Advances and Challenges in Pest Management for Protected Cultivation in India: Integrative Approaches and Future Prospects

ABSTRACT

Poly house farming in India has transformed agriculture by enabling year-round crop production and protecting crops from adverse weather. However, the controlled environment of poly houses represents unique challenges in pest management, making it crucial to implement effective strategies to maintain crop health and yield. Integrated Pest Management (IPM) offers a comprehensive approach that combines cultural, biological and chemical practices to control pests while minimizing environmental impact. The advantages of protected cultivation include increased productivity, improved produce quality and efficient resource utilization. Despite these benefits, poly house farming faces limitations such as high initial costs, the need for meticulous planning and ongoing crop protection requirements. Pest identification is vital for effective management, as misidentification can lead to inappropriate control measures. Common pests in poly houses include insects, slugs, mites, nematodes, pathogens and weeds. Pest monitoring strategies such as scouting, using monitoring tools and record-keeping are essential for timely and effective management interventions. Management strategies encompass physical, biological and chemical methods. Physical approaches include the use of sticky and pheromone traps, while biological control involves the release of natural predators and entomopathogens. Chemical management involves both biorational pesticides and conventional chemicals, with IPM emphasizing the integration of these methods to reduce reliance on harmful chemicals. Preventive measures like insect-proof screens and soil solarization, along with curative measures and advanced technologies like video camera networks and decision support systems, are pivotal for effective pest control. Future prospects include improving technology standards, enhancing computerized control systems, and fostering research and government support to advance protected cultivation in India.

Keywords: [Poly house Farming, Integrated Pest Management (IPM), Protected Cultivation, Pest Monitoring, Biological Control, Biorational Pesticides and Preventive Measures].

1. INTRODUCTION

Poly house farming has revolutionized agriculture in India by offering year-round crop production and shielding crops from adverse weather conditions, (Jensen *et al*.,2002). However, this controlled environment also presents challenges, particularly with pest management, which can threaten crop quality, yield and overall farm success, (Sabir *et al*., 2013). Effective pest management is crucial for maintaining a healthy and productive poly house environment. Integrated Pest Management (IPM) is a comprehensive approach that combines cultural, biological, and chemical practices to control pests effectively while minimizing their impact on crops. IPM strives to balance effective pest control with environmental sustainability and economic viability, making it a key strategy for successful poly house farming. Increasing population, climate change, decreasing land holdings and increasing demand for quality horticultural fresh produce forced us to shift towards crop production under protected cultivation. Protected cultivation practices can be defined as a cropping technique wherein the micro-climate surrounding the plant body is controlled partially or fully as per the requirements of the plant species. Chemical pest control has to be reduced owing to its unwanted effects on non-targeted organisms (Biondi *et al*., 2012) and pest resistance (Liang *et al*., 2012). Thus, alternative and sustainable long-lasting pest control methods are urgently needed to enhance the activity of beneficial organisms, (Wratten *et al*., 2012).

Scope of protected cultivation in India

- Cultivation in problematic agro -climate.
- Greenhouse around big cities.
- Export of horticultural produce.
- Greenhouse for plant propagation.
- Greenhouse technology for biotechnology.
- Greenhouse for cultivation of rare and medicinal plants.

Advantages of protected cultivation:

- Increased productivity
- Better quality of produce
- Nursery raising and hardening of plant
- Efficient utilisation of resources.

Limiting factors:

- Initial high cost
- Requires careful planning and management
- Needs marketing skills
- Still requires Crop protection: Abiotic- Temperature, RH etc. Biotic- diseases, weeds, Insect Pests etc.

Difference between protected and outdoor cultivation:

Both the production technologies and management practices under protected cultivation varies from that of open field condition. Though, the protected structures are helpful in excluding pests and diseases, the risk of damage by pest and diseases still prevails inside these structures. The warm, humid conditions and abundant food under protected conditions provide an excellent, stable environment for the multiplication of entered pest. For these reasons, sometimes pest severity is greater in the indoor environment than outdoors (Singh, 2014). So, it is important to understand current pest management approaches under protected structures to minimise the losses by effectively managing the pests.

IDENTIFICATION OF PESTS: Pest identification is critical for implementing the appropriate management tactics, misidentifying might mis leads to implement inappropriate management practices.

Types of pests found in protected cultivation: 1) Insects, 2) Slugs, 3) Mites, 4) Nematodes 5) Pathogens, 6) Weeds. (Table.1).

