

## Integrated Pest Management of Brown Planthopper (*Nilaparvata lugens*) to Control Rice Tungro Virus in Basmati Rice

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### Abstract

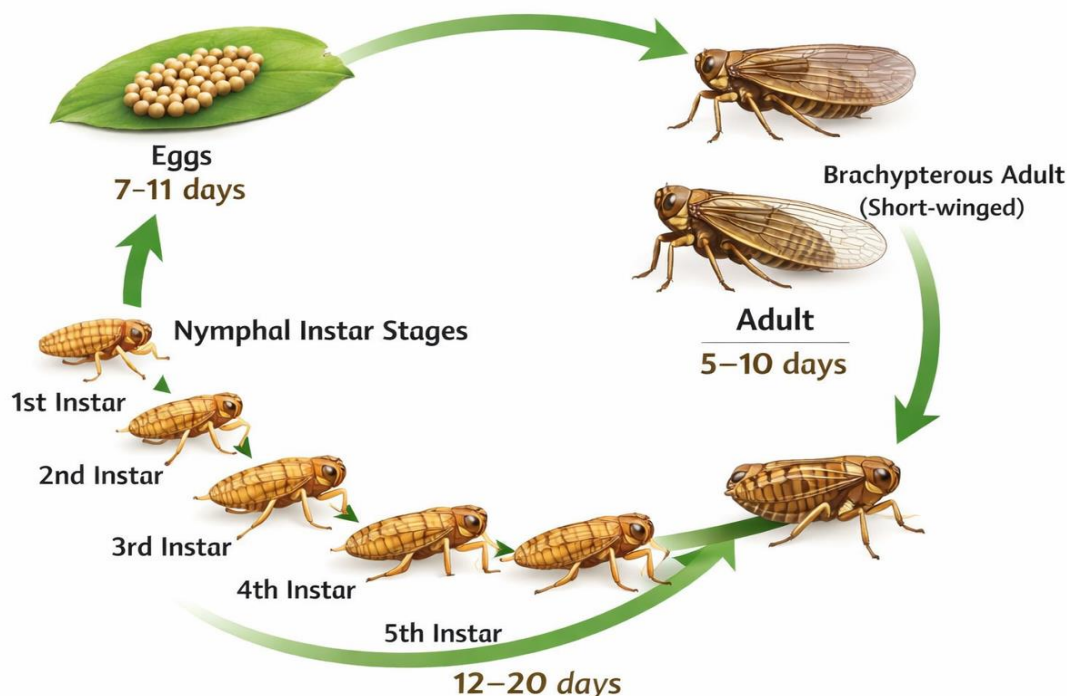
The brown planthopper (*Nilaparvata lugens* Stål), a monophagous delphacid pest of rice, poses a severe threat to Basmati rice production in the Indo-Gangetic plains through direct phloem feeding, hopperburn, and transmission of viruses such as Rice Ragged Stunt Virus (RRSV) and Rice Grassy Stunt Virus (RGSV), while indirectly exacerbating Rice Tungro Virus (RTV) epidemiology. Its high fecundity, short generation time ( $\approx 30$  days), wing dimorphism enabling long-distance migration, and rapid population buildup under high nitrogen and dense planting make conventional chemical control unsustainable, especially given stringent Maximum Residue Limits (MRLs) in export markets (EU, USA). This review outlines a comprehensive Integrated Pest Management (IPM) framework tailored for Basmati rice, integrating: (i) monitoring via light traps, field scouting, and Economic Threshold Levels (ETL: 3–5 hoppers/tiller); (ii) cultural practices including Alternate Wetting and Drying (AWD), balanced nitrogen management, wider spacing, alleyways, and synchronized planting; (iii) conservation of natural enemies (spiders, mirid bugs, entomopathogenic fungi like *Metarhizium anisopliae* and *Beauveria bassiana*); (iv) deployment of resistant varieties through gene pyramiding (Bph genes) and marker-assisted selection (e.g., Pusa Basmati 1847, 1885, 1886 with additional blast/BB resistance); and (v) judicious use of selective, low-residue insecticides (dinotefuran, pymetrozine, triflumezopyrim, buprofezin) only when ETLs are exceeded. Synergistic integration of these tactics reduces pesticide reliance by 50–70%, preserves ecosystem services, maintains Basmati grain quality for export, and enhances climate resilience. Challenges include migratory influxes, evolving insecticide resistance, and climate-driven outbreaks, necessitating regional surveillance, ecological engineering, and policy support for IPM adoption. This multi-tiered, ecosystem-based IPM strategy ensures sustainable, residue-compliant Basmati production while safeguarding farmer incomes and food security.

