occurred in 8 different countries. This has enhanced pest surveillance activities in 32 countries for important pests (Table 1). Some countries have adopted the IPPC standards for declaring a specified zone as pest-free area for a total of 16 pests. The pest-free status of a country facilitates the export of a given produce from the pest-free areas even if the pest is known to occur in the country.

Emerging pests in Asia-Pacific

The term emerging pest has been often loosely used in literature. In the field of plant health, it means diseases or pests that are newly discovered, have increased in occurrence or have spread to new locations (Anonymous 2010). European Food Safety Association defines an emerging plant pest as a newly identified pest for which a significant probability of introduction and/or spread may occur, or an unexpected new or increased significant probability of introduction and/or spread of an already known plant pest, or a new or an increased susceptibility of the host plants to a known plant pest (EFSA 2011).It may be noted that a pest can be emerging in a new locations or country for the first time but might have caused outbreaks in other regions (eg. BPH, Hispine beetle). Similarly a pest can always continue to be emerging in many locations or countries but may not assume severe proportion to cause an outbreak. A number of recently emerging pests affecting the Asia-Pacific countries and their movement within the region along with those having apparently restricted distributions is given in Fig 1.

Hispine beetle (*Brontispalongissima*) that has spread fast with outbreaks in South East Asia poses a significant risk of spread as emerging pest in countries such as India, Sri Lanka and Bangladesh (Rethinam and Singh 2007; Takano et al. 2012).Coconut mite (*Aceria guerreronis)* has potential to spread to other coconut countries in Asia where 85% of the world's coconuts are grown (CABI, 2016; Vincenzo, 2016). Cassava mealybug (*Phenacoccus manihoti*) which has decreased cassava production in West Java to 30-40%, now poses acute risk to cassava production in South-East Asia including the southern end of Karnataka in India, the eastern end of the NinhThuan province in Vietnam, and in West Timor in Indonesia (Parsa et al. 2012). Papaya mealybug (*Paracoccus marginatus*) which is native to Central America, was reported in 2002 in the Pacific Islands and in 2008 in Indonesia, India, and Sri Lanka and has spread in South and South East Asian countries, posing greatest threat to rest of Asia-Pacific countries including the Australian papaya industry (Meyerdirk et al. 2004;Muniappan et al. 2008, 2011; CABI, 2016). Fire ant (*Solenopsis invicta*) in China has been introduced into parts of Australia, and in some vulnerable ecosystems including islands in the Pacific (New Zealand) and has the potential to colonize numerous other regions (McGlynn, 1999; Korzukhinet al., 2001; CABI, 2016). Wheat blast (*Magnaporthe oryzae)* that recently emerged in Bangladesh from wheat imports from Brazil is the most recent episode of biosecurity threat to India and the Indian sub-continent (Saharan et al. 2016; Callaway 2016; Malakeret al. 2016). Tomato leaf miner(*Tuta absoluta*) damage on tomato was first noticed in Pune and Bangalore during 2014 in India and within a span of two years the pest spread to nearly 1.5 million hectares in other states. It has shown potential to damage fruits to the extent of 100% (ICAR, 2014).Tropical race 4 of Panama wilt of banana (*Fusarium oxysporum* f. sp. *cubense*) has now spread to many banana growing countries in Asia-Pacific (Buddenhagen 2009; Ploetz 2015; Ordonez et al. 2016). The Western flower thrips (*Frankliniell aoccidentalis*) emerging in Indonesia and India is responsible to transmit as many as five species of tospoviruses of which *Tomato spotted wilt virus* alone is known to cause loss above US $1billion (Tyagi and Kumar 2015).

Among the emerging pests which have limited distribution in the region *Coconut cadang-cadang viroid* (CCCVd) is found only in the Philippines but in case of its spread to Asia-Pacific region, it may cause a huge loss to coconut farming (EPPO, 2014). The banana bunchy top virus (BBTV) affecting banana worldwide and causing a loss up to 100% was first recognized in Fiji (1889) and from there it was introduced to Sri Lanka, and later spread to southern India and Bangladesh. BBTV is now also recorded in East and South East Asian countries but its most disturbing effects in recent years have been seen in Pakistan, where the virus has almost destroyed the country's banana industry (CABI 2016).San Jose scale (*Quadraspidiotus perniciosus*)is indigenous to Eastern Asia and from there has spread to many parts of the world. Most of the countries like Afghanistan, China (widespread), India (widespread), Japan, Republic of Korea, Nepal, Pakistan, Russia (Far East), have the pest present thereby destroying the orchards of many fruit crops (EPPO 2014).Potato cyst nematode (*Globodera rostochiensis*)has traversed from Andes Mountains in South America all the way to Asia- Pacific through Europe with infected potato tubers. In India, it is confined to states of Kerala and Tamil Nadu and in Japan it is

restricted in Hokkaido. Up to 80% of the crop can be lost when nematode populations are high (CABI 2016).Pinewood nematode (*Bursaphelenchus xylophilus*), native to North America has been introduced into China, Japan and South Korea and damaging the forests by causing the pine wilt through transport of infested wood materials, while the main vector for natural spread in China is the sawyer beetle, *Monochamus alternatus* (Xiang 2015). The nematode has spread steadily, damaging pines in 87000 ha and killing over 40 million pines. The direct economic loss is estimated to be US$3 billion from China alone (Yanget al. 1989).Coffee berry borer is one of the economically most important pests of coffee (Vega 2008) causing an estimated loss of $500 million worldwide. First found in Uganda in 1908, it was reported in Asia during 1990 from a coffee growing region in South India and has gradually spread to almost all the coffee growing areas affecting yield and quality of coffee, and reducing the income of coffee growers (Jaramillo et al. 2006).