With changing horticultural practices new pests like thrips, scales, whiteflies, mites, borers, caterpillars, slugs, nematodes etc. are emerging not only under open conditions but also under protected cultivation.

Table. 1 Insect-pests under protected cultivation

Common name	**Insect pests**	**Host**	**Distribution**
Aphids	*Aphis gossypii*	Capsicum	Punjab, Delhi
	Macrosiphoniella sanborni	Chrysanthemum	Karnataka, HP
	Macrosiphum luteum	Orchid	Sikkim
	Myzus escalonicus	Strawberry	New Delhi
	Myzus persicae	Capsicum, Gerbera	Punjab, Maharashtra
	Toxoptera aurantii	Orchid	Sikkim
Caterpillars	*Helicoverpa armigera*	Capsicum, tomato, Carnation	Punjab, Uttarakhand, HP
	Spodoptera litura	Rose, tomato, capsicum, cucumber	Karnataka, Punjab, HP
Leaf miners	*Liriomyza trifolii*	Tomato, Cucumber, Chrysanthemum, gerbera and many Ornamentals	
Mealy bugs	*Planococcus citri*	Orchids, cacti and Solanum species	
Thrips	*Scritothrips dorsalis*	Chilli, capsicum, rose	Karnataka
	Thrips palmi	Gerbera	Karnataka
	Thrips tabaci	Gerbera	Maharashtra
White flies	*Bemisia tabaci*	Gerbera, capsicum	Karnataka, Punjab
Yellow Mites/ Broad mite	*Polyphagotarsonemus latus*	Chilli, capsicum	Yellow Mites/ Broad mite
Strawberry mite	*Stenotarsonemus fragariae*	Strawberry	Strawberry mite
Red or carmine spider mite	*Tetranychus cinnabarinus*	Carnation	Red or carmine spider mite
Glasshouse Red Spider Mite	*Tetranychus neocalidonicus*	Cucumber	Glasshouse Red Spider Mite
Two -spotted Spider mite	*Tetranychus urticae*	Tomato, capsicum	Two -spotted Spider mite

		carnation and gerbera	
Bulb scale mite	*Stenotarsonemus laticeps*	Narcissus bulbs	Bulb scale mite
Bryobia mite	*Bryobia ribrioculus*	Cucumber	Bryobia mite

- **Snails/slug pests under protected cultivation:**

Some snail pests also reported under protected cultivation,

1. Grey Field Slugs *(Deroceras reticulatum) 2)* Garden slugs *(Arion hortensis)*
2. Keeled slugs (*Milax budapestensis*) 4) Black slugs (*Arion ater*)

- **Nematode pests under protected cultivation:**

Some nematode pests found under protected cultivation includes,

1. Potato Cyst Nematode (*Globodera rostochiensis* and *G. pallida*)
2. Stem and Bulb Nematode (*Ditylencus dipsaci*)
3. Chrysanthemum Nematode (*Aphelenchoides ritzemabosi*)
4. Root Knot Nematode (*Meloidogyne spp*)
5. Migratory plant Nematodes: *Xiphinema diversicaudatum*- Dagger nematodes *Longidours elongates*- Needle nematodes. (Gerson and Weintraub, 2007).

PEST MONITORING STRATEGIES:

These strategies will be helpful to know when to take management practices.

Scouting:

It's the visual observation of the plants for the presence of pests and their signs ofdamage. A hand lens will be helpful in detecting small pests, (Saha *et al. 2015).*
One should use a field data sheet to record the identification, location, and severity of all pest's present, and record the effectiveness of any treatments, (Papaioannou *et al*., 2012).

Monitoring tools:

It's different from scouting as here no direct plant observations were needed. As a monitoring tools we can use either sticky traps or pheromone traps. *E.g.:*
1) Yellow sticky cards to monitor whiteflies, aphids, thrips and leaf miner adults.
2) Blue colored sticky traps to monitor thrips.
3) Sex pheromone baited traps to monitor moths of tobacco caterpillar and tomato fruit borer.

Record Keeping:

Record keeping of Temperature, RH, counts from sticky cards, counts of pests on the plants, specific crop observation (height, leaf color, bud development, etc.) *etc.* will be helpful in understanding the pest better.