**Keywords:** Brown Planthopper, *Nilaparvata Lugens*, Basmati Rice, Integrated Pest Management (IPM), Rice Viruses (RRSV, RGSV, RTV), Natural Enemies, Resistant Varieties, Ecological

## 1. Introduction

The sustainability of Basmati rice cultivation in the Indo-Gangetic plains is increasingly threatened by a complex interaction between the brown planthopper (*Nilaparvata lugens*), a monophagous delphacid, and several viral pathogens, most notably the Rice Tungro Virus (RTV) complex (Hajjar et al., 2023). Basmati rice, recognized globally for its unique aroma and extra-long slender grains, represents a vital export commodity for India and Pakistan, necessitating management strategies that balance high-yield protection with stringent international food safety standards regarding pesticide residues (Haider et al., 2024). The brown planthopper (BPH), once categorized as a secondary pest, has risen to the status of a primary threat due to the expansion of irrigation, the intensive use of nitrogenous fertilizers, and the widespread adoption of high-yielding but often susceptible varieties (Pati et al., 2025). Beyond the direct physiological damage caused by phloem feeding, *N. lugens* serves as a persistent vector for Rice Ragged Stunt Virus (RRSV) and Rice Grassy Stunt Virus (RGSV), while its presence often overlaps with the epidemiology of RTV, typically transmitted by the green leafhopper (*Nephotettix virescens*) (Huang et al., 2015). This report evaluates the biological foundations of these threats and details an Integrated Pest Management (IPM) framework tailored to the specific agro-ecological and trade-related constraints of Basmati production (IREF, 2025). The developmental progression of *N. lugens* is illustrated in Figure 1. The figure highlights the rapid life cycle and overlapping generations that contribute to its explosive population growth under favorable conditions.

**Figure 1: Life Cycle of Brown Planthopper (*Nilaparvata lugens*)**



## 2. Bio-Ecology and Population Dynamics of *Nilaparvata lugens*

The brown planthopper is a monophagous insect, feeding exclusively on the genus *Oryza*, which makes its management uniquely dependent on the manipulation of the rice agro-ecosystem (Biswas, 2025). Its biological success is attributed to a high reproductive rate, a short generation

time, and a sophisticated migratory mechanism that allows it to exploit seasonal rice crops across vast geographical distances (Lacombe et al., 2021).

## 2.1 Life Cycle and Developmental Stages

The life cycle of *N. lugens* is comprised of three distinct stages: the egg, five nymphal instars, and the adult stage. A single generation typically requires approximately 30 days, although this duration is highly sensitive to ambient temperature and host plant quality (Namirtha et al., 2026). In the tropical regions of South and Southeast Asia, the insect remains active year-round, completing between 12 and 13 generations annually, whereas in temperate regions, its survival is limited by winter temperatures below 12 degrees C, requiring seasonal re-colonization via long-distance migration (Yang et al., 2022).

**Table 1. Developmental Stages and Characteristics of Nilaparvata lugens**

Stage	Duration (Days)	Key Characteristics
Egg	7-11	Whitish, laid in groups within leaf sheaths or midribs; turn darker with red eye spots before hatching.
Nymph	12-20	Five instars; yellowish-brown; wing buds appear in the fifth instar; aggregate at the plant base.
Adult	10-30	Dimorphic (macropterous and brachypterous); yellowish-brown to dark brown; 4.5-5.0 mm long.

