

Management Strategies for Major Sucking Insect Pests of Green Gram: Progress and Prospects

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Abstract: Green gram (*Vigna radiata* L.) is an important short duration pulse crop widely cultivated across South and Southeast Asia for its nutritional value, contribution to soil fertility and role in smallholder livelihoods. However, its productivity is severely constrained by a complex of sucking pests including aphids (*Aphis craccivora*), jassids (*Empoasca* spp.), whiteflies (*Bemisia tabaci*), thrips (*Thrips* spp.) and spider mites (*Tetranychus* spp.). These pests cause yield losses through direct sap feeding and indirectly by transmitting viral diseases, particularly yellow vein mosaic disease, often leading to serious economic damage. Prolonged dependence on chemical insecticides has resulted in resistance development, pest resurgence and negative impacts on natural enemies and the environment. This review summarized recent developments in the sustainable management of the main green gram sucking insect pests, with a focus on integrated pest management strategies that incorporate host plant resistance, biological control and natural enemy conservation, behavioural and ecological engineering techniques, the use of botanical and microbial biopesticides, selective application of reduced risk insecticides guided by economic threshold levels and cultural and agronomic practices. In order to increase productivity while maintaining the sustainability of the environment and human health, the analysis also highlighted future opportunities such as climate smart Integrated Pest Management (IPM), landscape-level biological management and breeding for lasting resistance.

Keywords: Aphid, Biocontrol, Sustainable management, *Vigna radiata*, Whitefly.

Introduction

Green gram (*Vigna radiata* L.), a vital short duration pulse crop across South and Southeast Asia, plays an out-sized role in smallholder nutrition, soil fertility and cash income. During 2023-24, green gram was cultivated over approximately 15.93 lakh hectares (39.38 lakh acres) in India. As per the Government's third advance estimates, the production of green gram in 2022-23 was estimated at 3.74 million tonnes [1]. However, its productivity is frequently limited by a complex of sap feeding insect pests including aphids, jassids/leafhoppers, whiteflies, thrips and various mite complexes, which reduce yield both directly (sap removal, distortion, sooty mould development) and indirectly (vectoring viral and phytoplasma diseases) [2]. These pests are particularly challenging because of their rapid population growth, cryptic feeding habits and frequent development of resistance to conventional insecticides, which has driven unsustainable spray cycles and negative impacts on natural enemies and pollinators. Over the last two decades, research has advanced integrated, sustainable management strategies that combine host-plant resistance, cultural and agronomic measures (timing, intercropping, tolerant cultivar deployment), biological control (conservation and augmentation of parasitoids, predators and entomopathogens) and reduced-risk insecticides used selectively within an IPM framework. Novel tools like use of pheromones, behavioral manipulation, precision monitoring and improved biopesticide formulations show promise for reducing reliance on broad spectrum chemicals while maintaining yield stability.

This review synthesised the sustainable management strategies of major sucking pests on green gram, evaluates their effectiveness and constraints of current management options and highlighted researchable prospects, including breeding for durable resistance, landscape-scale biological control and climate smart IPM that can help reconcile productivity with environmental and human-health objectives.

Major Sucking Pest Complex of Green Gram

Sucking insect pests represent the most persistent and economically significant constraint in green gram cultivation, as they remain active throughout much of the crop growth period. The major pests commonly associated with green gram include the aphid (*Aphis craccivora*), jassids or leafhoppers (*Empoasca* spp.), the whitefly (*Bemisia tabaci*), thrips such as *Thrips palmi* and spider mites (*Tetranychus* spp.). These pests generally infest the crop from the early vegetative stage and often continue until pod maturity, causing continuous physiological stress through sap feeding (Table 1). Among them, *B. tabaci* is particularly destructive because it transmits yellow vein mosaic virus, one of the most devastating viral diseases of green gram. This can lead to severe yield reduction or even complete crop failure under favorable conditions, with losses reported up to 100% [2]. Aphids also contribute to indirect losses through virus transmission. Jassids, such as *Empoasca kerri*, primarily cause damage by sucking plant sap, leading to symptoms like leaf curling, paleness (chlorosis) and eventual drying of leaves. Thrips, through their feeding, can cause a decrease in chlorophyll content and reduced photosynthetic efficiency by siphoning off plant contents and consuming mesophyll cells. Thrips also infest flowers, which can result in deformation of pods and reduced yield. Spider mites (*Tetranychus* spp.) become more problematic during hot and dry weather, their feeding on the underside of leaves causes characteristic white speckles that can progress to yellowing, bronzing and in severe infestations, the whole plant may become pale, accelerating premature senescence. The intensity and dominance of these sucking pests of mung bean vary with season, agroclimatic conditions and crop management practices; however, their combined infestation has been reported to cause yield losses ranging from 30% to as high as 80-100% in severe cases, particularly when viral diseases are involved [3].