PEST MANAGEMENT STRATEGIES:

After proper identification, it's necessary to initiate proper management strategyto manage the pests effectively. For this, we can use individual approaches or integrated approaches.
Physical approaches: (Papaioannou *et al*., 2012)

The technique is similar to monitoring approach, but here we use the traps more densely.
Colored sticky traps: (Lu *et al*., 2012).

- Yellow for white fly, mites, aphids
- Blue for thrips.
- Silver for aphids

- **Pheromone traps:** To attract moths, fruit flies, thrips.

Biological approaches:

Biological control of greenhouse insect pests can be achieved through release of biocontrol agents like predatory mites, pirate bugs, soil dwelling mites, and parasitic insectsor entomopathogens, (Table.2).

Table. 2 Key pests of greenhouses and their major natural enemies. (Saha *et al.*, 2015) and (Gerson *et al.,* 2007)

Target pest	Predator	Parasitoids
Mites	*Phytoseiulis persimilis* *Neoseiulis cucumeris* *Orius laevigatus*	
White fly	*Orius laevigatus* *Chrysoperla spp.*	*Encarsia formosa* *Eretmocerus mundus*
Thrips	*Orius laevigatus* *Neoseiulis cucumeris* *Thripoctenus americensis*	
Leaf miner	*Diglyphus isaea* *Dacnusa siberica*	
Mealy bugs	*Cryptolaemus montrouzieri*	*Anagyrus pseudococci* *Leptomastix dactylopii*
Aphids	*Orius laevigatus* *Chrysoperla spp.* *Apidoletes aphidomyza*	*Aphidus colemani* *Aphidus matricarae*
Jassids	*Chrysoperla spp.*	
Caterpillars	*Chrysoperla carnea*	*Trichogramma spp*.

Entomopathogens: We can use the entomopathogens like, (Gerson *et al.* 2007)

- **Fungus:** *Beauveria bassiana, Lecanicillium lecanii, Metarhizium anisopliae etc.* on aphids, whiteflies, thrips and spider mites.
- *B. bassiana* has been found to be compatible with predators such as *Encarsia* spp., *Eretmocerus* spp. and *Chrysoperla* spp.
- **Bacteria:** *Bacillus thuringiensis,* or BT is sold as Gnatrol, Dipel, Xentari.
  - Gnatrol controls a variety of leaf chewing caterpillars and is alsoused against fungus gnats, (Table.3).

Nematodes

Steinernema spp. and *Heterorhabditis* spp. *on* Fungus gnats (*Bradysia* spp.), shore flies, western flower thrips and leaf miners.

Key points- when using biological control agents

- Involves more work at first
- They are best used when pest numbers are fairly low.
- Perform best at moderate temperatures (65-85°F) and humidity's (60-90%).
- The effectiveness of the same beneficial may be different on different plants.
- If all the pests are destroyed, the beneficial will starve.

Table.3 Key Pests of Greenhouses and some of their Entomopathogens

Target pest	Entomopathogens
White fly	*Lecanicillium lecanii* *Beauveria bassiana*
Thrips	*L. lecanii* *B. bassiana*
Leaf miner	*Bacillus thuringiensis*
Mealy bug	*L. lecanii*
Jassids	*L. lecanii*
Caterpillars	*B. thuringiensis* *NPVs e.g. SlNPV, HaNPV etc.*

Chemical approaches:

As a chemical measure we can use either least toxic biorational pesticides or highly toxic chemical pesticide.

Biorational Pesticides:

Insecticidal soap sprays: kill pests by dehydration.
Horticultural oils: Are refined petroleum or vegetable oils that work by smothering pests.
Neem oil: It interferes with insect development, and other compounds like Pyrethrum and Rotenone.
Insect Growth Regulator's: They have a complex mode of action and kill insects bydisrupting their development.
IGRs can work in one of several ways:

- They can mimic juvenile hormones, so that insects never enter the reproductive stage of development;
- They can interfere with the production of chitin, which makes up the shell ofmost insects.
- Even though these biorationals were economically sound and ecologically safer, their use is limited because of their slow action, (Saha *et al. 2015)*

Chemical management:

Chemical pest control refers to the use of chemicals that kill the pests. These chemicals are called pesticides, (Shah *et al*. 2014) and (Sabir *et al*. 2012).

It's the most popular,

- Easier use
- Readily available
- Provides a quick means of killing pests
- Efficiency

- Cost effectiveness

Limitations:

- Need to select the pesticides having less persistence.
- Development of resistance in pest.
- Contributor to pollution.