The reproductive potential of *N. lugens* is characterized by its high fecundity, with a single female capable of laying several hundred eggs in clusters of 5 to 30 within the leaf sheath tissue (Khatun, 2025). This oviposition behavior not only facilitates rapid population growth but also causes physical damage to the vascular tissues, potentially serving as entry points for secondary bacterial or fungal infections (Stephens, 2024).

## 2.2 Wing Dimorphism and Migration

A defining feature of BPH biology is wing dimorphism, which allows the species to balance local population explosion with regional dispersal. Brachypterous (short-winged) adults are specialized for rapid reproduction within a favorable habitat, exhibiting significantly higher fecundity than their macropterous counterparts (Renault, 2020). Conversely, macropterous (long-winged) adults are the primary agents of migration, capable of traveling hundreds of kilometers facilitated by monsoon winds and low-level jet streams (Gidó, 2023).

**Table 2. Comparison of Morphological and Biological Features of BPH Adult Morphs**

Feature	Brachypterous Morph	Macropterous Morph
Wing Morphology	Wings shorter than the abdomen; non-functional for flight.	Wings longer than the abdomen; functional for long-distance flight.
Reproduction	High fecundity; faster nymphal development.	Lower fecundity; developmental duration often lengthened by density.
Ecological Role	Rapid local colonization and "hopperburn" induction.	Seasonal migration and exploitation of new rice areas.
Trigger Factors	Low nymphal density; high-quality host plants.	Overcrowding; poor host quality; environmental stress (drought).

The Indochinese peninsula has been identified as a major source of BPH migration into temperate regions, such as China, Korea, and Japan, with movement patterns closely linked to the spring and summer monsoons (Lv et al., 2023). In the context of the Indo-Gangetic plains, these migratory

waves can introduce viruliferous populations into Basmati-growing areas, necessitating regional monitoring and early warning systems (Kumari et al., 2025).

### 3. Viral Epidemiology and Transmission Mechanisms

The relationship between *N. lugens* and rice viruses is characterized by persistent transmission, where the virus is acquired during feeding, circulates through the insect's body, and is eventually transmitted to healthy plants via the salivary glands (Suzuki, 1992).

#### 3.1 Rice Tungro Virus (RTV) Complex

Rice Tungro Disease (RTD) is uniquely destructive because it results from the synergistic interaction of two unrelated viruses: Rice Tungro Bacilliform Virus (RTBV) and Rice Tungro Spherical Virus (RTSV) (Anand et al., 2022). While the green leafhopper (*N. virescens*) is the primary vector for this complex, the presence of BPH-vectored viruses like RGSV and RRSV can complicate the symptomatic landscape, leading to "yellowing syndromes" that are difficult to diagnose in the field without molecular tools (Cabauatan & Cabunagan, 1999).

- **Rice Tungro Bacilliform Virus (RTBV):** A badnavirus with a double-stranded DNA genome, responsible for the severe stunting and leaf yellowing observed in infected plants (Hull, 1996).
- **Rice Tungro Spherical Virus (RTSV):** A waikavirus with a single-stranded RNA genome. RTSV acts as a "helper" virus, providing the necessary proteins for the vector to acquire and transmit both RTBV and itself (Mohamed et al., 2023).

The transmission of RTV is semi-persistent, meaning the vector retains the virus for only a few days unless it feeds on an infected plant again. This contrast with the persistent transmission of BPH-vectored viruses (RGSV and RRSV) has profound implications for the speed and duration of disease outbreaks in Basmati crops (Falk & Tsai, 1998).

#### 3.2 Mechanism of Persistent Virus Transmission in BPH

In the case of Rice Ragged Stunt Virus (RRSV), the virus induces a caspase-dependent apoptosis in the salivary gland cells of *N. lugens*. Research using RNA interference (RNAi) to inhibit caspase-1 genes has demonstrated that this apoptotic process is a critical regulator of virus transmission from the insect vector to the host plant (Patel et al., 2016). This molecular interaction establishes a link between the insect's physiological response to the virus and the eventual epidemiological outcome in the rice field (Chen et al., 2016).