Table 1: Major sucking pest complex of green gram and its damage symptoms.

Major sucking pest complex	Damage Symptoms	Hosts
Aphid (<i>A. craccivora</i>)	In green gram, aphids infest tender shoots, young leaves and inflorescences by sucking plant sap. Heavy infestation causes leaf curling, yellowing and stunted growth. They secrete honeydew, which promotes the development of sooty mold, reducing photosynthesis. Aphids also act as vectors of viral diseases, leading to poor flowering and reduced pod formation, ultimately lowering yield.	Green gram, black gram, cowpea, chick-pea, pigeon pea, berseem
Jassids (<i>Empoasca</i> spp.)	Jassids feed mainly on the underside of green gram leaves by sucking sap. Their feeding results in yellowing at leaf margins, followed by browning and drying known as "hopper burn." Leaves may curl downward and plants show stunted growth. Severe infestation weakens the crop and reduces pod setting and overall productivity.	Cotton, okra, green gram, black gram, brinjal
Whitefly (<i>B. tabaci</i>)	Whiteflies suck sap from the underside of leaves in green gram, causing yellowing, wilting and stunted growth. They excrete honeydew that leads to sooty mold formation, interfering with photosynthesis. Whitefly is also a major vector of Yellow Mosaic Virus in green gram, which can cause severe yield losses under heavy infestation.	Cotton, tomato, green gram, black gram soybean, tobacco
Thrips (<i>T. palmi</i>)	Thrips damage green gram by rasping and sucking leaf tissues. Their feeding produces silvery streaks, curling and distortion of leaves. Affected plants show reduced growth, flower drop and poor pod development. Severe infestation can significantly decrease yield and seed quality.	Onion, garlic, green gram, cotton, chilli
Spider mites (<i>Tetranychus</i> spp.)	Spider mites infest the underside of green gram leaves, especially during hot and dry weather. They suck cell sap, causing tiny yellow specks (stippling) that later turn into bronzing of leaves. Fine webbing may be seen on heavily infested plants. Severe attack leads to drying and premature leaf fall, reducing photosynthetic activity and yield.	Green gram, soybean, cotton, vegetables, fruit crops

Management

Management of major sucking insect pests of green gram should be based on an IPM approach that emphasizes prevention, ecological regulation and judicious chemical use (Fig. 1). Key components include cultural and agronomic practices to reduce early pest establishment, deployment of resistant or tolerant varieties to limit whitefly and virus damage and regular pest monitoring using field scouting and economic threshold levels. Conservation of natural enemies, supported by behavioural tools and biopesticides, helps suppress pest populations in an environmentally safe manner. Chemical control, when required, should be selective, threshold-based and rotated across insecticide modes of action to delay resistance development. Integration of these strategies, supported by farmer participation and decision-support systems, provides a sustainable framework for managing sucking insect pests in green gram.

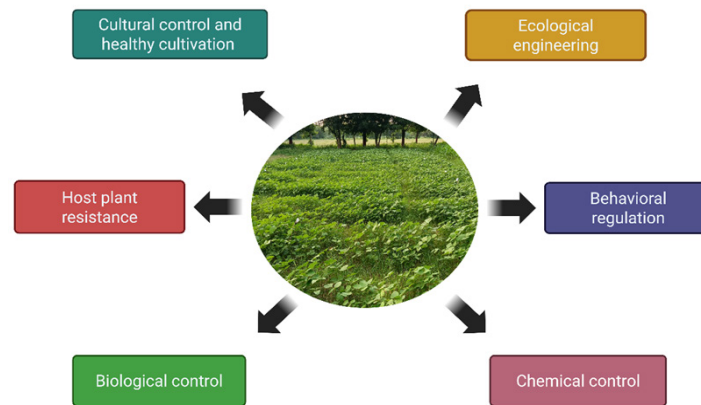


Figure 1: IPM framework for sustainable management of sucking pests in green gram.

