ARTICLE OF GENERAL INTEREST

An overview of the status and the potential impact of the exotic pathogens on Indian horticulture

S. LATHA and N. SATHYANARAYANA
National Institute of Plant Health Management, Rajendranagar, Hyderabad-500 030, India
Email: lathasrao@hotmail.com

INTRODUCTION

International trade is witnessing sea of changes in the post-WTO trade liberalization era. The increase in voluminous trade across globe has been several folds and the further advances in long distance transport and availability of cold-chain, refrigerated container facility facilitated trade in live plants, fresh fruits and vegetables across the globe. This trade has also increased the potential risk of plant pests accompanying the commodities. Though every country has and mainly relies upon Plant Quarantine system to prevent entry, establishment and spread of exotic plant pests, it is practically not possible to avoid accidental / intentional introduction of exotic pests. Further there is a global awakening on the importance of alien invasive species and the harm it can inflict on environment, apart from the direct damage to the crops. The threat of invasive alien species is further compounded by climate change. The exotic pests, not only affect agriculture, horticulture, pasture lands and forests, but also inflict major impact on environment and biodiversity of a nation.

Each country has its own import regulations as preventive measure to combat entry, establishment and spread of quarantine pests. In India, The Plant Quarantine (Regulation of Import into India) Order, 2003 (PQ Order, 2003) issued under the Destructive Insects and Pests Act, 1914 is the import regulation and being implemented by National Plant Protection Organization i.e. Directorate of Plant Protection Quarantine and Storage (DPPQS) through plant quarantine system. In accordance with Sanitary and Phytosanitary Measures of WTO, Quarantine Pests are notified based on the scientific approach of Pest Risk Analysis. More than 700 pests are regulated on various agricultural and horticultural commodities in the PQ Order. The import of plant and plant materials are regulated by the plant quarantine stations established at notified international airports/ seaports/ land frontiers through inspection, sampling and testing to prevent entry and establishment of exotic pests through imported plant and plant materials. Many exotic pests of quarantine significance have been intercepted in imported plant materials. In spite of the best efforts of regulating import to prevent the entry of exotic pests, many plant pests found their way into the country and are still causing economic impact to various stakeholders.

Impact of Pest Incursions into India

In the recent past, incursions of many exotic pests have taken place at a higher rate than ever before. The increase in global trade has direct relevance to these pest incursions. Many pests have invaded into India and it is quite difficult to pin-point the pathways of entry since India shares porous borders with many neighbouring countries. The incursions of pests such as papaya mealybug, coconut eriophid mite, eucalyptus gall wasp, erythrina gall wasp, coffee berry borer, spiralling whitefly, serpentine leaf miner, sunflower downy mildew, anthurium blight, crown gall, parthenium, phalaris etc., are still causing economic damage.

Plant pathogens such as Groundnut bud necrosis virus (GBNV), soybean bud blight, mungbean/ urd bean leaf curl, tomato bud blight and potato stem necrosis, bunchy top of banana, and Tobacco streak virus (TSV) in sunflower and other crops, are emerging as serious problems and continuing to spread over large areas. India faced losses of over US$ 236 million in recent years due to late blight disease of potato caused by Phytophthora infestans affecting potato field grown over 1.4 million hectares in the country. Foliar blight in wheat, bract mosaic in banana, sheath blight in maize and paddy are few other serious pathogens causing considerable losses. The plant pathogens introduced into India is enumerated in Table-1.