**Table 3. Classification and Symptoms of Major Rice Viruses**

Virus	Classification	Vector	Transmission	Key Symptoms
<b>RTV Complex</b>	Badnavirus/Waikavirus	<i>N. virescens</i>	Semi-persistent	Yellowing/orange leaves, severe stunting, sterile grains.
<b>RRSV</b>	Oryzavirus	<i>N. lugens</i>	Persistent	Serrated leaves, twisted tips, vein swelling, galls.
<b>RGSV</b>	Tenuivirus	<i>N. lugens</i>	Persistent	Severe stunting, profuse tillering, narrow yellow leaves.

### 4. Damage Mechanics and Economic Impact on Basmati Rice

The damage inflicted by *N. lugens* on Basmati rice is both direct, through the depletion of phloem sap, and indirect, through the transmission of viruses and the creation of secondary infection sites

(Hibino, 1996).

#### 4.1 Direct Feeding Damage and "Hopperburn"

BPH nymphs and adults aggregate at the base of the rice plant, inserting their piercing-sucking mouthparts into the leaf sheaths to extract phloem sap. This feeding removes vital carbohydrates and nutrients, disrupting the plant's vascular transport and reducing the photosynthetic rate by 40-60% (Omkar & Tripathi, 2020). At high population densities, the cumulative sap loss leads to "hopperburn," characterized by the rapid yellowing and necrosis of the plant in concentric circular patches, eventually resulting in tiller death (Biswas, 2025).

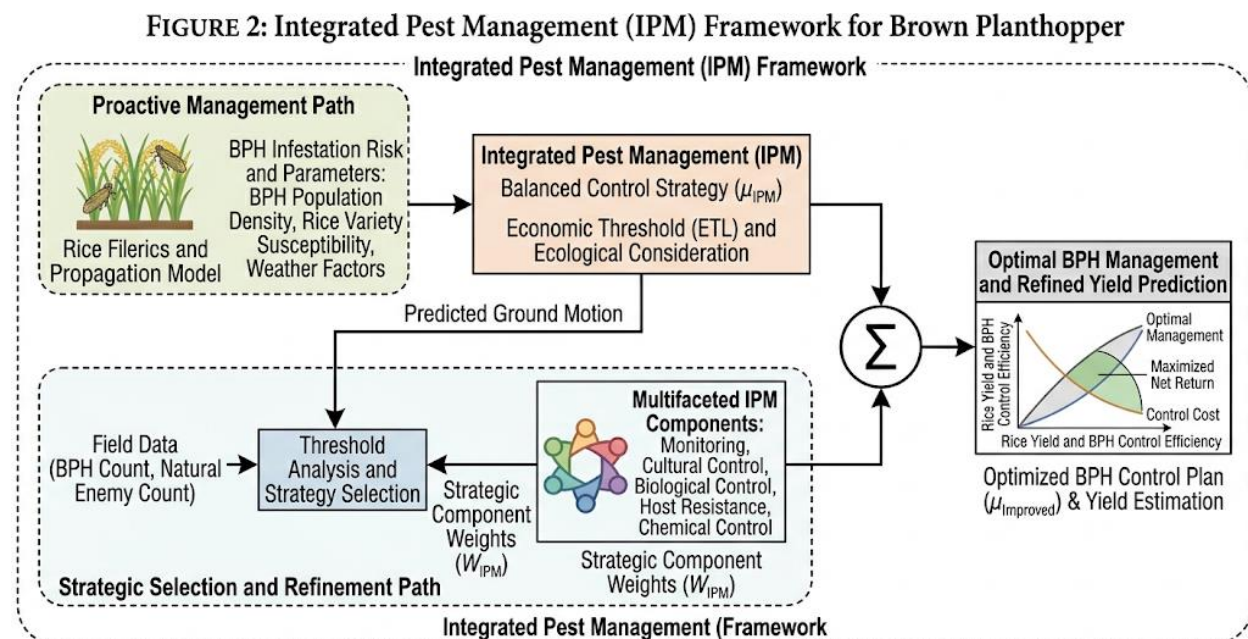
During the reproductive stage, BPH feeding significantly reduces grain filling. If infestation occurs at the panicle initiation stage, it can cause a 20-50% reduction in filled spikelets and lead to shriveled grains, which is particularly detrimental for Basmati rice where grain length and head rice recovery (HRR) are primary quality parameters (Singh et al., 2025).