It may be seen from Fig 1that during the last few years about 12 important emerging plant pests have been reported in 14 countries of the region some of which continue to spread further. Besides, some emerging pests with restricted distribution (Fig 1) were also observed. The emerging pests are infact the alarm bells for the region necessitating possible phytosanitary measures to contain their spread and to minimize the potential losses caused by them.

REGIONAL EFFORTS IN ENSURING PLANT BIOSECURITY

Regional cooperation and coordination are critical in reducing the outbreaks of pests and their movement in the region. FAO through its Regional Offices undertake plant protection activities related to Integrated Pest Management (IPM), pesticide management etc. and also facilitate the implementation of ISPMs of the International Plant Protection Convention (IPPC) which is an international agreement on plant health with 182 current signatories aims to protect cultivated and wild plants by preventing the introduction and spread of pests (https://www.ippc.int/en/).The IPPC thus has a strong presence in each of the FAO regions, delivering its services through Regional Plant Protection Organisations (RPPOs). Of the nine RPPOs of FAO two are in Asia-Pacific region viz., Asia-Pacific Plant Protection Commission (APPPC) and Pacific Plant Protection Organization (PPPO). The APPPC located at the FAO Regional Office Bangkok, was established in 1956 and has 25 countries from Asia and Pacific as members (http://www.fao.org/asiapacific/apppc/en/). The PPPO located at New Caledonia at the headquarters of the Secretariat of the Pacific Community was founded in October 1994 and has all 27 countries of Pacific Community as members (http://lrd.spc.int/plantprotectionorganisation-/pppo). All the 25 member states of APPPC and 27 of PPPO vary greatly in size and level of economic development. Both APPPC and PPPO have a multi-facet responsibility and functions that covers all the mandate of general plant protection of the member countries and also the mandate of IPPC for developing and harmonising Regional Standards for Phytosanitary Measures (RSPMs). They work with National Plant Protection Organizations (NPPOs) to review the plant protection status, promote appropriate measures to prevent introduction and spread of pests, develop and adopt RSPMs(Table 2, http://www.fao.org/asiapacific/apppc/en/), provide assistance to develop ISPMs, promote multi- and bilateral agreements, co-ordinate and arrange trainings, promote appropriate measures to control pests, including use of IPM, review status of and promote IPM and harmonize pesticide regulations. APPPC also promotes information exchange in the region through a website as a forum for the member countries to exchange information regularly about their plant quarantine, pest and pesticide management activities as well as other issues related to plant protection. PPPO has prepared a Pacific Islands Pest List Database (PLD) which stores records of pests that are currently known to affect agriculture, forestry and the environment in Pacific Island Countries and Territories.

The FAO introduced IPM against Cassava pink mealybug in Greater Meakong subregion countries to develop spread prevention strategies and ecological biocontrol options to manage the mealybug. Also

FAO, through its Asia Regional IPM Programme supported action-oriented research and development initiatives, most notably on late blight and leaf miner management as well as the promotion of bio-fumigation for control of soil-borne diseases. Besides, the EU-funded FAO programme on IPM for cotton in Asia had six member countries of Bangladesh, China, India, Pakistan, the Philippines and Vietnam where cotton is a chief cash crop and also faces huge losses due to many pests including those of transboundary importance. An on-going Project on Capacity Development in Implementation of Plant Pest Surveillance and Information Management in Southeast Asian Countries has been financed by Republic of Korea and involves Cambodia, Lao PDR, Myanmar, Nepal, Thailand and Vietnam (http://www.fao.org/fileadmin/templates/rap/files/meetings/2013/131129-report.pdf).Australia and New Zealand being the major trading partners of Pacific Island Countries (PICs) have been assisting in encouraging increased trade with them. The PICs limited ability to meet biosecurity requirements imposes a severe constraint on their capacity to increase export markets for currently important commodities and develop exports of a new range of products(http://lrd.spc.int/plantprotectionorganisation-/pppo).

CHALLENGES IN ENSURING BIOSECURITY IN ASIA-PACIFIC

Ensuring a well-developed institutional mechanism for plant protection and quarantine: The challenges in managing pest outbreaks and transboundary pests in Asia-Pacific stems from the very fact that the member countries fall under different categories of development i.e. developed, developing and the least developed. This has a direct bearing on their resources and capacity and hence the operational quality in dealing with the problem. Developed countries like Australia, New Zealand and Japan have the best of regulatory provisions, resources, programmes, institutional infrastructure for plant protection and quarantine facilities with appropriate research back-ups to meet the challenges of biosecurity to a great extent. Also there is a great variation among member countries in their organizational structures and the national mandates which may be more focussed on biosecurity where in transboundary pest movement may be a component of plant protection to deal with but not the major focus. Thus the compliance to implementation of different international standards as laid down by IPPC are just not at the same level within the region. This poses a huge challenge in harmonising the quarantine norms to combat the transboundary movement of pests at regional level.

