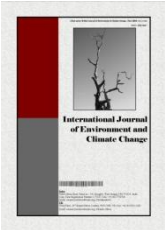

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Invasive Insects Outbreaks in India during the 21st Century-threat and Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The word "Exotic" is developed from the Greek and Latin word meaning "not of a native species, or "alien species". Alien arthropods threaten human health, threaten, food security, endanger valued species and disrupt ecosystem functions. The accelerating pace of commercialization and globalization creates opportunities for the movement of species to new areas of the world. Economic liberalisation has accelerated the movement of goods across borders and geographic obstacles without minimal quarantine, increasing the risk of exotic pest introduction into agroecosystems. Invasive Alien Species (IAS) are often regarded as one of the most serious dangers to the country's ecological and economic health. These species have a huge impact on biodiversity and natural agriculture systems, which are both extremely valuable. Pest invasions have lately been identified as a significant source of biodiversity loss. Preventing exotic species invasions is one of the most effective ways to limit the chance of invasion, but this requires recognising potential invasive species ahead of time.

Keywords: Invasive; alien species; agroecosystem; natural enemies.

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1. INTRODUCTION

Non-native or exotic creatures that occur outside of their natural suitable environment and dispersal potential are known as alien species. Alien species become invasive when they have been introduced outside of their normal habitats, either purposefully or accidently, into new places where they demonstrate the potential to establish, invade, and outcompete native species [1]. Invasive pests are found in a wide range of habitats around the world, and they affect many types of living organisms. Globalization has expanded international agricultural trade, but it has also raised the possibility of alien pests being introduced into India through the transfer of seeds and planting supplies. These species can multiply in great numbers and cause damage to economically significant plant species and crop plants if they are not accompanied by natural enemies that keep them in check in their native habitat. Even with thorough quarantine inspections, detecting cryptic beginning stages of insects that might be transmitted with consignments or through visitors is difficult. So, one of the best opportunities after the entry of an invasive pest, we have to reduce the impact of invasive alien species by preventing them to establish in the first place and to understand how they manage to move or be moved outside of their native range [1].

2. FEATURES OF INVASIVE SPECIES

Invasive species are robust, long-lived, voracious, aggressively spreading, and extremely resilient, with rapid growth, a broad food, the ability to travel vast distances, and prolific reproduction [2]. Invasive alien species have infiltrated and harmed native biota in nearly every ecosystem on the planet. They can be found in viruses, fungus, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds, and mammals, among other taxonomic groupings. Invasive species can alter ecosystem structure and species composition by suppressing or eliminating native species, either directly by competing for resources or indirectly by altering the way nutrients are cycled through the system [1]. They have negative consequences for the ecology, biodiversity, health, economy, and other areas of human welfare, as well as a reduction in agriculture production.

3. PATHWAYS FOR ENTRY AND ESTABLISHMENT

3.1 Natural Movement

Much of North America was engulfed in ice between 150,000 and 130,000 years ago. The advancing ice and changing environment forced plants and animals well beyond their native range throughout these periods. As the temperature warmed and the glaciers receded, these same species slowly followed the glaciers north, establishing new habitats. Many mammal species are assumed to have migrated from Asia to North America. At the same time, changes in temperature and landform can cause any species' native range to shift [3].

3.2 Unnatural or Human-assisted Movement

Unnatural species movement, in which a plant, animal, insect, or disease organism is introduced outside of its natural range into an area or ecosystem that they would not normally be able to reach on their own, is the prime cause of today's invading alien species problems. Today, human activity is the principal way by which new species penetrate new habitats and countries.

4. DREADED INVASIVE ALIEN INSECTS

A recent study showed that about 1300 species of invasive insect pests and pathogens had been introduced into 124 countries [3]. In Southeast Asia, 677 alien insect species are reported, including almost all insect orders, but most belong to Coleoptera, Hemiptera, and Lepidoptera insect orders [4]. In India, 173 invasive species include 54 terrestrial plants, 56 aquatic organisms, 47 organisms having agricultural importance, and 14 organisms of the island ecosystem [5].