#### 4.2 Indirect Damage and Viral Synergies

The economic impact of BPH is amplified by its role as a viral vector. RRSV and RGSV infections can lead to yield declines of 50-70% or even total crop failure in severe cases (Jones et al., 202'). In South Vietnam and increasingly in parts of South Asia, co-infections of multiple viruses have been linked to the "yellowing syndrome," which can devastate entire regions, as seen in the Mekong Delta where over 800,000 tons of rice were lost to viral infections in 2005 (Ali et al., 2014). For Basmati exporters, the poor grain quality resulting from viral infection including dark brown blotches, incomplete panicle exertion, and high sterility often results in the rejection of harvests for premium markets (Ye et al., 2024).

### 5. Integrated Pest Management: A Multi-Tiered Approach

IPM for *N. lugens* and RTV in Basmati rice focuses on the conservation of natural enemies, the use of resistant varieties, and the targeted application of selective insecticides based on rigorous monitoring (Alujoju et al., 2022). The holistic IPM framework adopted for BPH management is summarized in figure 2. It integrates multiple complementary strategies to achieve sustainable pest suppression.



## 5.1 Monitoring and Surveillance Techniques

Effective management relies on early detection before populations reach the exponential growth phase.

1. **Light Traps:** Used to monitor the arrival of macropterous immigrants. Operating light traps for two hours in the evening provides data on regional pest pressure and helps predict potential outbreaks (Kammar et al., 2020).
2. **Field Scouting:** Regular inspections should be conducted every 3-5 days, focusing on the base of the plant where humidity is high. Scouts should look for nymphs, adults, and signs of sooty mold, which grows on the honeydew excreted by the hoppers (Almaas, 2025).
3. **Economic Threshold Levels (ETL):** For BPH, the generally accepted ETL is 3-5 insects per tiller or 10-15 hoppers per hill during the vegetative and reproductive stages. For RTV, the threshold for the vector (*N. virescens*) is significantly lower often 2 insects per hill in endemic areas due to the risk of disease spread (Suzuki, 1992).

## 5.2 Cultural Practices and Habitat Management

Cultural interventions aim to make the environment less conducive to BPH development and RTV transmission.

- **Water Management (AWD):** Safe Alternate Wetting and Drying (AWD) is one of the most effective tools for BPH suppression. By allowing the soil to dry between irrigations, the micro-humidity at the base of the plant is reduced, which inhibits BPH nymphal survival and reproduction (Bayer, 2025).
- **Nitrogen Management:** Excessive use of nitrogenous fertilizers promotes rapid BPH population growth by increasing the nutrient quality of the phloem sap. IPM modules recommend the use of recommended doses of nitrogen and the avoidance of late-season "top-dressing" with urea (Guru-Pirasanna-Pandi et al., 2025).
- **Plant Spacing and Alleyways:** Maintaining a spacing of at least 20-30 cm and creating "alleyways" every 2.5-3 meters improves air circulation and sunlight penetration to the lower canopy, restraining BPH population build-up (Akhilesh et al., 2025).
- **Synchronized Planting:** Simultaneous planting over large areas ensures that susceptible stages of the rice crop are not continuously available to the pest, breaking the cycle of infection and re-infestation (Anand et al., 2022).

## 5.3 Biological Control and Ecological Engineering

The rice ecosystem naturally harbors a wide range of beneficial organisms that regulate hopper populations.