Movement of Domestic Quarantine pests

There are nine introduced pests that have been notified under domestic quarantine regulation by...
Status of exotic pathogens

Table 1. List of introduced pathogens into India

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name of pathogen</th>
<th>Introduced from</th>
<th>Path way</th>
<th>Year of first report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee rust</td>
<td><em>Hemillia vastatrix</em></td>
<td>Sri Lanka</td>
<td>Planting material</td>
<td>1879</td>
</tr>
<tr>
<td>Late blight of Potato</td>
<td><em>Phytophthora infestans</em></td>
<td>Europe</td>
<td>Potato</td>
<td>1883</td>
</tr>
<tr>
<td>Flag smut of Wheat</td>
<td><em>Urocystis tritici</em></td>
<td>Australia</td>
<td>Grains</td>
<td>1906</td>
</tr>
<tr>
<td>Grape downy mildew</td>
<td><em>Plasmopara viticola</em></td>
<td>Europe</td>
<td>Planting material</td>
<td>1910</td>
</tr>
<tr>
<td>Powdery mildew of Rubber</td>
<td><em>Oidium heveae</em></td>
<td>Malaysia</td>
<td>Planting material</td>
<td>1938</td>
</tr>
<tr>
<td>Black shank of Tobacco</td>
<td><em>Phytophthora parasitica</em> var. nitociana*</td>
<td>Dutch</td>
<td>Planting material</td>
<td>1938</td>
</tr>
<tr>
<td>Bunchy top of Banana</td>
<td>Bunchy top of Banana viroid</td>
<td>Sri Lanka</td>
<td>Planting material</td>
<td>1940</td>
</tr>
<tr>
<td>Crown gall</td>
<td><em>Agrobacterium tumefaciens</em></td>
<td>UK / Netherlands</td>
<td>Planting material</td>
<td>1940</td>
</tr>
<tr>
<td>Apple canker</td>
<td><em>Sphaeropsis malorum</em></td>
<td>Australia</td>
<td>Planting material</td>
<td>1943</td>
</tr>
<tr>
<td>Potato wart</td>
<td><em>Synchytrium endobioticum</em></td>
<td>Netherlands</td>
<td>Planting material</td>
<td>1953</td>
</tr>
<tr>
<td>Banana mosaic</td>
<td><em>Banana mosaic virus</em></td>
<td>-</td>
<td>Planting material</td>
<td>1961</td>
</tr>
<tr>
<td>Golden cyst nematode</td>
<td><em>Globodera rostochinensis</em></td>
<td>UK</td>
<td>Potato tuber / planting material</td>
<td>1961</td>
</tr>
<tr>
<td>Golden cyst nematode</td>
<td><em>Globodera pallida</em></td>
<td>UK</td>
<td>Potato tuber / planting material</td>
<td>1961</td>
</tr>
<tr>
<td>Apple scab</td>
<td><em>Venturia inequalis</em></td>
<td>UK</td>
<td>Planting material</td>
<td>1978</td>
</tr>
<tr>
<td>Downy mildew of Sunflower</td>
<td><em>Plasmopara halstedii</em></td>
<td>USA</td>
<td>Seeds</td>
<td>1984</td>
</tr>
<tr>
<td>Peanut stripe virus - Groundnut</td>
<td><em>Peanut stripe virus</em></td>
<td>China</td>
<td>Seeds</td>
<td>1987</td>
</tr>
<tr>
<td>Banana bract and streak virus</td>
<td><em>Banana bract and streak virus</em></td>
<td>Sri Lanka</td>
<td>Planting material</td>
<td>1995</td>
</tr>
<tr>
<td>Anthurium blight</td>
<td><em>Xanthomonas dieffenbachiae</em></td>
<td>Netherlands</td>
<td>Planting material</td>
<td>1996</td>
</tr>
<tr>
<td>Sunflower necrosis virus</td>
<td><em>Sunflower necrosis ilar virus</em></td>
<td></td>
<td></td>
<td>1997</td>
</tr>
</tbody>
</table>

Quarantine Pests prevented from Entry (Interception of Quarantine Pests)

The impacts of invasive pest incursions are poorly evaluated in India. To some extent the entry could have been prevented and the impact minimized if proper vigil, awareness and preparedness is in place. With availability of varied agro-climatic zones and crops, India is vulnerable to many pest incursions. Agricultural / Horticultural economy is under threat of such invasive species. However, many pests of quarantine significance have been prevented from entering into the country by Plant Quarantine Organization through import of commercial cargo and germplasm, which is witnessed by the important interceptions of exotic pests. Many exotic and economically important pests have been intercepted from time to time in the imported commodities by the Plant Quarantine, to cite a few, poty.