Ensuring pest-free movement of seed and planting materials: The international trade in seed and planting materials in bulk and exchange of germplasm are known to carry pests to long distances along with their movement (Khetarpal 2004, Khetarpal et al. 2009). The quarantine processing of germplasm material in most of the countries is often not as stringent as commercial material despite the fact that germplasm can be also potential source of spread of quarantine pests into the region. India has intercepted various quarantine pests in germplasm imports from outside the Asia-Pacific and also in imports from Asia-Pacific countries such as *Peronospora manshurica* on *Glycine max* from Indonesia, Japan, Malaysia, North Korea, South Korea, Taiwan, Thailand, and arabis mosaic virus on *Vigna radiata* from AVRDC (Taiwan), cherry leaf roll virus on *G. max* from AVRDC (Taiwan), Sri Lanka, Thailand, cowpea mottle virus on *V. unguiculata* from the Philippines, cowpea severe mosaic virus on *V. radiata* from Australia, tomato ringspot virus on *G. max* from AVRDC (Taiwan), Sri Lanka, Thailand, raspberry ringspot virus on *G. max* from AVRDC (Taiwan), pea enation mosaic virus on *Phaseolus vulgaris* from Nepal etc. (Bhalla et al. 2018; Chalam and Khetarpal 2008; Chalam et al. 2008, 2012, 2014, 2017, 2018; Khetarpal et al. 2001, 2006). If not intercepted many of these quarantine pests would have entered and become the emerging pests.

Ensuring the absence of important pests not yet introduced in Asia-Pacific: South American Leaf Blight (SALB) of rubber caused by *Microcyclus ulei* is one of the most important pests occurring on commercial commodities not yet occurring in Asia, particularly Southeast Asia where natural rubber is

playing a prime role in the economy of the country and there is a potential risk of the pathogen entry and establishment due to the favourable climatic conditions and rainfall similar to SALB endemic regions of the Amazon. Recently APPPC has brought out a contingency plan for SALB which provides background information to base a response. The plan provides a summary of information on the biology of the pest and the available control measures for the disease. It provides guidelines for steps to be undertaken and considered when developing a response plan for this pest. The response plan is operational and determines the resources that are needed (http://www.fao.org/asiapacific/apppc/en/). Mexican cotton boll weevil (*Anthonomus grandis*) is listed as an A1 quarantine pest by EPPO and has high quarantine significance for Asia-Pacific (CABI 2016). Since it exists in subtropical region, it indicates that the cotton-growing area in the region are at potential risk of invasion and there is a need to be vigilant. On maize which is an important food security crop in the region ergot disease (which is endemic in central Mexico) caused by *Claviceps gigantean* is yet not reported(CABI,2016).

Ensuring preparedness to mitigate uncertainties due to impact of climate change: It is well known that new plant pests and diseases may emerge due to evolving selection and adaptation to new climatic situations. Migratory plant pests, in particular locusts, are totally dependent on rain, temperature and vegetation and their habitats change rapidly. The desert locust like other locusts, can change its behaviour and physiology from solitary grasshoppers to gregarious stages that form swarms. Solitary desert locusts occur at low density in parts of India, Pakistan, Iran and Afghanistan. The outbreak area reaches from Mauritania to India and from southern Europe to Cameroon and Tanzania. Another key example of migratory pest is coffee berry borer. With climate change imminent, the coffee berry borer is expected to become an even greater threat (Jaramillo et al. 2011). http://www.apn.gr.jp/en/indexe.htmlDeveloping countries in the Asia-Pacific, especially India and Bangladesh, are likely to face the highest reductions in agricultural production in the world, due to climate change. This will be through direct effects on crop production such as floods and drought and indirect effects through the spread of pests and diseases (http://legacy.crcplantbiosecurity.com.au/content/climate-change-asian-pacific-regions.html).AnAsia-Pacific Network for Global Change project led by Cooperative Research Center for National Plant Biosecurity, Australia brought together Indian, Bangladesh and Australian policy experts and research scientists, comprising agro-meterologists, crop modellers, entomologists and plant pathologists demonstrating a global approach to addressing the risks posed by climate change to food security in both developing and developed countries (Luck et al. 2010).

Ensuring concerted efforts towards biosecurity by Regional Bodies: The regional bodies that exist and operate in various development activities in the region such as Association of South East Association Nations, South Asian Association of Regional Cooperation, Bay of Bengal Initiative for Multisectoral Trade and Economic Cooperation, Asia Pacific Economic Commission , The Pacific Community, Pacific Agreement on Closer Economic Relations, Pacific Islands Trade and Investment Commission, Asian Development Bank and the global and regional donor agencies need to prioritize on plant biosecurity engagements and synergize their action plans for economic, food and environmental security and work closely with FAO, APPPC, PPPO and NPPOs.

CONCLUSIONS AND KEY ACTION PLANS

The outbreaks of almost 90 pests occurred on important crops in Asia-Pacific recently and a number of economically important emerging pests were also recorded. This implies that domestic markets and their needs are likely to be more imperative in the coming future than the desirability of export markets. The number of emerging pests are increasing in the region owing to intensification of agriculture and movement of pests with increasing trade from and within the region. Classification of a pest as causing outbreaks and as emerging is considered useful, as for an outbreak a rapid response strategy is needed

by the policy makers whereas for an emerging pest an immediate and extensive pest specific surveillance programme and early detection protocols are called for. To ensure plant biosecurity there is a great variation in response of different countries to pest outbreaks owing to variation in their economic growth and hence their institutional mechanism and infrastructure. The developed countries Australia, New Zealand and Japan which have the best possible biosecurity infrastructure, mechanism and engagements are investing substantially in the region mainly because a lot of their imports are dependent on other developing and least developed countries and islands of the region. However, most countries of Asia-Pacific have insufficient enabling mechanism, procedures and resources allocated to surveillance and monitoring, border control and inspections, expertise in risk assessment, diagnostic tools for early detections, expertise in diagnosis (taxonomy), data collection and access to information, tools for rapid response to entry, establishment and spread and control measures at the source of the produce. FAO through APPPC and PPPO are coordinating with NPPOs for managing outbreak and spread of major pests and also facilitating the implementation of standards and guidelines for compliances to SPS Agreement, however, the economic conditions of many countries do not allow to sustain the global efforts after the project period is over. The role and responsibilities of national players specially the NPPOs thus become crucial. Attention of all policy makers, quarantine officials and researchers alike is needed to meet the challenges of biosecurity for ensuring food, economic and environmental security in Asia pacific.

