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A Review on Invasive Pests of Horticultural Crop Ecosystems

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ABSTRACT: The agricultural sector of India is under risk from numerous possible bioweapons, primarily invasive pest species. Exotic, introduced, alien, non-indigenous or non-native species that have been unintentionally or purposefully introduced by humans from one area to another are considered invasive pest species. Due to trade liberalisation and greater intercontinental travel by people, the invasion of invasive insects has grown globally. So far, 34 different invasive insect pests of horticultural crops are recorded in India. The valuable natural agricultural systems that support us and the biodiversity are both suffering severe harm from these animals. The damage to nature and the environment is frequently irreparable and direct and indirect health repercussions are becoming more significant. The exact monitory values of the losses caused by these invasive pests on horticultural crops are not properly known. By having a fundamental understanding of invasive pest species and fostering international collaboration through the sharing of knowledge about invasive pests and their natural enemies, the introduction of new pest species in a new area can be minimised. India will be safe from such invasive pests due to strict import rules, international trade and commerce cooperation, early detection and taxonomic identification at entry points.

Keywords: Invasive pests, horticultural crops and management.

INTRODUCTION

Horticulture output currently represents 30.4 per cent of agriculture GDP and is a significant driver of economic growth in many states across the country. India is the world's second largest producer of fruits and vegetables and the largest producer of many other commodities, including mango, banana, coconut, cashew, papaya and pomegranate. Fresh fruit and vegetable exports have increased by 14 per cent in value in international trade, while processed fruit and vegetable exports have increased by 16.27 per cent (Senguttuvan, 2020). However, the study of invasive pests and their management is important in the production of horticultural crops.

Exotic, introduced, non-indigenous or non-native species are additional terms for invasive pest species. We introduce it intentionally, accidentally or through human agency from one geographic region to another for societal or individual gain. The area's biodiversity is at danger because of these recently imported species. These imported species pose a serious threat to our biosecurity of nation in addition to the threat they pose to biodiversity (Chalapathi Rao *et al.*, 2018). The likelihood of some exotic pests entering unintentionally has increased in recent years due to frequent exchanges of planting material between nations. These insect pests can grow rapidly and harm crop plants and species of commercially significant plants.

The Destructive Insect and Pest Act of 1914 was implemented in India by the Directorate of Plant Protection, Quarantine and Storage through the Plant Quarantine (Regulation of Import into India) Order, 2003, which aims to protect horticulture and forest tree plants by preventing the entry, establishment, and spread of exotic plant pests. To carry out the stipulations of the PQ Order, 2003, Plant Quarantine stations are set up at various points of entry, including seaports, airports, and land frontiers. The list of exotic pests of horticultural crops are presented in table 1till to date.

Table 1: List of invasive insect pests of horticultural crops in India.