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virus in Oil Palm (Reddy, et al., 1996). Xanthomonas campestris pv. dieffenbachiae on Anthurium (Sathyanaryana, et al., 1998), Crown gall (Agrobacterium tumefaciens) pathogen in Rose (Sathyanaryana, et al., 2002), palm seed weevil (Caryobruchus gleditsiae) on Sabal palm seeds (Kumarasamy, et al., 2002), Cymbidium mosaic virus on Dendrobium (Sathyanarayana, et al., 2003), Garlic bulb canker (Embellisia allii) on garlic bulbs (Latha, et al., 2006), many nematodes on various ornamental and fruit plants (Latha, et al., 1997;1999), Hypothenemus obscurus (Tropical nut borer) on Butia seeds (Latha et al. 2011) and Fusarium oxysporum f.sp. callistephi on Marigold, Plumeria rust (Coleosporium domingense), downy mildew (Peronospora farinosa) on beet Peronospora manshurica on soybean, Xanthomonas vesicatoria on Chilli and tomato seeds, Chrysanthemum white rust (Puccinia horiana) on Chrysanthemum cut flowers, Odontoglossum ringspot virus on Orchids, were intercepted on agricultural commodities imported for commercial purpose. Further, exotic pests such as Uromyces betae on Sugarbeet, Fusarium nivale on Wheat, Cowpea mottle virus on Cowpea, Tomato black ring virus on French bean, Heterodera saechtii on Sugarbeet, Anthomonous grandis on Cotton and Quadrastichodella eucalypti on Eucalyptus and many such quarantine pests were intercepted on Germplasm materials (Khetarpal and Gupta, 2007).

Exotic pests of concern on Vegetable crops

India holds the second position in world production of fresh produce such as vegetables and fruits next to China. Many seeds of vegetables are imported from various countries in huge quantities to meet the domestic demand for seeds of high yielding varieties / hybrids. India is still free from many exotic pests of concern to horticultural crops. Vegetable seeds such as Beet, Carrot, Coriander, Chilli, Tomato, Onion, Okra, Egg plant, Cucumber, Ridge gourd, Bottle gourd, Bitter gourd, Cabbage, Broccoli, Cauliflower, Brussels sprout, etc., are imported regularly. The potential threats of many seed-borne pathogens accompanying such commodities are quite high and pose real threat to biosecurity of the nation. Major plant disease threats through imported vegetable seeds are enumerated in Table 2.

Fungi

Fusarium oxysporum f.sp. cucumerinum: Fusarium wilt of Cucumber is host specific and infects only Cucumber. The pathogen is externally and internally seedborne and can survive on stored seeds for more than a year.

Peronospora farinosa: Downy mildew of Beet is able to disseminate through imported seeds as seed-contaminant. The mycelium and oospores can be isolated from the contaminated seeds. The infection can cause weight loss in beet (25-32%) and loss in sugar content in sugarbeet ranging from 1.5 to 2.3 per cent. The major hosts are Beet and Sugarbeet.

Peronospora hyoscyami f.sp. tabacina: Commonly known as blue mould of tobacco. Major host is tobacco and minor hosts are Chilli and Eggplant. The role of infected seeds as main source of dissemination is not clear / undetermined so far.

Phomopsis longicolla: Levels of seed infection detected in USA are upto 87 per cent. The pathogen can survive upto 2 years if the seeds are kept under cool dry conditions. Has a wider host range of economically important crops such as okra, onion, groundnut, chilli, chickpea, tomato, bean, pea and cowpea.

Uromyces beticola (syn: Uromyces betae): Beet rust is a seed-borne pathogen infecting sugarbeet and beet. Teliospores contaminated seeds serve as main source inoculums.

