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Editorial

Phytoplasma Diseases in Asian Countries:Current Scenario and Emerging Issues

Phytoplasmas are obligate intracellular parasites of plant phloem tissues and of the insect hemolymph. They are pleomorphic in shape, wall-less intracellular gram positive bacteria associated to diseases of important crops worldwide.Phytoplasmas have emerged as one the most serious constraints in the production of several agricultural and horticultural crops all around Asian continents with severe losses in yield and quality every year. A significant progress on identification and characterization of phytoplasma strains, epidemiology and management has been achieved in Asia in last 25 years. So far, 17 ribosomal groups and 36 subgroups of phytoplasmas have been identified and characterized in more than 250 plant species in Asia. Sugarcane, bamboo species, sesame, vegetables, legumes, brassicas, palms, stone and pome fruits, seasonal ornamentals, tree species and weeds are majorly reported as natural hosts of phytoplasma strains in Asia. Besides, several leafhoppers, plant hoppers and psyllids and over 50 weed species have also been identified as natural vectors and reservoirs of phytoplasma strains in Asia.

The history of phytoplasma presence is more than 1000 years old in Asia and today phytoplasma disease records are available from all Asian countries.Phytoplasmas are a major limiting factor in the quality and productivity of ornamentals, horticultural and economically important agriculture crops in Asia, and the losses caused by them have disastrous consequences for the farming communities.The most important and emerging phytoplasma diseases in Asian continent includes sugarcane grassy shoot and white leaf, sesame phyllody, brinjal little leaf, tomato big bud, cowpea witches' broom, pigeonpea witches' broom, chickpea stunt and phyllody, grapevine yellows, coconut root wilt and lethal wilt, stone and pome fruit phytoplasmas, arecanut leaf yellows, sapota flat stem, sandal spike, date palm yellowing, jujube witches' broom, wheat blue dwarf, rice yellow dwarf, rice orange leaf, and lime witches' broom.Over the last 25 years, several emerging and re-emerging phytoplasma strains have been identified in different Asian countries which are one time or other found associated with severe economic losses. If this scenario continues, by the next decade, phytoplasma diseases will become a serious biotic factor in reducing the crop yields in Asian countries.

As phytoplasmas cannot be cultured *in vitro*, the routine culture-dependent metrics and characteristics for bacterial identification (morphological observation, biochemical assay, serotyping and antibiotic inhibition/resistance pattern assessment) cannot be employed. Phytoplasma detection and characterization heavily rely on the molecular diagnostic techniques. With the rapid development of molecular diagnostic techniques all over Asia, a variety of fast, sensitive, and cost effective phytoplasma detection methods have emerged, ranging from PCR, nested PCR, real time PCR, droplet digital PCR (ddPCR), and loop-mediated isothermal amplification (LAMP) -based detection methods for authentic characterization of phytoplasma strains in most of the Asian countries. These methods are devised based on highly conserved gene sequences of phytoplasmas, namely *16S rRNA* gene, *rp* gene, *secY* gene and *tuf* gene, etc. However, the rapid expansion of molecular techniques and the advent of high throughput genome sequencing have tremendously enhanced the nucleotide sequence-based phytoplasma taxonomy in Asian countries.

The commonly adopted classification system for phytoplasmas has been based on the sequence of 16S rRNA gene or the restriction fragment length polymorphism analysis. However, with the increased availability of genomic sequences, it is believed that comparison of phytoplasma at the whole genome is highly useful in finer taxonomic classification.By 2022, 18 Asian phytoplasma genome assemblies are available in GenBank from Japan,China, Taiwan, India, Iran and Lebanon enabling better understanding of the phylogenetic position, virulence, infection, transmissibility, host responses and interactions. Genome sequencing has also contributed to the development of phytoplasma detection methods which will aid in quick and reliable diagnostic of phytoplasmas in future.

In most Asian countries, the transmission of phytoplasmas is a serious concern. Insect vectors are the main sources for phytoplasma dissemination to other plants. Many leafhoppers, planthoppers and psyllid species are identified as potential natural transmitters for different strains of phytoplasmas infecting different crops all over Asia. Though the occurrence of these insect vectors in Asia have not been very well established, every care should be taken to restrict the entry of infested plant cuttings with insects to avoid entry of potential insects in a newer location of Asia. Further studies that evaluate vector populations in different crops-growing areas in Asia may determine the presence of new potential vectors involved in the phytoplasma disease epidemiological patterns. However, it is important to exchange the certified propagation materials that are free of diseases and vector across the borders, to limit the dissemination of phytoplasmas.