1. **Conservation of Natural Enemies:** Predatory spiders (e.g., wolf spiders), mirid bugs (*Cyrtorhinus lividipennis*), and coccinellid beetles are crucial for biological regulation. The BPH-to-spider ratio is a useful indicator of ecological balance; on resistant rice varieties, BPH individuals are more restless and thus more vulnerable to predation (Namirtha et al., 2026).
2. **Ecological Engineering:** Planting flowering crops like marigold on rice bunds provides nectar for parasitoids, while the use of "spider refuges" (straw bundles) helps build up predator populations early in the season (Bari et al., 2023).
3. **Microbial Control:** Entomopathogenic fungi such as *Metarhizium anisopliae* (strain CQMa421) and *Beauveria bassiana* represent promising biological alternatives to chemical pesticides (Chen et al., 2025). *M. anisopliae* has demonstrated field efficacy comparable to chemical insecticides like thiamethoxam, maintaining suppression for up to

14 days without disrupting the indigenous microbial communities of the rice phyllosphere (Al-Sadi et al., 2021).

Recent findings suggest that certain new-generation fungicides, such as Fenoxanil and Thifluzamide, are compatible with entomopathogenic fungi like *Cordyceps javanica* (Zhao et al., 2026). These fungicides may act as "double enemies" by allowing the fungal biocontrol to thrive while eliminating beneficial bacterial symbionts like *Arsenophonus* from the BPH, which otherwise confers higher fecundity to the pest (Xiao et al., 2025).

## 6. Genetic Resistance in Basmati Rice

Host plant resistance is the cornerstone of sustainable BPH and RTV management. The identification and introgression of resistance genes into Basmati backgrounds have been facilitated by advanced breeding techniques like Marker-Assisted Selection (MAS) and genome editing (Ellur et al., 2020).

### 6.1 Resistance in Traditional and Improved Varieties

Traditional varieties like Basmati 370 have long been known to possess resistance to RTSV, controlled by a single recessive gene. This resistance is genetically linked to grain width and heading date, presenting both opportunities and challenges for breeders aiming to preserve the iconic Basmati grain profile (Qadir et al., 2025).

In response to the breakdown of resistance in single-gene varieties, breeders are now focused on "gene pyramiding" incorporating multiple resistance genes (e.g., *Bph6*, *Bph9*, *Bph14*, *Bph15*, *Bph18*, *Bph32*) into a single cultivar (Wang et al., 2025).

**Table 4. Features of Improved Basmati Rice Varieties**

Variety	Parental Background	Targeted Resistance	Special Features
<b>Pusa Basmati 1847</b>	PB 1509	Bacterial Blight (xa13, Xa21), Blast (Pi2, Pi54)	Improved version of PB 1509; 115-120 days maturity.
<b>Pusa Basmati 1885</b>	PB 1121	Bacterial Blight, Blast	Improved version of PB 1121; 135-140 days maturity; extra-long slender grains.
<b>Pusa Basmati 1886</b>	PB 6	Bacterial Blight, Blast	Improved version of PB 6; 135-140 days maturity; no grain chalkiness.
<b>Pusa Basmati 1692</b>	PB 1509	Moderate resistance to Blast	Comparatively lower incidence of BPH; high yield.
<b>Vandana</b>	-	Drought tolerance; moderate resistance to Blast, Brown Spot, BPH, WBPH	Early maturing (90-95 days); suitable for upland conditions.

The recently released Pusa Basmati 1847, 1885, and 1886 are Near Isogenic Lines (NILs) developed through marker-assisted backcross breeding. While their primary resistance focus is on bacterial blight and blast, their adoption significantly reduces the need for broad-spectrum chemical sprays, thereby preserving the natural enemy complex that manages BPH and RTV vectors (Ellur et al., 2025). Farmers using these varieties have reported cost savings of US \$95 to \$134 per hectare due to reduced pesticide applications (Khanna et al., 2025).

## 6.2 The Role of *tsv1* in Tungro Resistance

The *tsv1* gene is a major locus for RTSV resistance, associated with a putative translation initiation factor 4G (eIF4G<sub>tsv1</sub>). Its successful introgression into popular but susceptible varieties has shown a significant improvement in tungro resistance, with a disease index score of less than or equal to 5 in high-pressure environments (Anjaneyulu et al., 1994).