Such alien pests consider the new habitat excellent and favourable to breeding and establishment, with no natural regulating elements such as natural enemies to keep them in check in their natural range. Classic biological control, which involves the introduction of efficient exotic natural enemies from the native range of the acquired pests to re-establish the lost balance between the pests and the natural enemies, is the best way to manage such invasive species. Despite the fact that dealing with these alien pests is a difficult endeavour, the

List 1. List of Invasive Pests in India during last two decades

Sr No	Common Name	Scientific Name	Native	First report	Host Plant	Year
1	Eucalyptus Gall Wasp	*Leptocybe invasa* (Fisher & La Salle)	Australia	Karnataka	*Eucalyptus spp.*	2001
2	Erythrina Gall Wasp	*Quadrastichus erythrinae* (Kim)	Panama-Central America	Thiruvananthapuram, Kerala	*Erythrina stricta Roxb.*	2005
3	Cotton Mealy bug	*Phenacoccus solenopsis* (Tinsley)	USA	Punjab	Cotton	2006
4	Papaya Mealy Bug	*Paracoccus marginatus* (Williams and Granara de Willink)	Mexico and Central America	Coimbatore, Tamil Nadu	Papaya	2008
5	Madeira Mealy bug	*Phenacoccus madeirensis* (Green)	Neotropical region South America	Bandipur National park, Karnataka	*Cestrum nocturnam*	2012
6	Jack Beardsley Mealy bug	*Pseudococcus jackbeardsleyi* (Gimpel and Miller)	Neotropical region South America	Tamil Nadu	Papaya, Banana, Custard Apple, Hibiscus	2012
7	Lantana Mealy bug	*Phenacoccus parvus* (Morrison)	South America	Bangalore, Karnataka	*Crysanthemum sp., Amaranthus sp.,* Tomato, Capsicum	2012
8	Rose Aphid	*Wahlgreniella nervata* (Gillette)	North American	Bangalore	Rose	2014
9	Tomato Pin Worm	*Tuta absoluta* (Meyrick)	South America (Peru)	Pune, Maharashtra	Tomato, Potato, Eggplant	2014
10	Western Flower Thrips	*Frankliniella occidentalis* (Pergande)	Western half of North America	Bangalore	Tomato, Groundnut, Cotton, Tobacco	2015
11	Rugose Spiraling White Fly	*Aleurodicus rugioperculatus (*Martin)	Mexico	Coimbatore, Tamil Nadu	Coconut, banana, Apple	2016
12	Fall Army Worm	*Spodoptera frugiperda* (Smith)	Western hemisphere tropics from US to Argentina	Karnataka	Maize, Sugarcane, Sorghum	2018
13	Woolly whitefly	*Aleurothrixus floccosus*	Neotropical		Guava, *Citrus* species	2019
14	Neotropical whitefly	*Aleurotrachelus atratus*	Neotropical		*Cocos nucifera* and *Dypsis lutescens*	2019
15.	Cassava mealybug	*Phenacoccus manihoti*	Africa	Kerala	*Cassava*	2020

entomologists at the National Bureau of Agricultural Insect Resources (NBAIR) have effectively dealt with all of them. Additional entomologists are needed at NBAIR to effectively manage the alien pests that are projected to enter India, according to the XII Plan.

1. **Blue gum chalcid, *Leptocybe invasa* Fisher and La Salle (Eulophidae: Hymenoptera)**

The blue gum chalcid is an Australian gall-inducing wasp. It's become a pest of planted eucalypt forests in Kenya, Morocco, New Zealand, Tanzania, and Uganda, among other places. It was discovered in Eucalyptus camaldulensis Dehnh and Eucalyptus tereticornis Smith planted forests and nurseries in Mandya in 2001. **Hosts:** *Eucalyptus camaldulensis*; *E. tereticornis*; *E. grandis*; *E. deanei*; *E. globules*; *E. nitens*; *E.botryoides*; *E. saligna*; *E.gunii*, *E. robusta*; *E. bridgesiana*; *E. viminalis*.