The key action plans proposed are:

- The Asia-Pacific countries need to ensure proper compliance to International and Regional Standards with special reference to that of pest risk analysis, pest surveillance and pest reporting. Some of the countries need to invest more on capacity building for developing infrastructure and expertise in various domains of SPS. Investments in early detection and control mechanisms will be critical, to avoid higher costs of eradication and control. A good border control and rapid diagnostic tools for better surveillance of plant pests is needed.

- There is a dire need by countries for strengthening of import and domestic quarantine programmes for pests with restricted distribution with a focus on Additional Declaration(s) in the Phytosanitary Certificate, provisions for post entry quarantine monitoring disinfestation/disinfection treatments. The countries need to regularly update their regulated pest list and also list of prohibited plant species from a given country based on evolving scenario of emerging pests.

- Knowledge Management on plant biosecurity at Regional level seems to be vital for easy access of information to researchers and other stakeholders so that needful innovative pest management strategies can be taken up well in advance. (Khetarpal and Dashora 2014). There is a need of enhanced regional cooperation and coordination through information sharing on emerging pests in the area. Database on pests of exotic and indigenous origin needs to be prepared by the countries. The Pest and Disease Image Library (www.padil.gov.au/) a publicly available online database of Australia and New Zealand is an example for other countries to emulate. Based on country database a regional database needs to be developed with coordinated efforts of APPPC and PPPO.

- Interdisciplinary research in areas of biosecurity and biodiversity needs to be encouraged in relation to diagnostics, epidemiology, resistance breeding and control of emerging pests. Development of Regional and National Plant Biosecurity Diagnostic Network as of Australia need to be developed for other countries. The network may include Remote Microscopy system, National reference collections, user-friendly portable devices for on-the-spot identification of known diseases which can detect multiple pests in the field, rapid, non-invasive detection of characteristic volatiles or

electromagnetic radiation from infected plants, microarray technology and ultimately, a national biosecurity chip for diagnosis of all current threats to agriculture.

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Table 1 : Legislative provisions, list of pest outbreaks, pests under surveillance and pests with control measures in Asia Pacific countries

Country Legislative provisions	**Outbreaks**	**Surveillance programme/ Pest- free status**	**Economically important pests meriting control options**
Afghanistan Plant Quarantine Act	Desert locust (*Schistocercagregaria*); Moroccan locust (*Dociostaurusmaroccanus*)	Desert locust (*S. gregaria*)	Desert locust(*S. gregaria*); Wheat sunn pest *(Eurygasterintegriceps*; *Aeliarostrata)*
Australia Australian Biosecurity Act 2015	Chestnut blight (*Cryphonectriaparasitica*); Giant pine scale (*Marchalinahellenica*); Red imported fire ants (*Solenopsisinvicta*); Russian wheat aphid (*Diuraphisnoxia*)	Australian plague locust (*Chortoicetesterminifera*); Migratory locust (*Locustamigratoria*); Spur-throated locust (*Austracrisguttulosa*)	Chestnut blight (*C. parasitica*); Citrus canker (*Xanthomonascitri*); Giant pine scale (*M. hellenica*); Red imported fire ant (*S. invicta*)