Common name	Scientific name	Origin	Introduced Year	Host Dynamics	Reference
Woolly apple aphid	*Eriosoma lanigerum* (Hausmann)	China/America	1889	Apple, Pear	Mishra (1920)
San Jose scale	*Quadraspidiotus perniciousus* (Comstock)	China	1911	Apple, *Populus* spp., *Salix* spp., *Aesculus* spp., *Alnus* spp	Singh (2004)
Diamond back moth	*Plutella xylostella* (Linnaeus)	Europe and East Asia	1914	Cruciferous vegetables *viz*., cauliflower, cabbage, *knol-khol* (*rabi*), mustard, radish, beet root and turnip	Fletcher (1914)
Lantana Bug	*Ortheziai nsignis* (Browne)	Sri Lanka/ West Indies	1915	Lantana, Coffee, Jacaranda, Gumwood, Brinjal, Rose etc	Muniappan and Viraktamath (1986)
Cottony cushion scale	*Icerya purchasi* (Maskell)	Australia	1921	Wattle tree, Guava and *Acacia decurrens*	Singh (2004)
Potato tuber moth	*Phthorimaea operculella* (Zeller)	Italy	1937	Stored potatoes, tobacco, tomato, brinjal, beat.	Singh (2004)
Pine woolly aphid	*Pineuspini* (Macquart)	Western and Central Europe	1970	*Pineuspatula*	Singh (2004)
Brown Peach Aphid	*Pterochloroides persicae* (Cholodkovsky)	Central Asia	1970	Peach, almond and other temperate crops	Mann *et al*. (1979); Mahendiran *et al.* (2018)
Banana Skipper	*Erionota torus* (Evans)	South East Asia	1987	Banana	Prasad and Singh (1987); Deka *et al.* (1996); Raju *et al.* (2015)
Subabulpsyllid	*Heteropsylla cubana* (Crawford)	Central America	1988	*Leucaena* plantations	Jalali and Singh (1989)
Serpentine leaf miner	*Liriomyza trifolii* (Burgess)	Florida (U.S.A)	1990	Pea, tomato, cucurbits, ornamental plants and castor	Singh (2004)
Coffee berry borer	*Hypothenemus hampei* (Ferrari)	Africa	1990	Arabica and Robusta types of coffee	Vega *et al*. (1999)
Spiralling whitefly	*Aleurodicus dispersus* (Russell)	Central America	1993	Mainly Guava, wide host range of 481 plants	Palaniswami *et al*. (1995)
Eriophyid mite	*Aceria gurreronis* (Keifer)	Mexico	1997	Coconut	Singh (2004)
Guava Stem borer	*Aristobia reticulator* (Voet)	China	1997	Guava, Litchi and Aonla	Shyleshae *t al.* (2000)
Silver leaf whitefly	*Bemisia argentifolii* (Bellows)	United States	1999	Tomato	Singh (2004)
Arecanut whitefly	*Aleurocanthus arecae* (Quaintance & Baker)	Asia	2003	Arecanut	David and Manjunath (2003)
Papaya mealy bug	*Paracoccus marginatus* (Williams & Granara de Willink)	Mexico	2005	Primary- Papaya, Other hosts- Guava, Cassava, Sweet Potato and Brinjal	Jhala *et al*. (2008)
Lotus lily midge	*Stenochironomus nelumbus* (Tok and Kur)	China	2005	Lotus	Deepu and Habeeburrahman (2008)
Erythrina gall wasp	*Quadrastichus erythrinae* (Kim)	Tanzania / East Africa	2005	Erythrina sp.	Faizal *et al*. (2006)
Blue gum chalcid	*Leptocybe invasa* (Fisher & LaSalle)	Australia	2006	*Eucalyptus camaldulensis*, *E. tereticornis* and *E. grandis*	Gupta and Poorani (2009)
Cotton Mealy bug	*Phenococcus solenopsis* (Tinsley)	North America	2006	Brinjal, Okra, Tomato and Chinarose	Nagrare *et al.* (2009)
Tomato Pin worm	*Tuta absoluta* (Meyrick)	South America	2014	Primary- Tomato, Other hosts-Potato, Brinjal, Tobacco,	Sridhar *et al*. (2014)