Ovipostion: Eucalyptus gall wasp lays eggs in the bark of shoots or the midribs of leaves

Damage: *L. invasa lays eggs in the midribs of leaves or the bark of shoots.* The eggs develop into minute, white, legless larvae within the host plant. When developing larvae form galls on the leaf midribs, petioles, and twigs, they cause damage (Plate 1). The galls can split the twigs, causing the cambium to die. On the galls, little circular holes indicating adult escape locations from pupae are frequent. Attacks on sensitive trees cause them to lose their growth and vigour. Trees that have been severely harmed have a twisted appearance, stunted growth, lodging, dieback, and eventually die [6].

Plate 1. Galls produced by *L. invasa* on the leaf midribs

Biological control: *Quadrastichus mendeli* and *Selitrichodes kryseri* are promising parasitoids.

2. **Erythrina gall wasp (EGW) *Quadrastichus erythrinae* Kim (Eulophidae: Hymenoptera)**

In the major black pepper (*Piper nigrum* L.) growing districts of Kerala and Karnataka, EGW is an invasive insect pest on *Erythrina* spp. EGW was first identified as a threat to *Erythrina* spp. in Taiwan in 2004 and was first detected in India in 2006 in Kerala's southern districts, including Thiruvananthapuram. Later that year, it was discovered on *Erythrina* spp. in Maharashtra's Pune, Satara, Sangli, and Kholapur districts, as well as Karnataka's Belagavi and Dharwad districts.

Nature of damage: Shoots become swollen, forming many thick-walled glob galls (Plate 2). After feeding within the galls, the larvae pupate, and the adult wasp cut exit hole through plant gall material to emerge.

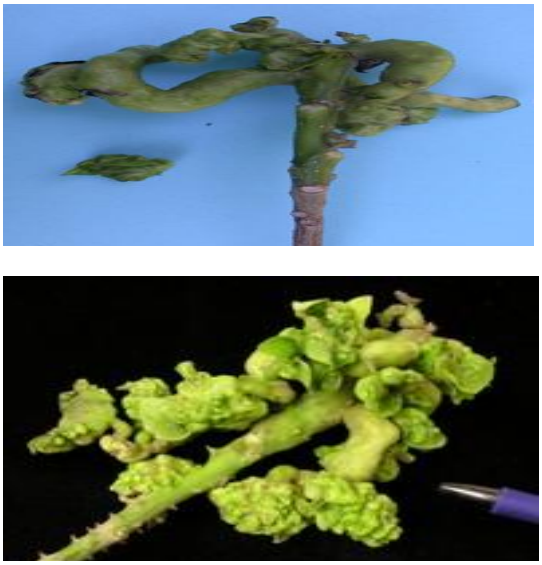

Plate 2. Swollen shoots of Erythrina by EGW

There is no severe incidence in Kolar, Mandya, and Ramnagar has been reported because promising parasitoid like *Aprostocetus gala* (Plate 3) was recorded with 7 to15 percent parasitization [7].

Plate 3. *Aprostocetus gala* on EGW

3. **Papaya mealybug:** *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae)

It is native to Mexico; the infestation was first recorded in India during 2007 on papaya, at Coimbatore, Tamil Nadu. By 2009, the pest assumed the major pest status across the country and caused massive damage to mulberry, tapioca, jatropha, cotton, and several fruits, flowers, and plantation crops in Tamil Nadu, causing 90 percent damage. In June 2010, the occurrence of papaya mealybug in Karnataka on Mulberry in the area of Chamarajanagar was reported. The incidence was seven percent, and the intensity was recorded to be 42.9 percent. It was confirmed that the pest has just made its entry from Talawadi in Tamil Nadu through infested mulberry cuttings [8,9].

Nature of damage: Nymphs and adults of *P. marginatus* suck the plant sap and weaken it (Plate 4). The leaves start to crinkle, yellow, and wither. The bug's honeydew, together with the resulting black sooty mould, reduces the plant's photosynthetic efficiency.