Bangladesh Plant Quarantine Act 2011	Papaya mealybug (*Paracoccusmarginatus*); Rice blast (*Magnaporthegrisea*); Rice bacterial leaf blight (*X. oryzae*); Rice brown plant hopper (*Nilaparvatalugens*); Stem borer common cutworm (*Spodopteralitura*); White fly (*Bemisia*sp.)	Rice pest; fruit fly (*Bactrocera*sp.)	Jute anthracnose (*Glomerallacingulata*); Gummosis of Jack fruit (*Phytophthora*sp.); Jute stem rot (*Macrophomínaphaseolina*); White mould (*Sclerotiniasclerotiorum*)
Bhutan The Plant Quarantine Act of Bhutan 1993	Army worm (*Mythimnaseparata*)	Chilli pod borer (*Helicoverpaarmigera*); Red palm weevil *(Rhyncophorusferrugineus*); Rice blast (*M. grisea*)	Army worm (*M. separata*); Chilli pod borer (*H. armigera*); Chinese fruit fly (*B. minax*); Citrus trunk borer (*Anoplophoraversteegi*); Rice case worm (*Nymphuladepunctalis*)
Brunei Agricultural Pests and Noxious Plants Act Section 24 (1) (F) Revised edition 1984	--	--	--
Cambodia Cambodian Phytosanitary Regulation 2005	Army worm (*M. separata*); Coconut rhinoceros beetle (*Oryctes rhinoceros*); Golden apple snail (*Pomaceacanaliculata*); Pink mealybug (*Maconellicoccushirsutus*); Rice brown plant hopper (*N. lugens*)	Citrus; Grain Insect; Potato ; Rice; Sugarcane; Tomato	Army worm (*M. separata*); Rice brown plant hopper (*N. lugens*); Golden apple snail (*P. canaliculata*)
China* Law of the People's Republic of China on the Entry and Exit Animals and Plants Quarantine (Order of President No.53) 2016	Army worm (*M. separata)*; Potato late blight (*Phytophthorainfestans*); Rice blast (*M. grisea*); Rice brown plant hopper (*N. lugens*); Rice leaf folder (*Cnaphalocrocismedinalis*);Wheat scab (*Gibberrellazeae*)	Coconut black headed caterpillar (*Opisinaarenosella*); Migratory locust (*L. migratoria*); Potato beetle (*Leptinotarsadecemlineata*); Rice brown plant hopper (*N. lugens*) *pest-free area declared for Codling moth (*Cydiapomonella*)	Army worm(*M. separata*); Coconut black headed caterpillar (*O. arenosella*); Fall webworm (*Hyphantriacunea*); Huanglongbing (*Diaphorinacitri*); Meadow moth (*Loxostegesticticalis*); Migratory locust (*L. migratoria*); Pine wilt disease (*Bursaphelenchusxylophilus*); Rice brown plant hopper (*N. lugens*); Rice leaf roller (*Cnaphalocrocismedinalis*); Rice sheath blight (C*orticiumsasakii*); Rice blast (*M. grisea*); Sirexwoodwasp (*Sirexnoctilio*); Wheat scab (*Gibberrellazeae*); Wheat stripe rust (*Pucciniastriiformis*)
Cook Islands Biosecurity Act 2008	Sweet potato whitefly *(B. tabaci*)	Queensland fruit fly (*B. tryoni*)	Sweet potato scarabee (*Euscepespostfasciatus*); Sweet potato weevil (*Cylasformicarius*)
Fiji Fiji BAF Legislation 2015	Chilli anthracnose (*Colletotrichum*sp.); Coconut rhinoceros beetle (*Oryctes rhinoceros*); Coconut stick insect (*Graeffeacrouanii*); Taro beetle (*Eucopidocaulus*)	Fruit flies (*Bactocera*sp.)	Chilli anthracnose (*Colletotrichum*sp.); Coconut rhinoceros beetle (*O. rhinoceros*); Coconut stick insects (*G. crouanii*); Fruit flies (*B. passiflorae, B. xanthodes*)

India* Plant Quarantine (Regulation of Import into India) Order; 2003 Draft Agricultural Biosecurity Bill 2013	Rice armyworm (*S. litura*); Desert locust (*S. gregaria*); Papaya mealybug (*P. marginatus*); Whitefly (*B. tabaci*)	Desert locust (*S. gregaria*); Fruit fly (*B. dorsalis*); Potato golden nematode (*Globoderarostochiensis*); Tomato leaf miner (*Tutaabsoluta*) *Pest-free area for Brown rot (*Ralstoniasolanacearum*) and ring rot (*Clavibactermichiganensis*) of potato	*Banana bunchy top virus*; Coconut eriophyid mite (*Aceriagurrreronis*);Coffee berry borer (*Hypotehnemushampei*);Cotton mealy bug (*Phenococcussolenopsis*); Desert locust (*S. gregaria*); Papaya mealybug (*P. marginatus*); Spiralling white fly (*Aleurodicus disperses*); Sunflower downy mildew (*Plasmoparahalstedii*)
Indonesia Animal, Fish and Plant Quarantine Law 1992	Rice bacterial leaf blight (*X. oryzae*); Rice brown plant hopper (*N. lugens*); Rice leaf blast (*M. grisea*); Rice stem borer (*Scirpophagaincertulas*); *Rice tungro virus*	Avocado; Bell pepper; Dragon fruit; Durian; Ginger; Lansium; Mango; Mangosteen; Orchids; Papaya; Pineapple; Raphis; Salacca	Chilli anthracnose (*Colletotrichum*sp.); Soybean downy mildew (*Peronosporamanshurica*); Khapra beetle (*Trogodermagranarium*); *Raspberry ringspot virus*; Stenocarpella ear rot (*Stenocarpellamacrospora*)
Japan Plant Protection Law 2010	Rice brown plant hopper (*N. lugens*); Rice white-backed planthpper (*Sogatellafrucifera*)	Japanese cedar longhorn beetle (*Callidiellumrufipenne)*	Fruit bugs (*Glauciassubpunctatus, Halyomorphahalys, Plautiacrossota*)
Laos PDR Plant Protection and Plant Quarantine Law No. 06/NA dated 9 December 2008	Yellow spined bamboo locust (*Ceracriskiangsu*)	Banana; Cassava; Locusts; Maize; Rice; Rubber; Tobacco; Water melon	Citrus canker (*X. citri*); Coconut hispine beetle (*Brontispalongissima*); Cassava pink mealybug (*Phenacoccusmanihoti*); Coffee berry borer (*Hypothenemushampei*); Sugarcane white leaf (phytoplasma);Yellow-spined bamboo locust (*C. kiangsu*)
Malaysia Plant Quarantine Act 1976 (2016); MAQIS Act 2016	Green paddy leafhopper (*Nephotettixvirescens*); Malayan black bug (*Scotinophoracoarctata*); Rice armyworm(*S. mauritia*); Rice brown plant hopper (*N. lugens*); Rice caseworm (*Nymphuladepunctalis*); Rice ear bug (*Leptocorisaoratorius*); Rice leaf folder (*Cnapalocrocismedinalis*); Rice white-backed planthopper (*S. furcifera*)	Mango seed weevil (*Sternochetusmangiferae*); South American Leaf Blight (*Microcyclusulei*)	Green paddy leafhopper (*N. virescens*); Rice ear bug (L. *oratorius*); Rice brown plant hopper (*N. lugens*) Rice leaf folder (*C. medinalis*)
Myanmar Plant Pest Quarantine Law 2015	Rice brown plant hopper (*N. lugens*); Diamondback moth (*Plutellaxylostella*); Golden apple snail (*P. canaliculata*); Rice stem borer (*Scirpophagaincertulas*)	Army worm (*H. armigera*)	Rice nematodes (*Ditylenchusangustus*, *Hirschmanniellaoryzea*); White fly (*B. tabaci*)
Marshall Islands Quarantine Restrictions Act	Coconut rhinoceros beetle (*O. rhinoceros*)	Fruit Fly (*Bactrocera*sp.)	Corn southern leaf blight(*Cochliobolusheterostrophus*); Leaf spot of seedling(*Bipolarisincurvata*); Sweet potato scab (*Elsinoebatatas*)
Micronesia Chapter 4 of Title 22 of the Code of Federated	Aphids; Cucumber beetle(*Diabroticaundecimpunctata*)	Fruit Fly (*Bactrocera*sp.)	Coconut hispid (*Brontispa*sp.); Coconut Rhinoceros beetle (*O. rhinoceros*); Coconut scale (*Aspidiotus destructor*); New