Cultural and Agronomic Practices

Cultural practices form the foundation of sustainable management of sucking pests in green gram. Timely sowing to avoid peak activity of vectors such as whitefly (*B. tabaci*), maintenance of optimum plant spacing and balanced fertilizer application, particularly avoidance of excessive nitrogen, which enhances host succulence and favors rapid multiplication of sucking pests, play a critical role in suppressing early pest establishment. Removal of weed hosts such as *Croton bonplandianus*, *Euphorbia hirta*, *Parthenium hysterophorus*, *Ageratum conyzoides*, *Abutilon indicum* and *Tridax procumbens*, which serve as alternate reservoirs for whitefly, aphids and associated viruses including YVMD, significantly reduces pest carryover and disease spread [4]. Crop rotation with non host crops and field sanitation further limit the persistence of pest populations between seasons. In India, adoption of Area-Specific Agro-Ecosystem Analysis (AESAs) based IPM practices are promoted by National Institute of Plant Health Management and implemented through Krishi Vigyan Kendras has resulted in reduced sucking pest incidence and lower pesticide use in green gram cultivation.

Host Plant Resistance (HPR)

The use of resistant or tolerant varieties is one of the most effective and ecofriendly strategies for managing whitefly transmitted yellow vein mosaic disease (YVMD). In India, breeding programmes under ICAR-AICRP on MULLaRP and ICAR-IARI have identified and released several green gram varieties with improved tolerance to YVMD and better yield stability. HPR in these cultivars operates through a combination of antixenosis, antibiosis and tolerance mechanisms, wherein resistant genotypes deter whitefly (*B. tabaci*) landing and feeding through morphological and biochemical traits, adversely affect vector survival and fecundity and restrict viral replication and systemic movement within the plant. Additionally, tolerant plants compensate for virus induced damage by maintaining photosynthetic efficiency and growth, thereby sustaining yield under infection pressure. Multi location trials across major pulse growing regions of India have consistently demonstrated reduced disease severity and higher productivity in resistant lines compared to susceptible cultivars.

Screening Methodologies for Resistance

Identifying resistant green gram genotypes relies on rigorous and systematic screening methodologies. These involve:

- **Field screening:** Genotypes are evaluated under natural field conditions, often in “hot spot” areas with high pest or disease pressure. For MYMV resistance, this includes planting infector rows to ensure high inoculum levels [5]. The Percent Disease Incidence is a common metric for MYMV resistance [5].
- **Screen house conditions:** To confirm resistance identified in field trials, genotypes are reevaluated under controlled screen house conditions. This minimizes environmental variability and ensures consistent pest/disease pressure, enhancing the reliability of resistance categorization [6].
- **Pest population assessment:** For sucking pests like whiteflies, aphids and jassids, resistance is assessed by monitoring the mean number of insects per plant or per leaf at regular intervals after sowing [7].
- **Disease scoring:** A standardized rating scale based on the severity of symptoms is typically used to categorize genotypes into groups such as highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible [6,8].

These screening efforts aim to identify germplasm that can be utilized as donors in breeding programs to develop new, resistant varieties [5].

Identified Resistant Green Gram Genotypes

Decades of screening efforts have identified several green gram genotypes exhibiting resistance or moderate resistance to sucking pests and/or MYMV:

MYMV Resistance

- Genotypes like IPM 02-03, KM 2241, PDM 139, Pusa 0672, HUM 16, ML 1464 and TARM-1 have shown resistance to MYMV under natural field conditions in Varanasi, making them potential donors for breeding [5]. Similarly, SML 1815 and MH 421 displayed resistant reactions against MYMV in specific screenings at Vamban, Pudukkottai, Tamil Nadu [9]. Genetic studies have even identified quantitative trait loci for MYMV resistance, such as *qYMIV1*, *qYMIV2*, *qYMIV3*, *qYMIV4* and *qYMIV5*, explaining a significant portion of variation in disease responses in India and Pakistan [10]. In a broader screening, KMP-13, KMP-19, KMP-20, KMP-22, KMP-23, KMP-24, KMP-40, KMP-45, MLGG-8 and WGG-42 were found to be immune to MYMV disease in Warangal, Telangana State [11]. Other resistant sources of MYMV have been reported in various reviews [12].