Plate 4. Nymphs and adult of *P. marginatus* on papaya fruit and leaf

Economic loss: Nearly 576 ha of papaya in Coimbatore districts had been affected. The pest has expanded to practically all ecological niches in India due to the transportation of contaminated papaya fruits, which has 60 plant species as hosts. Fortunately, the pest was successfully handled through the use of traditional biological control methods wherein *Anagyrus loecki*, *Pseudleptomastix mexicana* and *Acerophagus papaya* were imported from the USA (Plate 5). Predators like *Cryptolaemus montrouzieri*, lacewings, hoverflies and *Scymnus sp*. also play an essential role in managing this pest in the cotton ecosystem [10].

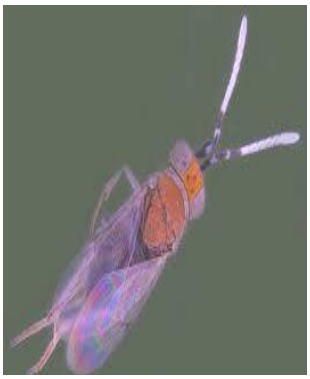

Plate 5. i) *Anagyrus loecki* ii) *P. Mexicana iii) A. papaya*

4. Cotton mealybug, *Phenococcus solenopsis* Tinsley (Hemiptera: Pseudococcidae)

Cotton mealybug is native to Central America; In India, the first incidence of *Phenacoccus solenopsis* in cotton was reported from Punjab in 2006. The widespread damage it caused in the country in 2006 has been of utmost concern to the entire continent. Cotton mealybug poses a significant threat to cotton cultivation all over the country and causes significant economic damage. The pest has invaded all cotton-growing areas in the country.

Economic loss: Mealybug was first discovered on cotton crops in India in 2003-04 [11]. This occurred in tandem with the advent of Bt. cotton, its widespread adoption by farmers, successful control of bollworms, and lower pesticide use. By 2006 and 2007, the pest has become a serious danger to Bt cotton in Punjab, Haryana, Rajasthan, Gujarat, and Maharashtra [12], resulting in major losses in cotton output. During the 2007 kharif season in Punjab, mealybug losses to cotton growers were projected to reach Rs. 159 crores [13].

Coconut hispine beetle, *Brontispa longissima* Gestro (Chrysomelidae: Coleoptera)

It is native to Indonesia and first introduced to India from Sri Lanka in 2009 through the movement of infected planting material. The pest has been spreading throughout Southeast Asia, and it was first discovered in Myanmar in 2004 and then the Philippines in 2005. The host of this pest are betel nut palm, coconut, African oil palm, bottle palm.

Biological control: Removing coconut and other palms to prevent the beetle from spreading. *Asecodes hispinarum and Tetrastichus brontispae* as in Plate 6 [14].

Plate 6 i) *Asecodes hispinarum* ii) *Tetrastichus brontispae*

5. Tomato leafminer: *Tuta absoluta* Meyrick (Gelichiidae: Lepidoptera)

It is native to South America and was initially observed in Pune on tomato plants during October 2014. The infestation of *T. absoluta* ranged from low to high (up to 15 mines/plant) in different tomato fields surveyed in six districts of Karnataka State viz., Bengaluru, Kolar, Chikkaballapur, Ramanagar and Tumkur. The percent infestation was to the tune of 87 percent [15,16].

Nature of Damage: T. absoluta larvae began mining tomato leaves, apical buds, stalks, and fruits as soon as they hatched. Mines (blotches), galleries on leaves, and pinhole-sized pores on fruits from the stalk end were all filled in frass after feeding. Larvae mostly attacked foliage, leaving blotch/leaf mines visible on both sides of the leaf. Dark frass can be seen inside the mines, and the mined portions have turned brown and dried over time.

Plate 7. Leaf mining by *Tuta absoluta* larva

Alternate hosts of *Tuta absoluta* are Tomato, Potato, Eggplant, Pepper, Tobacco and other solanaceous plants and weeds.

Egg parasitoids: *Trichogramma exiguum*, *Trichogramma nerudai*, *Trichogramma pretiosum* [17].