				Hot pepper	
Solanum Whitefly	*Aleurothrixus trachoides* (Back)	Neotropical region	2014	Solanaceae plants like Brinjal, Chilli, and Tomato. 24 host plants of 11 families.	Dubey and Sundararaj (2015)
Western Flower Thrips	*Frankliniella occidentalis* (Pergande)	Southwestern United States	2015	Chrysanthemum, Capsicum, Cucumber and Tomato	Tyagi and Kumar (2015)
Invasive Pest Thrips	*Thrips parvispinus* (Karny)	South East Asia	2015	Papaya, Dahlia and Chilli	Tyagi *et al.* (2015)
Rugose Spiralling Whitefly (RSW)	*Aleurodicus rugioperculetus* (Martin)	Florida (U.S.A)	2016	Primary- Coconut, Polyphagousupto 118 hosts	Sundararaj and Selvaraj (2017); Chalapathi Rao *et al.* (2018)
Arecanut aphid	*Tuberaphis xinglongensis* (Zhang)	East and South–east Asia and Africa	2017	Arecanut	Sunil *et al.* (2021)
Nesting Whitefly (NW)	*Paraleyrodes minei* (Iacarrino)	Syria	2018	Mainly Coconut, Spreading to other hosts	Dubey (2019)
Bondars Nesting Whitefly (BNW)	*Paraleyrodes bondari* (Perrachi)	Central America	2018	Mainly Coconut, Oilpalm and other hosts	Josephrajkumar *et al.* (2019)
Wooly Whitefly	*Aleurothrixus floccosus* (Maskell)	Neotropical region	2019	Guava, Citrus. Plants upto 20 families.	Sundararaj*et al.*, (2020)
Palm Whitefly	*Aleurotrachelus atratus* (Hempel)	Brazil	2019	Coconut, *Dypsealutescens*. Plants upto 110 species.	Selvaraj *et al.* (2019)
Cassava Mealy Bug	*Phenacoccus manihoti* (Matile – Ferrero)	South America	2020	Cassava	Sampath *et al.* (2021)
Leek moth	*Acrolepiopsis assectella* (Zeller)	Europe	2020	Onion, leek, garlic, shallot	Dewangan and Deole (2021)

Common traits of invasive pests: It has a very high and rapid reproduction even at unfavourable conditions with more compatibility to survive with the alien ecosystem. It ought to be able to survive on a variety of different food sources. It has the ability to outcompete a native species due to its rapid development. It is capable of travelling great distances. Phenotypic plasticity exists.

List of invasive insect pests of horticultural crops in India

1. Woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Aphididae: Hemiptera). With the importation of Chinese apple rootstock during the 18th century, this pest was introduced to India. It was initially noted in Conoor in 1889 and reports from Kumaun in the Hills of Utter Pradesh (now in Uttarakhand) and Shimla in 1909 and 1910, respectively, followed. In India, it attained pest status in 1920 (Mishra, 1920). Adults and nymphs attack the roots of the plants by sucking the sap from them, causing swellings that make the plant seem sickly and may even cause it to die.

2. San jose scale, *Quadraspidiotus perniciosus* (Comstock) (Diaspididae: Hemiptera). The scale had made way to India in 1911, and by 1933 it had become a nuisance in willow and poplar plantations as well as fruit orchards. In general, it targets wood, but in cases of severe infestations, it can also penetrate leaves and fruits. Bark frequently splits open and discharges gum, leaving a dark-brown gelatinous region in its wake.

3. Lantana bug, *Ortheziai nsignis* Browne (Orthezidae: Hemiptera). The bug was introduced in the year 1915 into Nilgiri region of India. This mobile scale insect's female has a sizable wax ovisac. The eggs hatch inside the ovisac because this species is parthenogenetic and the nymphs of the first in star then migrate outside to feed.

4. Cottony cushion scale, *Icerya purchase* Maskell (Margarodidae: Hemiptera). In 1921, it was unintentionally introduced to India. In South India's Nilgiri and Annamalai highlands, the cotton cushion scale has severely infested plants and spread over the entire nation.

5. Potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae). It was invaded in India in 1907 together with Italian potatoes and quickly spread over the country (Lefroy, 1907). Caterpillar initially tunnels through leaves, then move through veins into petioles, then to stems, and eventually to the soil's tubers. In a single year, it can complete 12 generations (Hill, 1993).

6. Diamond-back moth, *Plutella xylostella* (Linn.) (Plutellidae: Lepidoptera). The discovery of DBM on cruciferous vegetables by Fletcher in 1914 was widely disseminated in India. Later instars dig holes whereas early instars mine the underside of leaves. Larva mining and leaf skeletonization take place.

7. Pine woolly aphid, *Pineuspini* (Macquart) (Adelgidae: Hemiptera). It was first introduced in India in the 1970s in the South Indian Nilgiri Hills. The main method used by this aphid to spread to new places

is the movement of infected planting stock. *Pinus* spp. shoots are consumed by the pine woolly aphid, which can occasionally result in tip dieback.