Urocystis cepulae: The onion smut disease is not seed-borne, but the seeds can be contaminated with smut spores as it is primarily a soil-borne pathogen. The onion smut infects all Allium spp. Yield losses upto 70 – 90 per cent observed in severely infected plots.

Bacteria

Acidovorax avenuea subsp.citrulli: The host species for Fruit blotch are Watermelon, Melon, Cucumber and Pumpkin. The dissemination of the pathogen is through infected seeds. The fruit blotch bacterium can survive for several years on infected seed material. Seeds collected from infected fruits can have 80 per cent infection. Cause severe seedling mortality when overhead irrigation is used for raising seedling beds.

Clavibacter michiganensis sub sp. michiganensis: Tomato and Chilli are the hosts for Bacterial canker of Tomato pathogen. The pathogen is seedborne and infected seed is the main source of dissemination. The bacterium can survive on infected seed for more than a year and 82 per cent of infected seeds were found to be viable upto 18 months and 0 per cent survived if the seeds were stored for 2 years.

Clavibacter michiganensis subsp. sepedonicus: Commonly known as potato ringrot. Major hosts are Tomato, Potato, Eggplant and Sugarbeet. The pathogen is not transmitted through seeds of potato, however,
Table 2. Quarantine Pests of Concern in imported Vegetable Seeds

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Name of Commodity</th>
<th>Quarantine Pests of Concern to India</th>
</tr>
</thead>
</table>
| 1      | *Abelmoschus esculentus* (Okra) | *Phomopsis longicolla* (Pod and stem blight)  
*Cercospora abelmoschi* (Leafspot of Okra) |
| 2      | *Allium spp.* (Onion, Garlic, Shallot, Leek) | *Urocystis cepulae* (Smut)  
*Pseudomonas marginalis* pv. *marginalis* (Marginal necrosis)  
*Phomopsis longicolla* (Pod and stem blight) |
| 3      | *Apium graveolens* (Celery) | *Ditylenchus dipsaci* (stem and bulb nematode)  
*Pseudomonas viridiflava* (bacterial leaf blight of tomato)  
*Arabis mosaic virus*  
*Celery mosaic virus*  
*Peanut stunt virus*  
*Strawberry latent ringspot virus* |
| 4      | *Beta vulgaris* (Beet Root) | *Downy mildew* (*Peronospora farinosa*)  
*Bacterial blight* (*Pseudomonas syringae* pv. *aptata*)  
*Beetroot cyst nematode* (*Heterodera schachtii*)  
*Beetroot rust* (*Uromyces beticola*) |
| 5      | *Brassica spp.* (Cabbage, Cauliflower, Brussels sprouts, Broccoli, Chinese Cabbage) | *Leptosphaeria maculans* (black leg)  
*Pseudomonas viridiflava* (bacterial leaf blight of tomato) |
| 6      | *Capsicum spp.* (Pepper/ Chillies) | *Peronospora hyoscyami* sp. *tabacina* (Blue mould of Tobacco)  
*Tomato ringspot virus*  
*Tomato black ring virus*  
*Pepper mild mottle virus* |
| 7      | *Cichorium spp.* (Chicory and Endive) | *Bacterial blight* (*Pseudomonas cichorii*)  
*Anthracnose* (*Marssonina panatoniana*) |
| 8      | *Coriandrum sativum* (Coriander) | *Pseudomonas viridiflava*  
*Xanthomonas hortorum* pv. *carotae* (bacterial blight of carrot)  
*Celery mosaic virus* |
| 9      | *Cucumis sativus* (Cucumber) | *Fusarium oxysporum* f. *sp. cucumerinum* (fusarial wilt)  
*Black spot* (*Phomopsis sclerotioides*)  
*Arabis mosaic virus* (hop bare–bine)  
*Tomato ringspot virus*  
*Squash mosaic virus* |
| 10     | *Cucurbita maxima* (Banana Squash) | *Pseudomonas viridiflava* (bacterial leaf blight of tomato)  
*Zucchini yellow mosaic virus* |
| 11     | *Cucurbita moschata* (Pumpkin) | *Zucchini yellow mosaic virus* |
| 12     | *Cucurbita pepo* (Summer Squash) | *Arabis mosaic virus* (hop bare–bine)  
*Zucchini yellow mosaic virus* I  
*Acidovorax avenae* subsp. *citrulli* (bacterial fruit blotch) |
| 13     | *Daucus carota* (Carrot) | *Bacterial blight* (*Xanthomonas hortorum* pv. *carotae*) |
| 14     | *Lactuca sativa* (Lettuce) | *Arabis mosaic virus*  
*Tobacco rattle virus* |
| 15     | *Lagenaria siceraria* (Bottle gourd) | *Fusarium oxysporum* f.sp. *lagenariae* (bottle gourd wilt) |
| 16     | *Luffa aegyptiaca* (Sponge gourd) | *Zucchini yellow mosaic virus* |
| 17     | *Lycopersicon esculentum* (Tomato) | *Bacterial canker* (*Clavibacter michiganensis* sub sp. *michiganensis*)  
*Bacterial leaf spot* (*Pseudomonas syringae* pv. *tomato*)  
*Potato spindle tuber viroid*  
*Peronospora hyoscyami* sp. *tabacina*  
*Phoma andigena*  
*Clavibacter michiganensis* subsp. *sepedonicus*  
*Pepino mosaic virus*  
*Tomato aspermy virus*  
*Tomato black ring virus*  
*Tomato bushy stunt virus*  
*Tomato ring spot virus* |
infected seed tubers serve as major source of inoculum. Pathogen was isolated from seeds of sugar beet. The pathogen causes early death and extensive yield reduction. A high level of infection can cause total yield loss.