Larval Parasitoids: *Goniozuz nigrifemur* (Bethylidae), *Apanteles spp*. (Braconidae) *Bracon spp*. (Braconidae), *Chelonus sp*. (Braconidae) and *Dineulophus phthorimaea* (Eulophidae).

- **Management:** Immediately after the occurrence of *Tuta absoluta* in 2014, (DPPQS), GOI, a nodal agency for quarantine along with (ICAR) monitored the pest status in India. In 2015, Central Insecticide Board and Registration Committee (CIBRC), part of Directorate of Plant Protection, Quarantine and Storage made adhoc recommendation of a few insecticides like chlorantraniliprole 10.26% OD @ 0.3 ml/L, cyantraniliprole 18.5% SC @ 0.3 ml/L, flubendiamide 20%WG @ 0.3 ml/L, indoxacarb 14.5% @ 0.5 ml/L or imidacloprid 17.8%SL @ 0.3 ml/L.

Monitoring: Identify pest occurrence and take timely control measures. (Ex. Pest Control (India) Pvt. Ltd; Epheromone IPM Solutions etc.). Trapping of 20-50 moths/trap immediate action should be taken.

Cultural methods: Do not use seedlings from pest-infested areas. Two months gap between two crops to avoid carryover population. After ploughing, cover the soil with plastic mulch or perform solarisation and remove the alternate weed host *viz., Datura sp.* (Datura) and *Nicotiana glauca* (Tree tobacco) **Western Flower Thrips, *Frankliniella occidentalis* (Pergande) (Thripidae: Thysanoptera):** It is native to the Southwestern United States; in India first reported from Bangaluru on tomato [18]. WFT transmitted Tomato spotted wilt virus.

Host: Variety of hosts including groundnut, cotton, tobacco, vegetables (eggplant, tomato, carrot, peas, capsicum), fruits (grapes, apple, peach), ornamentals (gladiolus, hibiscus, roses).

Biocontrol agents of Western Flower Thrips [19].

i. ***Amblyseius swirskii*:** Feeds on both first and second instar larvae. Tolerates higher temperatures than *Neoseiulus cucumeris*. Feeds on pollen in the absence of prey.
ii. ***Neoseiulus cucumeris*:** Most widely used predatory mite for western flower thrips. Feeds on the first instar larvae.
iii. ***Orius spp.*:** Feed on larvae and adults of western flower thrips.
iv. ***Stratiolaelaps scimitus*:** Adults may kill up to 30 prey, including western flower thrips pupae.

6. Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* Gimpel and Miller (Hemiptera: Pseudococcidae)

It is native to Central and South America; it was recorded in India from Tamil Nadu in 2012on papaya and distributed throughout the Neotropical region and in southern Asia and found in association with papaya mealybug and cotton mealybug. It is a polyphagous pest feeding upon 93 plant species of vegetable, fruit, and ornamental crop species [20].

Host Plants: Pepper, Eggplant, Tomato, Tropical fruit trees, Tropical shrubs, Ornamentals.

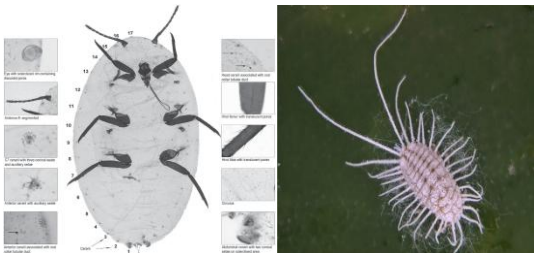

Plate 8. i) *P. jackbeardsleyi* (Ventral view) ii) *P. jackbeardsleyi* (Dorsal view)

Management: *P. solenopsis* and *P. marginatus*, fast establishment on weeds and ornamental crops. *P. beardsleyi* very slow establishing species and is expanding slowly. Under check by local natural enemies, *Cryptolaemus montrouzieri*, *Spalgis epius* and some species of gnats. Coccinellid, *Cryptolaemus montrouzieri* Mulsant are some natural emenies [21].