Table 4. Some of the important chemical formulations used against greenhouse insect pests

Target pests	Chemicals	References
Mites	Diafenthiuron, Fenpyroximate, Abamectin @ 0.5ml/L	Shah *et al*., 2014
Thrips, Whiteflies, Aphids	Imidacloprid @ 0.4g/L, Acephate @ 1g/L or Acetamiprid @ 0.2g/L, Abamectin @ 0.5 ml/L, Phosphomidan 0.2 mL	Kumar *et al*., 2007 and Kaur *et al*., 2013
Leaf miner	Spinosad @ 0.3ml/L, Abamectin @ 0.5ml/L	Sabir *et al*., 2010
Caterpillars	Spinosad, Chlorantraniliprole @ 0.3ml/L, Flubendiamide @ 0.1ml/L	Sabir *et al*., 2010

Applicator should take the safety measures,

1. Require Protective kit.
2. A re-entry period of at least 12 hr.
3. Fumigants must be avoided.

In order to avoid evolution of resistance in insects due to repeated use of same or same group of chemicals we need to use the different chemicals in rotation.

Integrated approaches:

The use of Integrated Pest Management (IPM) in protected environments is ideally suited. The use of IPM can virtually eliminate the need to use toxic and expensive chemical pesticides.

IPM is the coordinated use of pest and environmental information and available pest control methods to prevent unacceptable levels of damage by the most economical means with the least possible hazard to people, property and the environment.

Goals:

1. Integrating different approaches
2. Minimizing chemical use
3. Optimize pest control
4. Economically sound
5. Ecologically safe

PREVENTIVE MEASURES:

Mechanical methods:

1) Insect proof screens

Screening vents and doorways can greatly limit the movement of insect pests into the greenhouse. Selection of proper screen size mesh and assuring adequate airflow aremore important, (Saha *et al. 2015) and (*Bethke *et al*., 1991).

Insect-proof screens 10 x 20 micron and 10 x 22 micron give adequate exclusion of whiteflies *Trialeurodes vaporariorum* and *Bemisia tabaci* without impeding natural enemies (*Diglyphus isea* and *Eretmocerus erimicus*) movement, (Hanafi et al., 2007).

2) Airlock entrance/ provision of double door

In greenhouses, an airlock entrance room is essential. It's attached to the exterior ofthe greenhouse and enclosing the entry doorway. It allows workers to enter the airlockroom and close the outside door behind them before entering the greenhouse production area, (Saha *et al. 2015).*

3) Ultra-violet radiation absorbing sheets

The UV part of the solar spectrum plays an important role in the ecological behavior of insects, including orientation, navigation, feeding and interaction betweenthe sexes, (Saha *et al. 2015).*

UV blocking PE films found very effective in reducing the no. of injured fruit in tomato and produces higher yield in comparison to other covering material, (Papaioannou *et al*., 2012).

Cultural methods:

Soil solarization

Soil solarization is the process of trapping moist soils with clear polyethylene totrap solar radiation and raise soil temperatures to levels lethal to most insect, nematodes, pathogens and weed seeds.

Plant Quarantine & Sanitation

Another common discovery is insects coming into the greenhouse on infested plants from other areas. It is important to keep the area around the exterior of the greenhouse free of weeds and other plants that could harbor pests. Eliminate infestations by discarding or removing heavily infested plants.

Balanced use of fertilizer

Fertilization schedules based on balanced use of nutrients should be followed. Nitrogen should be applied only as needed for optimal growth. Application of potassium at desired levels has been found to reduce the incidence of insect-pests.

Use of Natural Insect Repellent, Attractant/Trap crops:

- Spearmint repels aphids
- Strong-smelling herbs like rosemary, thyme, and wormwood - repels moths andflies.
- A pot of mint repels cabbage white butterflies.
- Neem plants are another safe way to deter insects.
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Attractants/trap crops: -

- Planting border rows of *Portulaca oleracea* in rose can be used as a trap cropfor tobacco caterpillar under protected environment.
- Whiteflies are attracted to lettuce and tomatoes. (Sringarm *et al.,* 2013)

CURATIVE MEASURES:

Even though with the preventive measures, if the pest population reaches economic threshold level we need to implement curative measures to minimize the losses.