Sucking Pest Resistance

- Genotypes such as Virat, TM-37 and Shikha have shown the least mean whitefly incidence per plant in Jabalpur, Madhya Pradesh [7]. Similarly, minimum aphid incidence was observed on Virat, Shikha and TM-37 [7]. Low leafhopper counts were recorded on Virat, Shikha, PDM-139 and TM-37 [7]. Some insect resistant sources for whiteflies are also available and are being used in breeding programs [13].

Biological Control and Natural Enemy Conservation

Conservation of natural enemies such as coccinellids, chrysopids, syrphids, predatory bugs, parasitoids and entomopathogenic fungi plays a vital role in regulating sucking pest populations. Indian studies have documented effective suppression of aphids and whiteflies through natural enemy activity when broad spectrum insecticides are avoided. Entomopathogenic fungi such as *Beauveria bassiana* and *Lecanicillium lecanii* have shown promising results against whiteflies and thrips under field conditions in different agro-climatic zones of India [14].

Biological control, supported through the conservation of natural enemies, is a key component of sustainable management of sucking insect pests in green gram. Beneficial organisms such as coccinellids, chrysopids, syrphids, predatory bugs, parasitoids and entomopathogenic fungi help regulate pest populations when the crop ecosystem is not disrupted by excessive chemical use. Studies from major pulse growing regions of India have shown that avoidance of broad spectrum insecticides and adoption of selective, need-based pest management practices favour the buildup of natural enemy populations, resulting in reduced incidence of aphids and whiteflies. Habitat management approaches, including intercropping, maintenance of flowering refugia and reduced soil disturbance, further support the survival and effectiveness of predators and parasitoids. In addition, entomopathogenic fungi such as *B. bassiana* and *L. lecanii* are well suited to conservation based biological control, as they are compatible with beneficial insects and have shown consistent field level suppression of whiteflies and thrips under different agroclimatic conditions in India [15].

Botanical insecticides and microbial biopesticides are gaining importance in India due to their safety to non target organisms and compatibility with IPM. Neem based formulations (azadirachtin) have been widely evaluated and recommended for the management of aphids, whiteflies and thrips in green gram. Recent field demonstrations and on-farm trials in India have shown that neem formulations and microbial agents can significantly reduce vector populations and delay virus spread when applied at early stages [16].

Effectiveness and Evidence for Biological Control Agents in Green Gram

A combination of entomopathogenic fungi like *Lecanicillium lecanii* and neem oil, even at half their recommended concentrations, has demonstrated efficacy comparable to chemical insecticides in reducing jassid and whitefly populations while preserving beneficial predators [17]. Furthermore, botanicals like Agniastra, Brahmastra, Dashparni ark and Neemastra have proven effective against a range of insect pests, including whiteflies and jassids [18]. For instance, neem oil 5% has been particularly effective against whiteflies and jassids, achieving population reductions of 51.55% and 59.96%, respectively [18]. Similarly, NSKE 5%, Brahmastra 5%, Agniastra 5%, Tobacco leaf extract 5%, Neemastra 5% and Dashparni ark 5% also exhibited significant efficacy against these pests [18]. This underscores the potential for integrated approaches that combine biological and botanical interventions to achieve robust pest control in green gram cultivation, aligning with eco-friendly agricultural practices [19]. Moreover, the deployment of predatory species such as *Phytoseiulus persimilis* and *Chrysoperla carnea* alongside entomopathogenic fungi like *Metarhizium anisopliae* has demonstrated considerable promise in controlling mixed infestations of *Tetranychus urticae* and *B. tabaci* in green bean crops, offering a viable alternative to conventional chemical treatments [20].

The table 2 illustrated the diverse array of biological control agents that have been identified against key sucking insect pests of green gram and related legumes. These include a variety of predatory insects, specialized parasitoids, entomopathogenic microorganisms and plant-derived extracts. Such agents offer a sustainable and environmentally sound approach to pest management, reducing the reliance on chemical interventions. The precise identification and application of these natural enemies are crucial for effective integrated pest management strategies in green gram.