7. Madeira mealybug, *Phenacoccus madeirensis* Green (Hemiptera: Pseudococcidae)

It is native to the Neotropical region and found in Pakistan, Philippines, Vietnam, Thailand, and

Japan. It is the latest invasive mealybug in India and was first recorded from Karnataka. It is a highly polyphagous pest that attacks 152 plant species belonging to 46 families, including many agronomic and horticultural crops grown both indoors and out [22].

Host Plants: Cotton, tomato, potato, brinjal, tapioca, mulberry, acalypha, *Hibiscus rosasinensis, Lantana camera* and *Clerodendron viscosum.*

Plate 9. Madeira mealybug

Natural Enemies: Parasitoids: *Allotropa sp, Anagyrus sinope, Anagyrus qadrii (*Predominant*), Anagyrus sloeckii, Anagyrus amnestos* [23].

Predator: *Cacoxenus persipicax, Cryptolaemus montrouzieri* and *Scymnus* sp.

Anagyrus amnestos (Hymenoptera: Encyrtidae): Promising parasitoid of the invasive Madeira mealybug. Parasitism rate ranged 17–40% within 24 hours, each female parasitoid producing a range of 58–71 offspring over her lifetime at an average female: male ratio of 2:1. *A. amnestos* preferred parasitizing second instar and adult of *P. madeirensis* [24].

10. Lantana mealybug: *Phenacoccus parvus* Morrison (Pseudococcidae)

It is native to South America and spreaded in Africa, tropical Pacific region of Australia, Southern Asia and China. It was first reported from India in Bangalore on China Aster *Callistephus chinensis* [25]. It is a pest of more than 50 species of host plant belonging to 26 families. It is also a promising biocontrol agent for *Lantana camera* in Queensland and Australia.

Plate 10. Lantana mealybug

11. Rugose Spiraling White Fly *Aleurodicus rugioperculatus* Martin (Aleyrodidae)

It is native to Belize, Guatemala, and Mexico and spread to 22 other Central and South American countries, including Florida, USA. It was first reported from India in the Pollachi area of Coimbatore district, Tamil Nadu in Coconut farm. This whitefly has only been brought to India, the sole country in the Oriental region [26,27].

Host Plants: Coconut, banana, apple and several ornamental crops. Coconut and banana are the most common and preferred hosts. More minor infestations were seen on guava, citrus, mango, sapota, okra, custard apple, jatropha, and hibiscus [28].

Plate 11. Damage

Damage: Rugose spiralling whitefly egg spirals on the underside of leaves. The presence of a heavy white waxy substance. Around the whitefly-infested area, there was sticky honeydew. Mold growth with a black sooty appearance. Damage to the leaves [29].

Management

Biological control: *Encarsia guadeloupae* Viggiani, *Encarsia dispersa, E. noyesi, Alueroctonus vittatus, Nephaspis oculata and Menochilus sexmaculatus* [30]. *E. guadeloupae* (Hymenoptera: Aphelinidae) parasitized 40 to 70% banana [31] and 20–60% on coconut in Tamil Nadu and Kerala has been reported [26].

12. Fall Armyworm: *Spodoptera frugiperda* (Smith) (Lepidoptera, Noctuidae)

It is native of the Western hemisphere tropics from the U.S.A to Argentina and spread to Africa in the 2016 on maize crop. In India, it was first reported from Karnataka in Chikkaballapur, Hassan, Shivamogga, Davanagere and Chitradurga district in 2018 [32,33].

Hosts in India: Maize and sorghum in southern Karnataka and sugarcane in Maharashtra. Within only six months, almost 50 percent of the country, including Mizoram, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Gujarat, and West Bengal, FAW infestations has been reported. It prefers young maize plants and attacks all stages of the maize plant, whereas foliar consumption is major; under heavy infestations, it also feeds on maize ears. The foliar damage appeared as ragged feeding and moist sawdust-like frass found near the whorl and upper leaves of the plant.