8. Brown peach aphid, *Pterochloroides persicae* Cholodkovsky (Aphididae: Hemiptera). The alien invasive aphid *Pterochloroides persicae* (Cholodkovsky) was reported in India for the first time sporadically from Kashmir valley, Shimla and Punjab on peach crop (Mann *et al.*, 1979).

This aphid weakens young fruit trees, causes branches to wither and reduces productivity by feeding on the inner cortex (Phloem). Premature fruit drop, leaf curving, an uneven twig curvature, stunted growth and sooty mould development as a result of excessive honey dew production are damage indications (Mahendiran *et al.*, 2018).

9. Banana skipper, *Erionota torus* Evans (Hesperiidae: Lepidoptera). The *Erionota* species was first identified in Southeast Asia and is now widely spread in Sikkim, Manipur (Prasad and Singh, 1987); Assam (Deka *et al.*, 1996). The *Erinota* species, which is traditionally known from the Himalayan East and Southeast ward, was described from Sikkim in India (Raju *et al*., 2015). Elakkibale, Sugandhalu and Grand Naine cultivars, which are members of the Dwarf Cavendish group (Srinivas Reddy and Hemadri 2018), are particularly vulnerable to this pest.

The first in star caterpillars feed on leaf edges while also building their own shelter by rolling the leaf edges, which they did in great numbers (11–20) on both leaf edges. In certain orchards, banana leaves completely defoliate, leaving only the midrib, causing serious damage.

10. Subabulpsyllid, *Heteropsylla cubana Crawford* (Psyllidae: Hemiptera). It originated in Central America and was brought to India in 1988 in Bangalore and the Chengalpattu area of Tamil Nadu. Young shoots are entirely deformed by the psyllid by sucking the sap from their leaves, inflorescences and young shoots.

11. Serpentine leaf miner, *Liriomyza trifolii* Burges (Agromyzidae: Diptera). The native land of pest is USA (Florida), where it was unintentionally introduced in the years 1990–1991. It was possibly brought to California, USA, along with cut chrysanthemum flowers in the early 1970s (Parrella, 1987). The first account of it occurring in India initially surfaced in the proceedings of the Hyderabad-based annual castor research workers' group conference. The mesophyll portion of the leaves is what the larvae mine for food. Accelerate leaf shedding to reveal fruits like tomatoes. It acts as a vector of diseases. Reduction in crop yields. Aesthetic value of ornamental plants is reduced.

12. Coffee berry borer, *Hypothenemus hampei* Ferrari (Scolytidae: Coleoptera). In India, Gudalur of Nilgiris was where the first reports of the coffee berry borer were made in 1990. It has since spread to other coffee-growing regions in Kerala (Wyanad), Karnataka and Tamil Nadu (Gudalur and Kilkotagiri) (Kodagu). The adult beetle measures 1.0-1.9mm, brownish-black. The majority of the population is often female. In order to lay bean-shaped eggs, the fertilised female bores an entrance hole in the terminal pore or in the calyx ridge of the differential tissue that surrounds the pore.

13. Spiralling whitefly, *Aleurodicus disperses* Russell (Aleyrodidae: Hemiptera). It is an origin from Caribbean region and Central America reported for the first time from Kerala in 1993 (Jhala *et al.*, 2008) and afterwards from remaining parts of peninsular India (David and Regu 1995). The nymphs and adults can cause early leaf drop by sucking sap from the host plants. Many whitish, waxy flocculent materials secreted by whitefly nymphs. In addition, the production of sticky honeydew provides a substrate for the dense growth of sooty mould, which inhibits photosynthesis.

14. Eripohyid mite, *Aceria gurreronis* Keifer (Eriophidae: Arachnida). It was first discovered in 1997 in Ernakulam district of Kerala, and it has since spread to significant coconut-growing regions. A survey carried out in Kerala in 1999 found that roughly 42% of plants were impacted, with an estimated yield loss of around 22 per cent. According to estimates, mite infestation caused a 2.12 per cent decrease in nut weight (Sreejith, 2011). The nuts discolour and the market value of nuts is affected.