Ecological Engineering

Ecological engineering for green gram leverages habitat manipulation and biodiversity to strengthen natural biological control of major sucking pests while reducing insecticide dependence. Recent advances emphasized the use of flowering refugia and banker/companion plants (e.g., marigold, coriander, sunflower, cowpea) to provide nectar, pollen and shelter that sustain parasitoids (*Encarsia*, *Eretmocerus*) and predators (ladybirds, lacewings, syrphids), thereby lowering vector populations and virus transmission (Fig. 2). Push-pull style designs, targeted intercropping (sorghum, millet, sesame) and border crops have been shown to disrupt pest host finding and microclimate favourable to vectors. Integration of ecological engineering with biopesticides and threshold based selective sprays further preserves beneficial arthropods and improves the overall effectiveness of IPM programmes [38]. Newer trends include landscape scale habitat networks, farmer-led on-farm demonstrations and data driven selection of flowering species to maximize natural enemy provisioning under local conditions. Together these approaches offer scalable, low-cost pathways to resilient green gram production.

Table 2: Biological control agents and their target sucking insect pests of green gram.

Target pest	Biological control agent type	Specific Biocontrol Agent(s)	Reference(s)
Aphids (<i>A. craccivora</i>)	Predators	Ladybirds (<i>Hippodamia variegata</i> , <i>Coccinella undecimpunctata</i> , <i>Menochilus sexmaculatus</i> , <i>Brumus suturalis</i> , <i>Harmonia dimidiata</i> , <i>Coccinella septempunctata</i> , <i>Scymnus</i> spp.), lacewings (<i>Chrysoperla carnea</i>), mirid bugs (<i>Orius</i> sp.), rove beetles (<i>Paederus alfieri</i>), spiders (<i>Singa</i> sp., <i>Dictyna</i> sp.).	[20-22]
	Parasitoids	<i>Aphidius</i> spp., <i>Lysiphlebus fabarum</i> , <i>Trioxys</i> sp., <i>Diaeretiella</i> sp., <i>Aphidius colemani</i> .	[20,23]
	Entomopathogens	Fungi (<i>B. bassiana</i> , <i>Akanthomyces lecanii</i> , <i>M. anisopliae</i>).	[24-27]
	Botanical extracts	Extracts from mint, eucalyptus, <i>Allium tuberosum</i> , <i>Caesalpinia ferrea</i> , <i>Piper aduncum</i> , <i>Carica papaya</i> , <i>Dieffenbachia picta</i> , <i>Cucurbita moschata</i> , <i>Annona squamosa</i> , <i>Xylopiya aethiopica</i> , <i>Curcuma longa</i> , <i>Allium sativum</i> , <i>Azadirachta indica</i> (neem), <i>Musa paradisiaca</i> , <i>Tephrosia vogelii</i> , <i>Clutia abssynica</i> , <i>Clausena anisata</i> , <i>Lobelia gibelloa</i> .	[28-30]
Whiteflies (<i>B. tabaci</i>)	Predators	Predatory mites (<i>Amblyseius swirskii</i>), beetles (<i>Delpastus catalinae</i> , <i>Delpastus</i> spp., <i>Nephaspis</i> spp., <i>Serangium japonicum</i>), lacewings (<i>Chrysoperla carnea</i> , <i>Ceraeochrysa</i> sp.), mirid bugs (<i>Macrolophus pygmaeus</i> , <i>Nesidiocoris tenuis</i>), spiders.	[31-33]
	Parasitoids	<i>Encarsia</i> spp. (<i>E. lutea</i> , <i>E. formosa</i> , <i>E. nigricephala</i> , <i>E. pergandiella</i> , <i>E. sophia</i> , <i>E. artemopae</i>), <i>Eretmocerus</i> spp. (<i>E. mundus</i> , <i>E. eremicus</i>), <i>Prospaltella lutae</i> .	[31]
	Entomopathogens	Fungi (<i>B. bassiana</i> , <i>Cordyceps fumosorosea</i> , <i>Isaria javanica</i> , <i>Paecilomyces javanicus</i> , <i>M. anisopliae</i> , <i>L. lecanii</i>).	[30,34]
	Botanical extracts	Extracts from <i>Azadirachta indica</i> (neem), <i>Xylopiya aethiopica</i> , <i>Curcuma longa</i> , <i>Allium sativum</i> , <i>Musa paradisiaca</i> , <i>Tephrosia vogelii</i> , <i>Clutia abssynica</i> , <i>Clausena anisata</i> , <i>Lobelia gibelloa</i> .	[35]
Jassids (<i>Empoasca</i> spp.)	Predators	Ladybirds (<i>Chilocorus cacti</i> , <i>Cycloneda sanguinea</i> , <i>Hyppodamia convergens</i>), lacewings (<i>Chrysopa collaris</i>), mirid bugs (<i>Orius insidiosus</i>), assassin bugs (<i>Zelus longipes</i>), long-legged flies (<i>Chrysotus</i> spp.), stilt-legged flies (<i>Taeniptera</i> sp.), ants (<i>Solenopsis geminata</i>), paper wasps (<i>Polistes crinit's Felton</i>), damselflies (<i>Enallagma civile</i>), miscellaneous spiders.	[36]
	Parasitoids	Egg parasitoids (<i>Stethynium empoascae</i>). Note: Some studies found no insect parasites for jassid stages in pigeon pea.	[36,37]
	Entomopathogens	Fungi (<i>M. anisopliae</i>).	[17,36]
	Botanical extracts	Extracts from <i>Azadirachta indica</i> (neem), <i>Xylopiya aethiopica</i> , <i>Curcuma longa</i> , <i>Allium sativum</i> , <i>Musa paradisiaca</i> .	[17,35]