Management

Monitoring: Pheromone traps @ 5/acre

Cultural Measures: Deep ploughing, timely sowing and avoiding staggering sowings. Intercropping (eg. Maize + pigeon pea/black gram/green gram). Bird perches @ 10/acre (up to 30 days). Sowing of 3-4 rows of trap crops (eg. Napier). Clean cultivation and balanced use of fertilizers.

Mechanical control: Hand picking, applying dry sand and ash into the whorl, mass trapping (traps @ 15/acre).

Biological control: The *in situ* protection of natural enemies by habitat management or augmentative release of *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 per acre. Also the spray of biopesticides like *Metarhizium anisopliae* @ 5g/litre , *Nomuraea rileyi* @ 3g/litre, *Bacillus thuringiensis v. kurstaki* @2g/L(or) 400g/acre can be used [34].

Chemical control: Spray either of the insecticides like 5% NSKE / Azadirachtin 1500 ppm @ 5ml/l of water, emamectin benzoate @ 0.4 g/l of water, spinosad @ 0.3 ml/L of water, thiamethoxam 12.6% + lambdacyhalothrin 9.5%@ 0.5 ml/l of water or thiamethoxam 12.6% + lambdacyhalothrin 9.5%@ 0.5 ml/l of water.

Companies producing Pheromone traps: ISCA Technologies, California, U.S.A, Russell IPM and Pherobank. Whereas in India are Pheromone Chemicals, Hyderabad, Green Revolution (Kolhapur, Maharashtra), Innovac Bioscience Private Limited (Vadodara, Gujarat), Land Marshal Chemical Industries (Guntur, Andhra Pradesh).

5. INTERNATIONAL SCENARIO

The 1992 Convention on Biological Diversity (CBD) includes prohibitions on alien species that pose a harm to ecosystems, habitats, or species. Since the 1950s, the International Plant Protection Convention (IPPC) has worked to limit the introduction and spread of plant pests. National plant protection services and the IPPC's governing body, the Interim Commission on Phytosanitary Measures (ICPM), agreed that the CBD's goal of preventing the introduction of alien species is very similar to the IPPC's goal. The ICPM introduced supplements to two international phytosanitary standards in 2003. The secretariats of the IPPC and the CBD have incorporated a Memorandum of Cooperation and developed a joint work strategy to avoid conflicting improvements within the two conventions regarding invasive alien species and plant pests, as requested by the Conference of Parties to the CBD at its seventh meeting. A comparison of these guiding principles with IPPC requirements reveals a lot of overlap and significant connection.

Suggestions/ future threats/ management [35].

Invasive alien species are posing complicated and far-reaching difficulties that jeopardise both the earth's natural biological treasures and our people's well-being. While the problem is global, the extent and severity of the consequences for society, economic life, health, and natural heritage vary greatly among countries and areas.

Some parts of the global IAS problem necessitate answers adapted to each country's unique values, needs, and goals, while others necessitate worldwide action. To prevent the international spread of invasive alien species and coordinate a fast and efficient reaction to invasions, governments, economic sectors, non-governmental organisations, and international treaty organisations must work together. Consolidated and coordinated action is necessary at the national level. This might be included in a national biodiversity policy and action plan, with close involvement of economic sectors and the identification of personnel responsible for operational actions involving potential IAS as a critical prerequisite. Many countries lack the necessary capacity and experience to cope with IAS. As a result, more research and capacity building in the areas of IAS biology and control, as well as biosecurity challenges, must be prioritised.

6. CONCLUSION

There is a need for a global information system on the biology and control of invasive insect pests. It is necessary to supply and exchange tools, mechanisms, best management practises, control strategies, and resources. The Global Invasive Species Information Network (GISIN) is currently developing such a system, which will connect to the Convention on Biological Diversity's Clearing House Mechanism. The establishment of economic tools and incentives for prevention, as well as public awareness and education about IAS, must be given top priority in action plans.

DISCLAIMER

The products used for this research are commonly and predominantly used in our research area and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for litigation but the advancement of knowledge. Also, the research was not funded by the producing company rather, it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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