15. Guava stem borer, *Aristobia reticulator* Voet (Cerambycidae: Coleoptera). In China, this borer is a common pest of long an trees. However this pest was noticed for the first time in India during 1997 as a stem borer on guava (Shylesha *et al.*, 2000). In Arunachal Pradesh this pest was also reported in Litchi (Kumawat *et al*., 2017) and in Aonla (Kumawat and Wangchu 2021).

The larvae of the beetles tunnel within the stem while they feed on the bark by girdling stems, branches and delicate twigs. The saplings and branches sustained the most harm from the grubs. The females made a slit in the bark and placed one egg there. Grubs that had just hatched began feeding sub-cortically before moving into the sapwood. Grubs continued to descend the branches while moving through their tunnels, feasting and expelling frass. Under the bark, a pupal cell was produced by the grub. Cut circular exit holes on the outside of the pupal cell, and beetles crawled out. The beetle has a life cycle that lasts around a year.

16. Silver leaf whitefly, *Bemisia argentifolia* Bellows (Aleyrodiadae: Hemiptera). It was introduced in the year 1999. It causes Leaf curl viral disease in Tomato (To LCVD).It infests by piercing plant leaf and extracting sap from it. It causes early leaf shedding, leaf withering and leaf chlorosis, early withering and plant thinning. Additionally, it slows down plant growth and yield.

17. Arecanut whitefly, *Aleurocanthus arecae* Quaintance & Baker (Aleyrodiadae: Hemiptera). This pest was introduced in the year 2003 noticed on Arecanut palm in Karnataka state, Andhra Pradesh (David and Manjunath 2003). It belongs to the group of *Aleurocanthus* sp. which possess very coarse marginal teeth (4-5 teeth) in the puparial stage. The puparium is blackish brown colour with powdery wax sparsely distributed on the cases found on the under surface of the arecanut leaves (David and Manjunath 2003).

18. Papaya mealy bug, *Paracoccus marginatus* Williams & Graner de Willink (Pseudococcidae: Hemiptera). It is a native from Neotropical region (Mexico, Guatemala) and introduced to Coimbatore (Tamil Nadu). It was noticed in Papaya in the year 2007. Leaves show crinkling. Leaves and fruits are covered with honey dew and sooty mould. It became a polyphagous pest and there was a potential economic loss of 60 to 80 %. It is believed that the transportation of infected fruits is what caused it to spread to Kerala, Karnataka, Maharashtra, and Tripura currently. (Muniappan *et al.,* 2008).

19. Lotus lily midge, *Stenochironomus nelumbus* Tok and Kur (Chironomidae: Diptera). It is a native pest of china and distributed to Kerala, India in the year 2005. It leads to excessive leaf rotting disease. The newly hatched grub mines into the sub-cuticular parenchyma tissue.

20. Erythrina gall wasp, *Quadrastichus erythrinae* Kim (Eulophidae: Hymenoptera). It is native pest from Singapore and Mauritius and introduced in Thiruvananthapuram, Kerala in the year 2005. On *Erythina* spp., it is a significant invasive pest in the black pepper crops of Kerala and Karnataka. In the Wayanad District of Kerala in 2006, *Erythina* plants had damage of around 60 per cent. The mode of entry is through exchange of plant materials. Major symptoms of the pest are gall enlargement and malformation, wilting of leaves, severe defoliation and death of trees.

21. Blue gum chalcid, *Leptocybe invasa* Fisher & La Salle (Eulophidae: Hymenoptera). It is a wasp that induces gall formation introduced from Australia reported in planted forests and nurseries of *Eucalyptus camaldulensis* and *E. tereticornis* from India.

Site of oviposition of *L. invasa* is bark of shoots or the leaf midribs. Within the host plant, the eggs hatch into tiny, white, legless larvae. Damage is caused when the growing larvae form galls on the petioles, midribs and twigs of leaves. Invulnerable trees experience a loss of growth and vigour after repeated damage. Trees that have been severely assaulted have twisted appearances, stunted growth, lodging, dieback and eventually die.

