Recent invasive insects in vegetable ecosystems: threats, impacts, and strategies for sustainable management

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Abstract: Horticulture plays a pivotal role in ensuring food security, healthy diets, and environmental sustainability. This article explores the importance of horticulture, particularly in vegetable production (including underutilized and exotic crops), highlighting its contributions to diverse diets, biodiversity preservation, and economic growth. However, invasive insects substantially threaten horticultural ecosystems, causing significant damage, economic losses, and disruptions. The article delves into the traits that make invasive insects successful in new environments, emphasizing the need for comprehensive management strategies. A detailed understanding of invasive insect species in India, such as the rugose spiralling whitefly, pinworm, and black thrips, reveals their detrimental impact on vegetable crops. The article underscores the urgency of implementing effective pest management strategies and emphasizes the importance of constant vigilance to prevent and manage future outbreaks, ensuring the long-term sustainability of vegetable ecosystems.

Horticulture plays an important role in food security, healthy diets, and environmental sustainability. It involves cultivating various plants, including fruits, vegetables, herbs, and ornamental plants, which contribute to promoting diverse and nutritious diets. Horticultural practices contribute to biodiversity preservation, reduction in soil erosion, rural livelihood empowerment, and economic growth through agribusiness opportunities, as highlighted by the International Society for Horticultural Science (ISHS). Vegetables are essential to a balanced diet because they provide essential vitamins, minerals, and dietary fibre, contributing to overall health and well-being (Kovačević et al. 2020). The high nutrient content of these foods supports immune function, lowers disease risk, and enhances digestion, making them crucial for a healthy lifestyle. Production of vegetables is anticipated to increase to 204.61 million metric tonnes from the 200.45 million metric tonnes reported in the 2020–21 timeframe (Second Advance Estimates, 2021–22). At this juncture, underutilized vegetable crops play a vital part in the Indian diet and are closely associated with traditional cuisine. The increasing recognition of the diverse range of underutilized species is important for environmental health and particularly relevant for climate change mitigation. Therefore, improving the cultivation of these vegetables could potentially replace other commonly consumed vegetables without compromising the availability of essential nutrients and phytochemicals in the agricultural and food industries. Endemic underutilized vegetables resist abiotic and biotic stresses, including drought, high temperatures, pests, and diseases, while maintaining productivity (Palanivel and Shah, 2021). These interventions can potentially improve a nation's food and nutritional security with stability in agricultural income. On the contrary, invasive insects pose a significant challenge for many growers, hindering the potential outcome.

Invasive species refer to any species, subspecies, or lower taxon introduced outside its natural historical or current distribution. This includes any part, gametes, seeds, eggs, or propagules of such species that can survive and reproduce. Invasive insects (non-native) pose risks to human well-being, imperil food production, threaten valued species, jeopardize economic stability, and disturb the functioning of ecosystems (Venette and Hutchison, 2021). In the context of horticultural ecosystems, invasive insects play a significant role by causing considerable harm to crops, resulting in reduced yields, heightened production expenses, and the disruption of agricultural systems. Pests and pathogens, lacking natural predators, can quickly spread, resulting in substantial economic losses, food security risks, and the necessity for enhanced pest management strategies. This situation affects local economies and global trade. The economic cost of biological invasions is estimated to be at least US$ 1.288 trillion in Brazil (Adelino et al. 2021), US$4.52 trillion in the USA (Fantle-Lepczyk et al. 2022), US$ 432.6 billion in Asia (Liu et al. 2021). This article aims to understand their damage symptoms and the potential attributes behind their invasiveness. Additionally, studying invasive insects allows for developing effective management strategies to mitigate the negative consequences of their presence.

Potential traits of invasive insects

Invasive insects possess traits that facilitate their successful establishment and proliferation in new environments. These traits, such as rapid growth and reproduction rates, allow them to thrive and reproduce even in unfavourable conditions, giving them an edge over native species in population growth. Moreover, their ability to thrive in adverse ecosystems is enhanced by their phenotypic plasticity and wide tolerance to environmental fluctuations (Jardeleza et al. 2022). Invasive insects commonly display adaptable feeding behaviours, allowing them to exploit various food sources. Moreover, the ability of these organisms to travel long distances, often with the help of human activities, enables them to spread to different regions quickly. These attributes enhance their competitive ability against native species, contributing to ecological disruption and economic impact. Their ability to adapt to urban environments, agricultural systems, and trade networks allows them to take advantage of human activities, unintentionally facilitating their spread. Comprehensive management strategies are crucial for effectively addressing the challenges posed by invasive insects. Early detection, monitoring, and rapid response measures are crucial in preventing and mitigating the establishment of invasive species, thereby reducing their potential far-reaching consequences on ecosystems, economies,