**Pseudomonas cichorii**: Commonly known as bacterial blight of Endive. This pathogen has a very wide host range and can incite disease in large number of plant species. The important ones are Okra, Cabbage, Cauliflower, Rake, Turnip, Chilli, Celery, Carrot, Tomato, and Bean. The pathogen can be transmitted by seeds. The serpentine leaf miner (*Liriomyza trifoli*ii) is able to transmit *Pseudomonas cichorii* from infected to uninfected Chrysanthemum.

**Pseudomonas syringae pv. aptata**: Seed-contamination with the sugarbeet leafspot bacterium seems to be the source of dissemination. Beet, Chilli, Cucumber, Sunflower, Lettuce, Bean, Egg plant and cowpea are the major hosts.

**Pseudomonas marginalis pv. marginalis**: Lettuce marginal leaf blight is a common pathogen associated with bean seeds. Crop losses up to 10 – 40 per cent were recorded in Canada and New Zealand. The major hosts are Onion, Celery, Beet, Cabbage, Cauliflower, Broccoli, Choricry, Chilli, Cucumber, Carrot, Sunflower, Lettuce, Tomato, Tobacco, Parsley, Bean, Radish and Potato.

**Pseudomonas viridiflava**: The bacterial leaf blight of Tomato is carried as surface contaminant of seeds and transmitted through seeds. The major hosts are Onion, Cabbage, Cauliflower, Broccoli, Brussels sprout, Celery, Chilli, Melon, Cucumber, Pumpkin and Tomato.

**Xanthomonas hortorum pv. carotae**: Carrot and Coriander are the hosts for carrot leaf blight pathogen. The seeds produced from infected plants are readily contaminated with this pathogen. Seed-borne transmission of this pathogen is the major source of dissemination. Yield losses have been observed in carrot fields.

### Viruses and Viroids

**Arabis mosaic nepovirus (ArMV)**: Arabis mosaic virus is transmitted by *Xiphinema diversicaudatum* nematode and through infected seed. 15 species in 12 plant families are known to carry the pathogen on seeds. Major hosts are Celery, Sugarbeet, Cucumber, Carrot and Lettuce. Further, the virus is reported to be transmitted through Dodder.