22. Cotton mealy bug, *Phenococcus solenopsis* Tinsley (Pseudococcidae: Hemiptera). The earliest *P. solenopsis* infestations in India were recorded for the first time in 2005 in Cotton at Gujarat (Nagrare *et al.*, 2009), spread rapidly after introduction to various parts of country. *P. solenopsis* is a polyphagous pest with a wide host range such as Brinjal, Okra, Tomato and Chinarose.

23. Tomato pin worm, *Tuta absoluta* Meyrick (Gelechiidae: Lepidoptera). Tomato leaf miner, *Tuta absoluta* was reported on tomato for the first time at Indian Institute of Horticultural Research (IIHR), Karnataka, India during 2014 *rabi* season (Shylesha *et al.,* 2018). It was noticed for the first time at Nauni Solan of Himachal Pradesh during 2015 (Sharma and Gavkare 2017).

Tomato leaves, apical buds, stalks or fruits are mined by young larvae. Inconspicuous mines (blotches) and galleries appear on leaves after feeding and fruits with pinhole-sized holes from the stalk end are typically covered in frass. Inside the mines, one can see dark frass (excrement) and the excavated regions over time turned brown and desiccated.

24. Solanum whitefly, *Aleurothrixus trachoides* Back (Aleyrodiadae: Hemiptera). This neotropicalsolanum whitefly, *Aleurothrixus trachoides* was found to be invasive in India (Dubey and Sundararaj 2015). It infests solanaceae crops like brinjal, tomato and chilli. Heavy infestations lead to chlorotic spots and curling of leaves resulting in their premature shedding and in severe infestation mortality of seedlings of chilli and tomato are observed (Sundararaj *et al.,* 2018).

25. Western flower, *Frankliniella occidentalis* Pergande (Thripidae: Thysanoptera). The western flower thrips, *Frankliniella occidentalis*, is most significant invasive pest of many crops during the 1970-80s worldwide. This is the first report on tomato crop from Bengaluru, Karnataka (Thyagi and Kumar 2015).

Direct economic damage is caused by feeding and oviposition, while indirect economic damage by the spread of plant pathogenic viruses of the genus Tospovirus (Peribunyaviridae) (Macharia *et al*., 2015). It is the most effective vector of the seven Tospovirus species, including the ones that cause tomato spotted wilt (TSWV), tomato zonate spot virus, tomato chlorotic spot virus and chrysanthemum stem necrosis. Feeding on tissues that are actively growing results in stunted and deformed plant growth, which eventually reduces production.

26. Invasive pest thrips, *Thrips parvispinus* Karny (Thripidae: Thysanoptera). This invasive pest was firstly reported on papaya from Bangalore (Tyagi *et al.*, 2015) and *Dahlia rosea* (Rachana *et al.*, 2018). Besides, that it is currently threatening chilli cultivation also in India. *Thrips parvispinus* (Karny) is native of the South East Asian pest species, a significant pest species of quarantine relevance that has been reported from Thailand to Australia and is a problematic pest on a number of agricultural and horticulture crops (Mound and Collins 2000). They significantly reduce productivity by causing widespread flower loss, fruit deformity and fruit drop in chillies. The emergence of *T. parvispinus* in several places across our country has drawn attention because it is a serious pest that causes substantial crop losses.

27. Rugosespiralling whitefly, *Aleurodicus rugioperculetus* Martin (Aleyrodiadae: Hemiptera). This dangerous exotic pest was reported for the first time on coconut (*Cocos nucifera* L.) at Pollachi, Tamil Nadu during August, 2016 (Sundararaj and Selvaraj 2017). Currently, RSW is highly polyphagous with 118 hosts belonging to 43 plant families including economically important crops in United States (Francis *et al*., 2016).