States of Micronesia-Quarantines			Guinea sugarcane weevil (*Rhabdoscelusobscurus*); Red coconut scale (*Furcaspisoceanica*)
Mongolia Environmental Protection Law of Mongolia	Grasshopper (*Loxostegesticticalis*); Mongolian locust (*Oedaleusasiaticus*)	-	Mongolian locust (*O. asiaticus*)
Nauru Agriculture Quarantine Bill (Plant & Animal Quarantine Regulation 2004)	Melon fly (*B. cucurbitae)*	Fruit fly*(Bactrocera*sp.)	Mango fly (*B. frauenfeldi*); Oriental fruit fly (*B. dorsalis*); Pacific fruit fly (*B. xanthodes*)
Nepal* Plant Protection Act 2007	Army worm (*Mythimna*sp.); Rice brown plant hopper (*N. lugens*); Sugarcane plant hopper (*Pyrillaperpusilla*)	Citrus pests; Fruit Flies; *Pest-Free area for Mandrin orange and sweet orange fruit fly	Citrus fruit fly (*Bactrocera*sp.); Cotton bollworm (*H.armigera*); Epilachna beetle (*Epilachnavigintioctopunctata*); Black blister beetle (*Epicautavittata*); Green peach aphid (*Myzuspersicae*); Potato cut worm (*Agrotissegetum*); Tomato semi-looper (*Chrysodeixischalcites*); Potato tuber moth (*Phthorimaeaperculella*); Red ant (*Pogonomyrmexbarbatus*); White grubs (*Cyclocephala*sp.)
New Zealand New Zealand's Biosecurity Act and Regulations 2007	Brown marmorated stink bug (*Halyomorphahalys*); Fruit fly (*Bactrocera*sp.)	Brown marmorated stink bug (*H. halys*); Fruit fly (*Bactrocera*sp.); Gypsy moth (*Lymantriadispar*)	Fruit flies (*Bactrocera*sp.); Potato psyllids (*Bactericeracockerelli*)
Niue Draft Biosafety (Genetically Modified Organisms) Regulations 2006; Draft Environment (Amendment) Bill 2006	Aphid (*Aphis craccivora*); Pineapple mealybug (*Dysmicoccusbrevipes*); Southern green stink bug (*Nezaraviridula*)	Fruit fly (*Bactrocera*sp.)	Citrus leaf miner (*Phyllocnistiscitrella*)
North Korea Plant Protection Act 2012	Diamondback moth (*P. xylostella*); Small white butterfly (*Pierisrapae*)	Fruit fly (*Bactrocera*sp.)	Armyworm (*H. armigera*); maize smut (*Ustilagomaydis*); Maize stem borer (*Atherigonaorientalis*); Diamondback moth (*P. xylostella*); Small white butterfly (*Pierisrapae, P. ramorum*)
Pakistan Phytosanitary Requirements According to Law of the Islamic Republic of Pakistan in the Field of Plant Quarantine for Importing Countries 2016	Desert locust (*S. gregaria*); Dubas bug (*Ommatituslybicus*)	Fruit fly (*Bactrocera*sp.)	American boll worm (*H. armigera*); Army worm (*S. litura*); Cotton leaf folder (*Syleptaderogata*); Dubas bug (*O. lybicus*); Pink boll worm (*Pectinophoragossypiella*); Spotted boll worm (*Eariasinsulana*); Thrip (*Thripstabaci*); White fly (*B. tabaci*)
Papua New Guinea National Agriculture Quarantine and Inspection Authority Act 1997	Mango fly (*B. frauenfeldi*); Melon fly (*B. cucurbitae*); Potato late blight (*Phytophthorainfestans*)	Fruit fly (*Bactrocera*sp.); Khapra beetle (*Trogodermagranarium*)	Coconut hispine beetle (*B. longissimi*); Crazy ant (*Anoplolepisgracilipes*); Fruit fly (*Bactrocera*sp.); Ratoon stunting disease (*Leifsoniaxyli*)