Sl. No.	Common name	Scientific name	Host	Entry to India (Place)	From/ Native	Biological control	References
1	Potato tuber moth	*Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae)	Potato	1906 (East Bengal-Now in Bangladesh)	Italy	Copidosoma koehleri, an egg - larval parasitoid; Chelonus blackburnii - exotic parasitoid	Lefroy, 1907
2	Serpentine leaf miner	*Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae)	Tomato	1991 Hyderabad, Telangana	Florida	Chalcidoidea, Pteromalidae and Braconidae -Diglyphus begina, D. intermedius	Viraktamath et al. 1993
3	South American tomato pinworm/ Tomato leaf minor	*Tuta absoluta* (Meyrick,1917) (Lepidoptera: Gelechiidae)	Tomato	2014 Pune, Maharashtra	South America	Nesidiocoris tenuis Reuter; Neochrysocharis formosa (Westwood); Habrobacon sp.; Goniozussp. Trichogramma achaeae	Shashank et al. 2015

4	Black thrips	*Thrips parvispinus* (Karny) (Thysanoptera: Thripidae)	Chilli	2015, Bengaluru, karnataka	Indonesia	Beauveria bassiana @ 4.00 g or ml/L (spore load - 1x108 cfu/g or ml), Pseudomonas fluorescence – NBAIR-PFDWD @ 20g/L or Bacillus albus – NBAIR-BATP @ 20 g/L	Tyagi et al. 2015
5	Rugose spiraling whitefly	*Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae)	Coconut	2016, Tamil Nadu	Central America	Encarsia guadeloupae	Sundararaj and Selvaraj (2017)
6	Cassava mealybug	*Phenacoccus manihoti*	Cassava	2020, Kerala	African continent	Apoanagyrus lopezi	Joshi et al. 2020

Table 1. List of invasive insect pests on vegetables

and society.

Impact of invasive insect species on vegetable ecosystem

Invasive insect species can have significant direct and indirect impacts on vegetable ecosystems, affecting both native species and the overall ecological balance (Table 2).

Status of some recently invaded insect species in vegetables including underutilized and exotic crops

Direct consequence	Indirect Consequence
1. Predation on Native Species	1. Changing Food Webs
2. Competition for Resources	2. Decreasing Biodiversity
3. Disease Transmission	3. Altering Ecosystem Conditions
4. Reproductive Interference	
5. Altered Trophic Interactions	
6. Displacement of Native Species	
7. Genetic Introgression	
8. Ecological Imbalance	

Table 2: Direct and indirect impact of invasive insect pests on vegetable ecosystem

The Aleurodicus rugioperculatus, or rugose spiralling whitefly (RSW), is a highly harmful species that causes significant losses in agricultural and horticultural ecosystems. This insect's rapid and extensive spread across the nation has caused concerns among millions of horticultural growers. While the species can infest numerous crops, it is important to acknowledge its significant impact on underutilized vegetable crops (Singh et al. 2022). The attack on two new host crops, Amaranthus tricolor (L.) and Solanum torvum, demonstrates the robustness of the species at CHES (ICAR-IIHR), Bhubaneswar (Fig 1). Additionally, there have been reports of infestation on minor cucurbits (Coccinia grandis, Momordica dioica). The Tuta absoluta, also known as the pinworm, has significantly reduced the market value of tomatoes in several states since 2014 (El-Shafie, 2020). Larvae cause feeding damage by penetrating the leaf and consuming mesophyll tissues, creating irregular mines on the leaf surface and adversely affecting the plant's photosynthetic capacity. Consequently, affected leaves wither, reducing overall photosynthetic efficiency and potentially compromising the plant's ability to defend against other harmful agents. The galleries and mines formed in the leaves disrupt the plant's normal development, leading to potential necrosis (Biondi et al., 2018). In severe infestations, leaves may exhibit a scorched appearance. Additional common signs and symptoms of T. absoluta damage include puncture marks, abnormal shapes, exit holes (pin size), rot from secondary infections, and larval excrement on fruit. Mature larvae, particularly in the third to fourth instar, can feed on various plant parts, causing substantial harm to the plant.