**Peanut stunt virus (PSV)**: Peanut stunt virus naturally infects several leguminous and solanaceae crops. Major hosts are Celery, Groundnut, Soybean, Tomato, Tobacco, Bean, Pea and Cowpea. The pathogen is transmitted by Aphid vectors in the field. Seed-transmission is observed in Groundnut, Soybean, Bean and Tobacco.

**Pepper mild mottle tomatovirus (PMMV)**: Bell pepper, Chilli and Tomato are the hosts for PMMV. The virus is seedborne and commonly found on outer seed coat and rarely on endosperm. The seed-borne infection is very high, however if the seeds are stored for more than 11 months the viability of PMMV decreases. The levels of infection on seed can range from 0.23 to 100 per cent. PMMV is known to cause considerable yield loss (20-30%) in Bell pepper and Chilli. Like other tobamoviruses, PMMV is highly contagious.

**Potato spindle tuber viroid (PSTVD)**: Potato spindle tuber viroid can be readily transmitted through Tomato and Potato seeds and pollen. Tomato, Potato, Eggplant and Sweet potato are the major hosts for this viroid. Known cause yield losses in Potato and Tomato.

**Strawberry latent ringspot virus (SLRSV)**: SLRSV is transmitted by free-living soil nematodes and through seeds. Major hosts are Celery, Strawberry and many fruit crops. 70 per cent seed infection in naturally infected plants has been reported. Since the virus has a wider host range in fruit trees, it is economically important as it can impact yield and vigour of infected plants.

**Tomato bushy stunt virus – Lycopersicon virus 4 (TBSV)**: Chilli, Tomato and Eggplant are the major hosts.
for TBSV. Seed-borne incidence at a rate of 50-65 per cent was demonstrated in Tomato seeds. This is a destructive pathogen and yield losses upto 80 per cent were recorded in Tomato fields.

**Tomato ringspot nepovirus (ToRSV):** Capsicum, Tomato are the major agricultural host, however, tomato ringspot virus has got a wider host range. ToRSV is seedborne and can be disseminated through seeds to newer areas. The devastating effect of the pathogen is correlated with nematode vector belonging to *Xiphinema* spp. The virus is known to cause severe damage in pome fruits, strawberry and raspberry. Yield loss upto 80 per cent are recorded due to this virus infection.

**Nematodes**

*Ditylenchus dipsaci*: Stem and bulb nematode is known to attack more than 450 plant species including many weeds. More than 20 biological races have been recorded, and some are known to exhibit host specificity. But most of them are polyphagous. Major hosts are *Allium* spp. (Onion, Garlic, Leek), sugarbeet, bean, peas and potato. The nematode can survive in dry seeds and planting materials in an anhydrous (dessicated) condition for many years. Stem and bulb nematode is seedborne in 15 plant species. The contamination of stem and bulb nematode in commercial seed stocks ranged from 36 – 45 per cent on economically important crops such as bean, pea, beet, carrot, onion and leek. Seed infection serves as main source of dissemination in international trade.

*Heterodera schachtii*: Beet cyst nematode has vast host range, the important hosts are beet, sugarbeet, cabbage, cauliflower, mustard, rape, turnip, bean, pea, radish and spinach. *Heterodera schachtii* is a soil-borne nematode and the cysts can be carried as surface contaminant of seeds or soil clods and plant debris.

**CONCLUSION**

The enormous responsibility of preventing these pest incursion lies with all the stakeholders. Proper inspection, sampling and testing and appropriate action in the event of pest interception or pest report to mitigate shall help the food security of the nation and also help in preventing further spread. The exorbitant expenditure incurred to control exotic pests can be avoided. More than 50 per cent of the population is directly or indirectly dependent on agriculture as main source of livelihood. Promotion of safe trade, use of certified seeds and timely containment and eradication measures are the key principles to save biodiversity of India.

**REFERENCES**


*MS Received :* 1 June 2012
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