Whitefly feeding stresses the host plant by withdrawing nutrients and water as well as producing honeydew, which coats the lower leaves and encourages the growth of sooty mould, which may limit the plant ability to synthesise food (Chalapathi Rao *et al.,* 2018). Symptoms such as egg spirals of the RSW are present on the underside of leaves, along with thick white waxy material, sticky honeydew, the growth of black sooty

mould, leaf damage and early leaf drop in some plants (Chalapathi Rao *et al.,* 2018).

28. Arecanut aphid, *Tuberaphis xinglongensis* Zhang (Aphididae: Hemiptera). *T. xinglogensis* was recorded in India for the first time on Arecanut as a new host and confirmed with the help of molecular characterization (Sunil *et al.,* 2021). Nymphs and adults suck the sap from the spindle region but less from leaf portion. The more infestation was noticed on spindle region than on leaf and the population was more during summer months. The pest intensity ranged from 18.53 to 36.00 aphids/2.5 sq. cm.

The aphid makes crowded colonies on spindle region. Nymphs are yellowish green coloured, pear shaped. Alates are with light brownish yellow body. Wings held horizontal above abdomen. Adult female brownish but gives greyish white appearance due to wax powder deposits on dorsum. Weak fringe of white wax surrounding abdomen, which breaks as the aphid walks in the colony. Appendages light brown.

29. Nesting whitefly, *Paraleyrodes minei* Iacarrino (Aleyrodiadae: Hemiptera). Species in this genus have been given the common name "nesting whiteflies" after the distinctive wax pattern that develops around the pupa on the leaf surface. It builds loosely woven, fuzzy wax nests and lacks the oblique grey banding on its wings.

Males are smoky grey in colour, while females are white. Male whiteflies have smoky grey wings with three orange-tinted whip-like antenna (Chandrika *et al*., 2018). *P. minei* constructs up to 30 colonies of nest on coconut leaflets which leads to sooty mould development in leaves (Josephrajkumar *et al.,* 2018).

30. Bondar'snesting whitefly, *Paraleyrodes bondari* Perrachi (Aleyrodiadae: Hemiptera). *Paraleyrodes bondari* (Bondar's nesting whitefly) (Hemiptera: Aleyrodidae) is one of 17 species in genus *Paraleyrodes* that occur throughout the Neotropics. In India, first incidence of the neo-tropical invasive BNW was recorded on coconut palms from Kerala (Josephrajkumar *et al.,* 2019).

It builds distinctive woolly wax nests on the abaxial surface of palm leaflets and has oblique greyish bands on its wings that resemble "X" shape. Young nymph consists of transparent "wax" skirt. While, older nymph is covered with flocculent wax and surrounded by fiberglass-like rods. Presence of abdominal compound pores (33-35 m) of the puparium with ovoid facets that resemble flower petals (Sundararaj *et al*., 2018 and Josephrajkumar *et al.,* 2019). Heavy Bondar's nesting whitefly infestations cause circular and white "nests" which makepolka-dot manner by contrasting with black sooty mold (Stocks, 2012).

31. Wooly whitefly, *Aleurothrixus floccosus* Maskell (Aleyrodiadae: Hemiptera). It is a highly polyphagous pest recorded on guava (*Psidium guajava* L.) first time in India during 2019 (Sundararaj *et al*., 2020). It is documented to feed on more than 20 plant families and prefers more on citrus species and guava.

The nymphal stages are vulnerable and cause much damage to the guava leaves by sucking sap from abaxial surface. Woolly whitefly segregates more honeydew in the leaves of guava comparing to the other invasive whiteflies.

32. Palm whitefly, *Aleurotrachelus atratus* Hempel (Aleyrodiadae: Hemiptera). Palm whitefly, *Aleurotrachelus atratus* Hempelis a highly invasive whitefly whose infestation was reported for the first time in India in addition to the oriental region (Selvaraj *et al.,* 2019).

It infests mainly on the abaxial leaflet surface ranging from 97 to 186 nymphs per group with 3 to 48 groups per leaflet. In severe cases greater than 60 per cent coverage of leaflet by the nymphs result in chlorosis or necrosis and loss of vigour with drying of the leaflets. Further, secretion of honeydew acts as a medium for sooty mould development (Selvaraj *et al.,* 2019).