Philippines* Philippine Plant Quarantine Law 1978	Cassava phytoplasma disease; Coconut scale insect (*A. destructor*)	Army worm (*M. separata*); Coconut scale insect (*A. destructor*); Rice grain bug (*Leptocorisaacuta*); Rice bacterial leaf blight (*X. oryzae*); *Rice tungro virus* *Pest-free area for Banana Xanthomonas wilt (*X. campestris*pv.*musacearum*) and *Banana bract mosaic virus*	Armyworm (*M. separata*); Rice bacterial leaf blight (*X. oryzae*); Rice black bug (*Scotinopharacoarctata*); Rice grain bug (*L. acuta*)
Samoa Phytosanitary Requirements/ Restrictions/ Prohibtions 2015	Taro leaf blight (*Phytophthoracolocasiae*)	Coconut rhinoceros beetle (*O. rhinoceros*); Fruit flies (*B. kirki, B. xanthodes*)	Fruit flies (*B. kirki, B. xanthodes*)
Singapore Control of Plants Act 2000	Golden apple snail (*P. canaliculata*); Rice brown plant hopper (*N. lugens*)	Coconut rhinoceros beetle (*O. rhinoceros*)	Cotton bollworm (*H. armigera*); Golden apple snail (*P. canaliculata*); Rice brown plant hopper (*N. lugens*)
Solomon Islands Biosecurity Act 2013	Taro beetles (*Papuanawoodlarkiana*, *P. biroi*,*P. huebneri*, *P. trinodosa*)	Little fire ant (*Wasmanniaauropunctata*); Surinam cockroach (*Pycnoscelussurinamensis*)	*Dasheen mosaic virus*; Taro leaf blight (*P. colocasiae)*
South Korea Korea's Plant Protection Act	Fire blight (*Erwiniaamylovora*)	Cabbage white butterfly larvae (*P. brassicae*)	Cabbage white butterfly larvae (*P. brassicae*)
Sri Lanka Plant Protection Act of Srilanka 2016	Rice brown plant hopper (*N. lugens*); Rice thrips (*Stenchaetothripsbiformis*)	Mealy bug; Rice pest	Black cut worm (*Agrotis*sp.); Cabbage caterpillar (*Plutellaxylostella*); Mealybug (*Planococcuslilacinus, P. marginatus*, *P. cryptus*); Rice sheath blight (*Rhizoctoniasolani*); Root knot (*Meloidogyne*spp.)
Thailand* Plant Quarantine Act B.E.2507 and amended 2011	Coconut blackheaded caterpillar (*O. arenosella*)	Corn downy mildew (*Peronosclerosporaphilippinensis*); Maize leaf blight (*Bipolarismaydis*); Maize vascular wilt (*Pseudomonas avenae*; *P. syringae*) *Pest-free area for Corn downy mildew (*P. philippinensis*); Maize leaf blight (*B. maydis*); Maize vascular wilt (*P. avenae*; *P. syringae*)	Cassava pink mealybug (*P. manihoti*);Coconut black headed caterpillar (*O. arenosella*)
Timor-Leste Timor-Leste's legislation relating to phytosanitary restrictions 2016	Desert locust (*S. gregaria*)	Cotton blue disease (*Cotton leafroll dwarf virus*); Desert locust (*S. gregaria)*	*Banana bunchy top virus*
Tonga Plant Quarantine Act 1988; Noxious Weed Act 2015	Banana weevil (*Cosmopolites sordidus*)	Bacterial crown rot (*E. papaya*)	Bacterial crown rot (*E. papaya*); Banana aphid (*Pentalonianigronervosa*); Mediterranean fruit fly (*Ceratitiscapitata*); Melon aphid (*Aphis gossypii*); Oriental fruit fly (*B. dorsalis*)

RSPM No. (Year)	Regional Standards		
RSPM No.1 (2004)	Guidelines for the development of the heat disinfestation treatments of fruit fly host commodities		
RSPM No.2 (2004)	Training requirements for plant quarantine inspectors		
RSPM No.3 (2005)	Requirements for the establishment and maintenance of pest free areas for tephritid fruit flies		
RSPM No.4 (2005)	Guidelines for the confirmation of non-host status of fruit and vegetables to tephritid fruit flies		
RSPM No.5 (2007	Guidelines for the application of emergency actions and the establishment of emergency measures		
RSPM No.6 (2007)	Guidelines for PRA on scale insects associated with commodities for human consumption		
RSPM No.7 (2014)	Guidelines for protection against South American Leaf Blight of rubber		
RSPM No.8 (2009)	Guidance on the operation of land border entry points for local trade		
RSPM No. 9 (2014)	Approval of irradiation facilities		
RSPM No. 10 (2014)	Approval of fumigation facilities		
Vanuatu Plant Protection Amendment Act 2013	Taro leaf blight (*P. colocasiae*)	Fire ants; Melon fly (*B. cucurbitae*); Banana corm and leaf spot (*Marasmiellusstenophyllus*)	Bacterial soft rot (*E. chrysanthemi*); Corm rot (*Atheliarolfsii*); Taro leaf blight (*P. colocasiae*)
Vietnam Law on Plant Protection and Quarantine issued in 2001	Yellow-spined bamboo locust (*C.kiangsu*); Grasshopper (*Hieroglyphustonkinensis)*; Sawfly (*Shizocera*sp.)	Basic survey of pests on forest trees; National Programme for surveying and detecting early quarantine pests	Black pepper fungi (*Phytophthoraparasitica, P. palmivora)*; *Fusariunsolani*;*Pythium*sp.; *Lasiodiplodiatheobromae*; *R. solani*; *Roselli*asp.