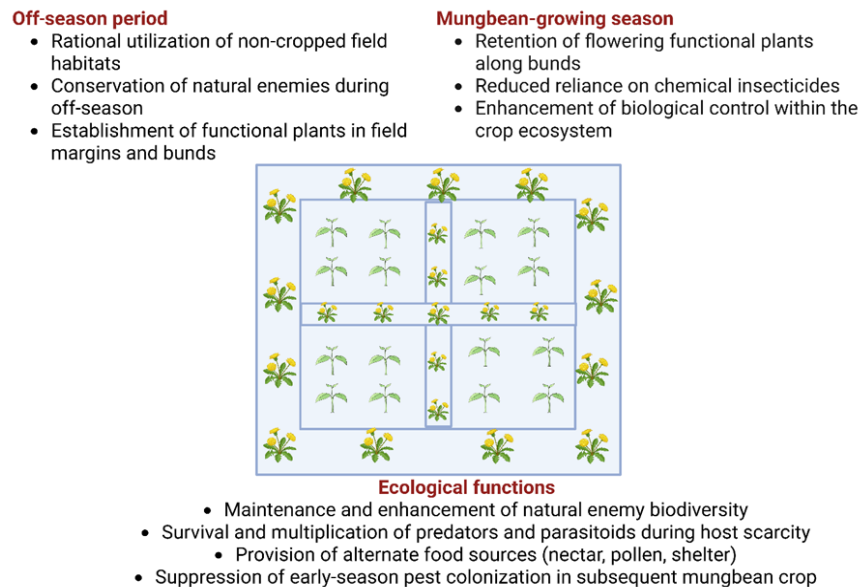


Figure 2: Schematic representation of ecological regulation strategies for the management of sucking pests in green gram.

Behavioural Control

Behavioural control exploits the natural responses of insect pests to visual and chemical cues and offers an ecofriendly option for managing sucking pests in green gram. Yellow sticky traps are widely used to attract and monitor populations of whiteflies, aphids and jassids, while blue sticky traps are particularly effective against thrips. Installation of sticky traps at appropriate densities helps in early detection of pest buildup and can also contribute to partial population suppression under field conditions. In addition, pheromone traps, though more commonly used for lepidopteran pests, aid in overall pest surveillance and support timely decision making within an integrated pest management framework. Behaviour modifying approaches such as use of reflective mulches have also been reported to reduce whitefly landing and virus transmission by disrupting host location behaviour. When combined with cultural and biological control measures, behavioural tools help minimize insecticide dependence and improve the sustainability of green gram pest management [39].

Chemical Control and Resistance Management

Chemical control remains an important component when pest populations exceed economic threshold levels; however, its use must be selective and need based. Indian studies have indicated that repeated and indiscriminate use of systemic insecticides, particularly neonicotinoids, has contributed to the development of resistance in whitefly (*B. tabaci*) populations in different cropping systems, including pulses [40]. Hence, rotation of insecticides with different modes of action, use of selective molecules and integration with biological and cultural practices are strongly recommended. Research trials have demonstrated that judicious insecticide use within an IPM framework reduces whitefly abundance and YVMD incidence while minimizing adverse ecological effects [41].