33. Cassava mealy bug, *Phenacoccus manihoti* Matile – Ferrero (Pseudococcidae: Hemiptera). The most recent serious biological invasion is the Cassava Mealy Bug, *manihoti* Matile – Ferrero (Pseudococcidae: Hemiptera). The incidence of mealy bug species was first noticed on Cassava in Thrissur, Kerala during April 2020. They are pink coloured with mealy coating and usually infest the shoot tips and under surface of the leaves. All the stages *viz.*, eggs, nymphs and adults cause curling of the leaves at growing tip of the plant leading to formation of bunchy tops and adventitious buds on almost all the internodes. Heavy population resulted in the leaf drying and entire defoliation (Sampath *et al.,* 2021).

34. Leek moth, *Acrolepiopsis assectella* Zeller (Acrolepiidae: Lepidoptera). Leek moth is an exotic pest introduced from Europe in year 2020. The adult moth is brownish white coloured with nocturnal habitat. The larvae feed on leaf surface and mine galleries 2-5 mm long in the epidermis of the leaves. Feeding by larvae infests plants and is specifically devastating on early *Allium* spp. Plants (Dewangan and Deole 2021). Grooves and holes in the inner leaves of mature plants are examples of symptoms. The inner sides of hollow leaves may be fed on by larvae, which then produce translucent "windows" or bands on the leaf tissue (Dewangan and Deole 2021). The information on its management practices is inadequate.

Prevention of invasive species. The first step in prevention of invasive insect pests is identification and paying close attention. These could be listed on a "blacklist" and denied admission according to national law. It is reasonable to consider a species safe (to put it on a "white list") if it has passed a risk assessment examination, but monitoring is still necessary to make sure the prediction holds true over time. Most species in the globe should be put on a "grey list" because it is unknown whether they could become invasive.

Management of new invasive insect pests. The basic steps in management of new invasive pests vary depending on the type of organism, population size, biology, status of pest and available mitigation options.

1. Identification: The professional should appropriately identify the invading insect pests.

2. Risk assessments: Find out first how much risk the invasive insect problem poses to the neighbourhood. Examine the biology of the organism, its local and global distribution, the pest's status, available

mitigation measures and the window of opportunity for taking action.

3. Eradication programme: The eradication of invasive species should be carried out widely if the pest poses a substantial risk. Other outreach initiatives should be launched to inform the public about this pest.

4. Risk assessment review: Understanding invasive species and the degree of risk they pose in new environments is essential. It is important to be aware of the biology, distribution, economic significance, and management options.

5. Monitoring: The survey data for the majority of organisms two years or two generations is taken into consideration for the program's success in eradicating them.

CONCLUSION

Globalization led to the invasion of insects, which were a serious threat to the local flora and wildlife and even led to the extinction of several species. The globalisation of agriculture has boosted worldwide trade and the movement of seeds and planting materials has raised the potential of invasive pest introduction into India. These species can multiply greatly and harm economically significant plant species and crop plants if they are not accompanied by the natural enemies that keep them in check in their native habitat. By having a fundamental understanding of invasive pest species and cooperating internationally through the sharing of information on invasive pests and their natural enemies, the introduction of new pest species in a new area can be minimised.

The output of horticultural crops is primarily affected by the severe effects of invasive pest species on the environment, agriculture and horticulture ecology. These species have a significant negative impact on biodiversity and may also affect the economy of nation. In order to detect invasive organisms and evaluate their ecological issues, environmental concerns in various habitats, economic harm and control options, scientists must collaborate across disciplines. This emphasises how crucial quarantine is in halting the spread of harmful exotic pests.

FUTURE SCOPE

1. Studies on host range and co-existence of exotic pest complex in horticultural crops.
2. Integrated Pest Management (IPM) strategies of invasive insect pests of horticultural ecosystem. Documentation of natural enemies *viz.*, parasitoids and predators associated with invasive pests of horticultural crops.

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