*Relate to countries where pest free area has been declared for certain pests as given under column 3
Sources : FAO 2014; Hyun and Choi 2014 ; Kranthi 2016; Yongfang 2015;

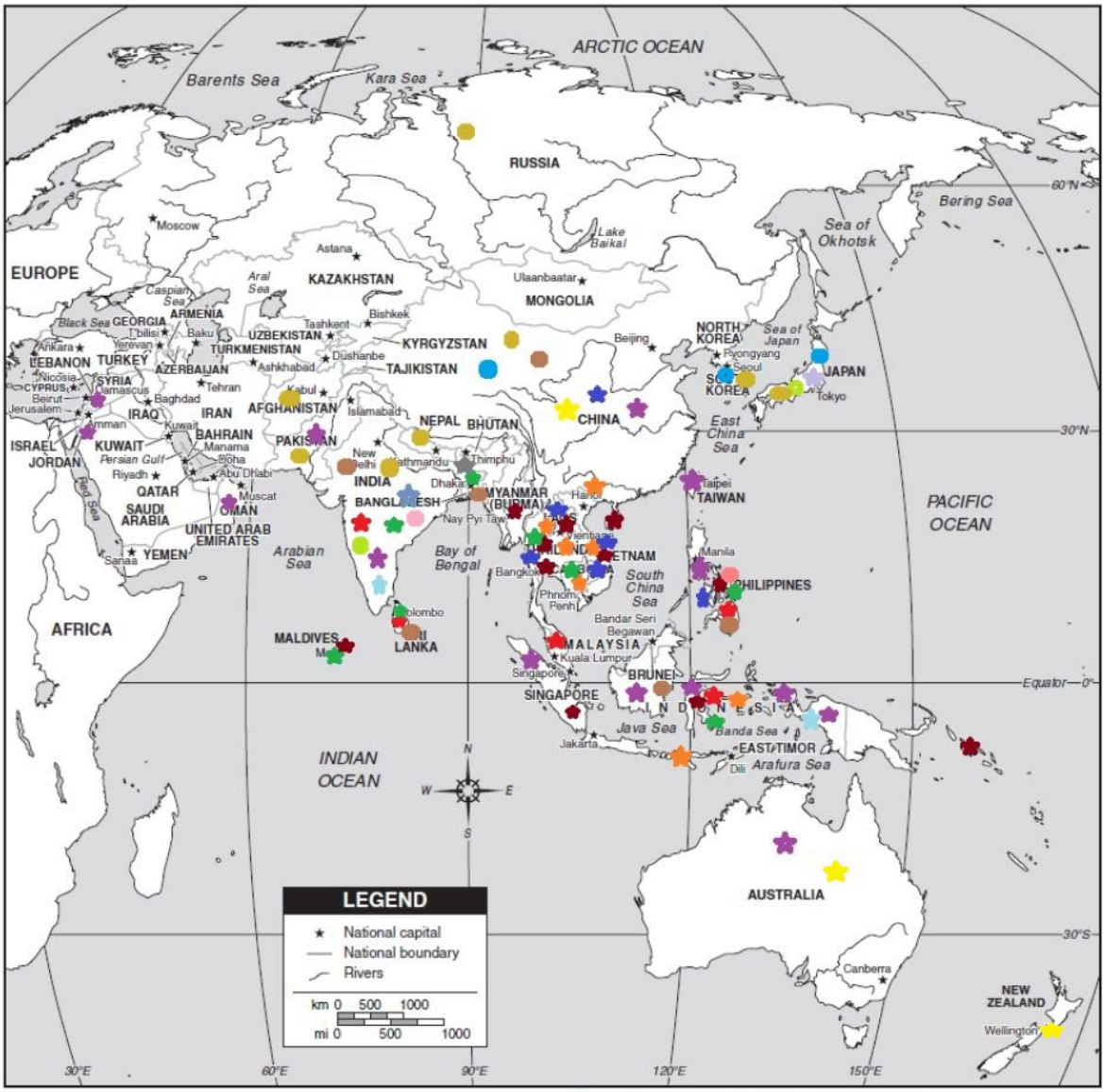
http://www.fao.org/asiapacific/apppc/en/; http://lrd.spc.int/plantprotectionorganisation-/pppo; http://www.nppc.gov.bt/wp-content/uploads/2016/07/4.-Chilli-pod-borer.pdf;

https://www.rhs.org.uk/advice/profile?pid=457; http://www.mbdsnet.org/79105-2/;http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/427515/Exotic-Pest-Alert-Tomato-potato-psyllid.pdf

Table 2: Regional Standards for Phytosanitary Measures (RSPMs) developed by APPPC

Source :http://www.fao.org/asiapacific/apppc/en/

Fig. 1: Distribution of important emerging pests in Asia-Pacific (Pests indicated with circles in different colours are the pests with restricted distribution)



Cassava mealybug (*Phenacoccus manihoti*)

Hispine beetle (*Brontispa longissima*)

Papaya mealybug (*Paracoccus marginatus*)

Cassava witches' broom (Phytoplasma)

Wheat blast (*Magnaporthe oryzae*)

Tomato leaf miner (*Tuta absoluta*)

Banana bunchy top virus

Potato cyst nematode (*Globodera rostochiensis*)

Pinewood nematode *(Bursaphelenchus xylophilus)*

Coconut mite (*Aceria guerreronis*)

Fire ant (*Solenopsis invicta*)

Tropical race 4 of Panama wilt of banana (*Fusarium oxysporum* f. sp. *cubense*)

Guava rust (*Puccinia psidii*)

Western flower thrips (*Frankliniella occidentalis*)

Coffee berry borer (*Hypothenemus hampei*)

San Jose scale (*Quadraspidiotus perniciosus*)

Coconut cadang-cadang viroid