The most recent surge of the invasive pest, Thrips parvispinus (Karny) (Thysanoptera: Thripidae), on chili (Capsicum annuum L.) in the southern states of India (Andhra Pradesh, Karnataka, and Telangana) resulted in damage ranging from 70% to 100%, regardless of the chili cultivars cultivated by farmers (Sridhar et al., 2021). In India, the presence of T. parvispinus was initially documented by Tyagi et al. (2015) on papaya, Carica papaya (Caricaceae), in Bengaluru. They underscored the importance of consistently monitoring its presence in other regions of India due to the likelihood of it becoming a pest of concern. Damage symptoms induced by T. parvispinus in chili included profound punctures and scratches on the underside of leaves. The infested lower surface of the leaf exhibited a reddish-brown hue, while the upper side displayed a yellowish appearance. Common symptoms encompass distorted leaf lamina with necrotic areas and yellow streaks. Severely infested leaves showed upward curling. Brownish streaks emerged on petals on floral components due to thrips' scraping. The consequential damage led to the drying and withering of flowers, resulting in a diminished fruit set (Sridhar et al., 2021). The plant's growth was adversely affected by severe infestation, as thrips fed on the growing portions of the plants. Numerous adults, both males and females, were observed congregating in significant numbers, feeding and concealing themselves in the nectar-producing regions of chilli flowers, causing extensive flower drop and substantial crop losses.

a: RSW infestation on the fruit of Solanum torvum; b: RSW infestation on leaf of Amaranthus tricolor (L.);

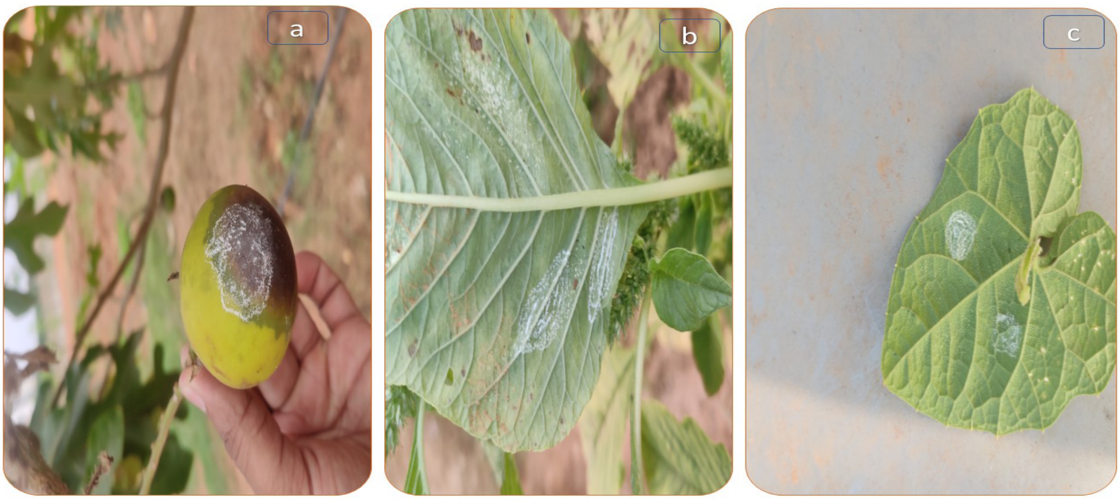

Fig. 1. Rugose spiralling whitefly (RSW) infestation on underutilized vegetable crops

c: RSW infestation on the leaf of minor cucurbit

The swift proliferation, substantial damage, and capability to impact multiple crops and plant varieties emphasize the importance of implementing effective pest management strategies and maintaining constant vigilance to prevent and manage similar future outbreaks.

Management

A holistic management strategy is the key to tackling invasive species in the long run. It can be addressed at three different levels of invasion of pests.

Conclusion

Vegetables are crucial for achieving food security, promoting healthy diets, and supporting environmental sustainability. Those crops promote diverse and nutritious diets, preserve biodiversity, and mitigate soil erosion. The introduction and spread of invasive insect species have significant negative impacts on vegetable ecosystems. These impacts include the disruption of native species, alteration of food webs, reduction in biodiversity, and creation of ecological imbalances. The outbreak of T. parvispinus, T. absoluta, and A. rugeoperculatus in India exemplifies the significant impact of invasive pests. The swift dissemination and significant harm inflicted by this species underscore the pressing requirement for efficient pest management strategies and proactive measures to avert and manage comparable outbreaks in the future.

Preventive measures	Post quarantine measures	Curative measures
The pest has not been introduced	Species introduced but not spread to a nearby area	Introduced invasion has established
Pest risk analysis (PRA) Quarantine and monitoring	Rejection of the consignment from which the pest has been introduced Eradication using fumigation of the consignment lot	Cultural Biological Chemical

Table 3. Invasive insect pest management strategies

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