Economic Thresholds

Chemical control of sucking insect pests in green gram should be guided strictly by economic threshold levels (ETLs) to avoid unnecessary insecticide applications and to support sustainable pest management. ETLs represent the pest density at which control measures must be initiated to prevent the population from reaching the economic injury level (EIL). In green gram, commonly adopted ETLs include aphids: 10-15 aphids per 10 cm terminal shoot, whitefly: 5-6 adults per leaf or 10-20 adults per plant, jassids: 2-3 nymphs per leaf and thrips: 8-10 individuals per leaf [42]. For whitefly-transmitted yellow vein mosaic disease (YVMD), a lower threshold of 1-2 whiteflies per plant is recommended during early crop stages due to the high risk of virus transmission [43]. Adoption of ETL based insecticide application has been shown to reduce pesticide load, conserve natural enemies and delay resistance development in sucking pest populations under Indian agro-ecosystems.

Regular monitoring through visual scouting, yellow sticky traps and use of locally validated economic threshold levels is essential for timely management decisions. Farmer Field Schools and On-Farm Trials conducted by KVKs in India have successfully demonstrated that pest monitoring and AESA-based decision-making significantly reduce unnecessary pesticide applications and improve net returns in green gram cultivation.

New Technologies

Recent advancements in insect pest management have led to the development of several innovative technologies and new generation products that support sustainable control of sucking insect pests in green gram.

Novel chemistry insecticides with unique modes of action such as flonicamid, spirotetramat, pymetrozine, sulfoxaflor, cyantraniliprole and other diamide molecules have demonstrated high efficacy against *B. tabaci*, *Aphis* spp., *Empoasca* spp. and *Thrips* spp. These insecticides primarily affect feeding behaviour, lipid biosynthesis, or muscular activity, resulting in effective pest suppression with comparatively lower toxicity to natural enemies when used judiciously. Their incorporation into insecticide rotation programmes is particularly important for managing resistance in whitefly populations, which pose a major challenge in pulse crops.

Biopesticides and microbial based products have emerged as important components of sustainable insect pest management. Entomopathogenic fungi such as *Isaria fumosorosea* has shown promising results against sucking pests by infecting different developmental stages of whiteflies, aphids and thrips. These bioagents are particularly suitable for integration into IPM programmes due to their compatibility with predators and parasitoids and their minimal impact on the environment.

Recent years have also witnessed growing interest in precision and digital pest management technologies. Tools such as smart pheromone traps, sensor based sticky traps, mobile app assisted pest surveillance and decision support systems enable realtime monitoring of insect pest populations and improve the accuracy of ETL based interventions. Advances in semiochemical research, including improved pheromone formulations and kairomone based attractants, have enhanced the effectiveness of behavioural manipulation techniques. Furthermore, emerging approaches such as nano formulations of insecticides, RNA interference (RNAi) based pest control and endophytic microbial products represent future prospects for highly target specific and environmentally safe insect pest management in green gram and other pulse crops.

Conclusion

Sustainable management of sucking insect pests in green gram requires a holistic approach that integrates host plant resistance, cultural practices, biological control and judicious use of chemical insecticides within an IPM framework. Microbial formulations, such as entomopathogenic fungi and bacteria, offer ecofriendly alternatives that effectively suppress pest populations while conserving natural enemies. Combining these biocontrol agents with botanical insecticides like neem oil at reduced concentrations has been identified as a viable strategy for managing sucking pests while preserving beneficial arthropods. New generation insecticides and biologicals provide powerful IPM tools as they are less disruptive to beneficial populations compared to older organophosphate, carbamate and pyrethroid pesticides. The indiscriminate use of synthetic chemicals has led to pesticide resistance, resurgence of secondary pests and environmental hazards, necessitating a shift toward ecofriendly alternatives such as cow based products, plant based pesticides and green-labelled formulations that enhance natural enemy populations. Future research should focus on optimizing application methods, evaluating compatibility among different biocontrol agents and developing farmer friendly delivery systems to maximize the adoption of these sustainable practices. Continuous collaboration, innovation and knowledge exchange will be essential for driving the evolution and adoption of effective IPM programs in the years to come. Adequate support for plant protection research is essential to meet the challenges of producing healthy food from the available land with minimal adverse effects on the environment, which can be achieved through the development of a consortium approach involving international organizations, national agricultural research and extension systems, non-governmental agencies and farmers in the research agenda.

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