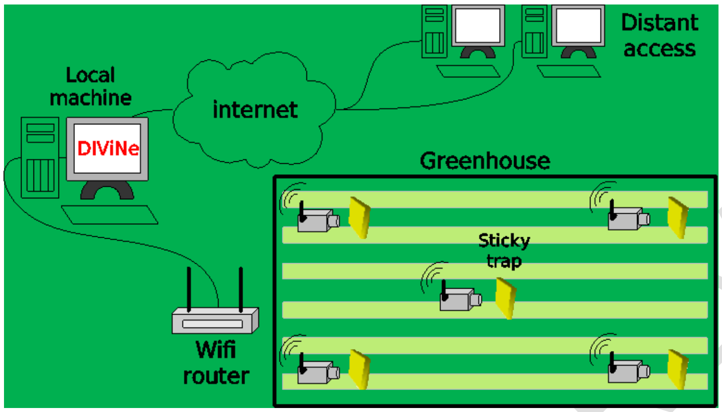
Selection of curative measures:

While selecting the combination we must be careful. Preferably least toxic chemicalsshould be used.

- E.g. Flonicamid, Methoxyfenozide were suitable with predators like *Orius laevigatus and Amblyseius swirskii.* (Colomer *et al.,* 2011).
- Spinosad with some predatory mites (Rahman *et al.,* 2010).

Towards a Video Camera Network for Early Pest Detection in Greenhouses

- Integrated Pest Management
- Early pest detection to reduce pesticide use
- Approach: Automatic vision system for *in situ*, non-invasive, and early detection
    - Based on a video sensor network
    - Using video processing and understanding, machine learning, and a prior knowledge
- Help producers to take protection decisions, (Vincent Martin *et al*., 2004).



First DIViNe Prototype (Vincent Martin *et al*., 2004)

Fig .1 DIVINE: A Decision Support System
Detection of Insects by a Video Network

Table.5 Difference between Manual method and Divine System

Identification and counting of pests	**Manual method**	**DIVINE system**
Result delivery	Up to 2 days	Near real-time
Advantages	Discrimination capacity	Autonomous system, temporal sampling, cost
Disadvantages	Need of a specialized operator (taxonomist); precision versus time	Predefined insect types; video camera installation

Robotics in protected cultivation

Automation in agriculture focuses on maintaining robotic tasks to improve efficiency and productivity. Advanced safeguarding technologies are used in high-value crop production, such as tomatoes, sweet peppers, cucumbers, roses, chrysanthemums, and gerberas. In Western societies, there is a trend toward expanding production facilities due to rising labor costs, a shortage of skilled workers, health issues from repetitive tasks, and increasing competition both nationally and globally. Precision farming techniques, which treat plants individually, are becoming common as they enhance yield quality and resource efficiency. These challenges, combined with labor constraints, have intensified the demand for automation and robotics in agriculture, particularly for tasks like harvesting (Van Henten, Jan *et al*., 2013 and Ummyiah, 2017).

FUTURE PROSPECTS OF PROTECTED CULTIVATION

The protected cultivation is still in its preliminary stage in India and concerted efforts are required from all concerned agencies to bring it at par with the global standards

The future need for improving this technology

- Standardized proper design of construction of poly houses should be followed to the avoid entry of pest.
- Computerized Control System maximize returns it includes opening and closing of ventilators and side wall roll up curtains, CO_2 Generator, Climate Control, Temperature, Humidity, Heat Radiation, Control of EC that will avoid congenial conditions to pest, ph., ppm level of elements in irrigation water etc. as required to the plant.
- Major research in protected cultivation has to be done by ICAR and SAU's, and Government initiatives/efforts in popularizing the protected cultivation technology among the farming community of the country are to be strengthened.

4. CONCLUSION

Poly house farming represents a significant advancement in agricultural practices, offering enhanced productivity, quality and resource efficiency. However, the controlled environment of poly houses also poses unique challenges in pest management. Integrated Pest Management (IPM) emerges as a vital strategy, combining cultural, biological and chemical approaches to address these challenges effectively. By implementing comprehensive pest monitoring and management strategies, including the use of physical, biological and chemical methods and emphasizing preventive and curative measures, farmers can safeguard their crops and optimize yields. Future advancements should focus on standardizing construction practices, integrating computerized control systems and fostering research and government support to enhance the effectiveness of protected cultivation. These efforts will ensure that poly house farming not only meets current demands but also aligns with global standards for sustainable and productive agriculture.

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