Overall, monitoring pests and trading certified plants are the most crucial steps to prevent the phytoplasma spread. Considering that the phytoplasmas are mainly spread by insect vectors or *via* vegetative propagation (grafting or cuttings) and several plant species can be a natural host for several phytoplasma strains, the risk of outbreak of phytoplasmas diseases in agricultural areas of Asia could be facilitated by vegetative propagation, import of infected plant material, and discovery of new or already known insect vectors that are able to spread phytoplasma strains in crops.

In the last decades, an extensive increase in phytoplasma reports has been published from the Asian countries especially China, India, Iran, Turkey, Japan, Korea, Indonesia and Arab Gulf countries. This knowledge increased the awareness of risks related to the introduction of new phytoplasma diseases and their strains and their potential spread through the commercial exchanges of infected propagation material inside Asian and from other parts of the world, which would threaten the agricultural related ecosystems and industry. Asian countries have a great genetic diversity of phytoplasma strains. Over more than 250 plant species are known to be hosts of 26 ribosomal groups of phytoplasmas in Asian countries. Maximum reports are available from India, China and Iran. Currently, climate change, particularly global warming, affects not only the multiplication of phytoplasmas but also the fitness and population dynamics of insect vectors, which have a great impact on the geographical distribution and severity of phytoplasma diseases in Asian countries.

As a whole, phytoplasmas belonging to the 16SrI, 16SrII, 16SrIII, 16SrV, 16SrVI, 16SrVIII, 16SrIX, 16SrX, 16SrXI, 16SrXII, 16SrXIV, 16SrXXX and 16SrXXXII groups have a range of plant hosts all over Asia. As a result, phytoplasmas and their associated diseases have become an emerging threat to agriculture in Asia countries. Further efforts on epidemiology and to elucidate the molecular mechanisms of plant-insect vector-phytoplasma interactions, full genome sequencing of the emerging phytoplasma strains of Asia and management aspects will greatly contribute to a sustainable development of eco-friendly tools to control the phytoplasma-associated diseases in Asia.

As there is no effective cure for the phytoplasma-associated diseases, the management options mostly emphasize the awareness of the phytoplasma diseases in society, growers and scientific community all over Asia. The scientific literature concerning phytoplasma occurrence, characterization, detection, and management is growing at a fast pace all over Asia, hence increasing awareness about different emerging phytoplasma diseases and their significance of relevant importance would help in planning future management strategies.

No single approach can provide effective and long lasting management of phytoplasma diseases. Newer approaches are being continuously developed and explored to manage the diseases in Asia, but it has always been suggested that an integrated approached would be of more practical. In the field, phytoplasma disease management is based mainly by conventional agronomical approach of eradication of infected plants/alternate hosts and control of insect vectors. Use of resistance plants is considered to be an effective and environmentally safe long term sustainable approach for preventing the recurrence of emerging phytoplasma diseases.Aside from using insecticides to target the insect vectors, a few other approaches for phytoplasma disease management should be adopted including thermotherapy, development of resistant plant varieties, and propagation of phytoplasma-free planting materials which may project better management strategy.

A temporary remission of symptoms by applying tetracycline antibiotics into the plant was successfully demonstrated for several phytoplasma maladies in Asian countries, but their regular use is limited due to impractical application and environmental risks, hence it is necessary to look for other environmentally friendly approach towards management of phytoplasma diseases. The production of genetically engineered plants by introducing disease–resistance genes into cultivated crops together with the use of resistance inducer microorganisms,

would represent novel potential tools to control phytoplasmas in recent years. Legislative regulations and quarantine facilities enforcement to restrict the entry of exotic phytoplasma strains in new locations in Asia should be implemented and established at national and international entry points.

Overall, monitoring of pests and trading of certified plants are the most crucial steps to prevent the phytoplasma spread in Asian continent. It is also important to regularly examine and detect the new variants of the phytoplasma strains which are constantly emerging in different Asian countries. Indeed, disease prevention and control should also consider the potential role of phytoplasma strains belonging to the 16SrI, -II, -V, -VI, -IX, -XI,-XII and –XIV groups associated with emerging diseases in economically important agricultural crops in Asia which will open new possible epidemiological patterns in crop ecosystems throughout Asia. Markets for agri-food products are changing in developing countries at a pace that is unequalled in modern history. Thus, agriculture department in many Asian countries should have a proper channel for plants or crops to go through the unified trading process. The spread of phytoplasma diseases in Asia can be effectively checked by utilizing molecular diagnostic tools, rigorous pest monitoring and trading of certified plants.

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