## 7. Chemical Management and Trade Constraints

Chemical control remains a critical component of IPM, particularly during sudden pest outbreaks. However, for Basmati rice, the choice of insecticide is heavily dictated by the Maximum Residue Limits (MRLs) set by importing countries like the USA and the European Union (Krishnaiah, 2018).

### 7.1 Selective Insecticides and Efficacy

Modern IPM strategies prioritize "greener" insecticides that are effective against BPH but have lower impact on non-target organisms.

1. **Dinotefuran 20 SG:** A neonicotinoid that acts through both contact and ingestion, causing a rapid cessation of feeding. At a dose of 40 g a.i./ha, it has shown superior efficacy in reducing BPH populations without inducing phytotoxicity (et al., 2013).
2. **Pymetrozine 50 WDG:** A selective blocker of feeding that targets the chordotonal organs. It is highly effective against BPH and is considered safe for many beneficial insects (Alugoju et al., 2022).
3. **Triflumezopyrim 10 SC:** An innovative molecule that acts on the nicotinic acetylcholine receptor but is chemically distinct from neonicotinoids. It provides long-lasting protection (up to 21 days) with a single application and has a favorable environmental profile (Haider et al., 2024).
4. **Buprofezin:** An insect growth regulator (IGR) that inhibits chitin synthesis, particularly effective against BPH nymphs (Huang et al., 2015).

### 7.2 Pesticide Residue and International Trade

Basmati rice exports from India and Pakistan have faced significant setbacks due to non-compliance with international MRL standards. For instance, the EU's reduction of the MRL for tricyclazole from 1 mg/kg to 0.01 mg/kg in 2018 led to an estimated loss of US \$200 million for Indian exporters as shipments were redirected or rejected (Nader, 2020).

**Table 5. Maximum Residue Limits (MRLs) for Key BPH Insecticides by Region**

Pesticide	India MRL (ppm)	USA MRL (ppm)	EU MRL (ppm)	Japan MRL (ppm)
Dinotefuran	0.03	2.8	0.01*	2.0
Imidacloprid	0.05	1.5	0.01*	1.0
Buprofezin	0.05	0.4	0.01*	0.5
Pymetrozine	0.02	0.2	0.01*	0.3

Exporters must navigate a fragmented regulatory landscape where MRLs for the same molecule can vary by a factor of 200 between countries. For example, the USA tolerance for dinotefuran is approximately 80 times higher than India's, while the EU applies a default limit of 0.01 ppm for many insecticides that lack specific authorization (Stephens, 2024). This discrepancy necessitates the use of high-performance analytical methods like HPLC and QuEChERS to ensure that Basmati rice meets the stringent requirements of global trade (Yang et al., 2022).

## 8. Conclusion

The brown planthopper remains one of the most formidable biotic constraints to sustainable Basmati rice cultivation in the Indo-Gangetic plains, inflicting direct yield losses through hopperburn and indirect damage via persistent virus transmission, while complicating export compliance due to pesticide residue concerns. A well-designed Integrated Pest Management (IPM) program that harmonizes monitoring (light traps, scouting, ETLs), cultural manipulations (AWD, nitrogen optimization, synchronized planting), biological control (conservation of predators and entomopathogenic fungi), host-plant resistance (pyramided Bph genes in elite Basmati backgrounds), and selective chemical interventions offers the most effective, economically viable, and environmentally sound solution. Adoption of resistant varieties such as Pusa Basmati 1847, 1885, and 1886, combined with ecological engineering practices, has already demonstrated substantial reductions in insecticide applications (up to 70%) and improved grain quality without compromising the premium aroma and physical attributes demanded by international markets. However, success depends on overcoming persistent challenges: long-distance migratory influxes linked to monsoon patterns, evolving insecticide resistance, climate change-induced shifts in pest phenology, and limited farmer awareness of IPM principles. Strengthening regional early-warning systems, promoting farmer field schools, incentivizing low-residue technologies, and fostering public-private partnerships for bio-pesticide production and resistant seed dissemination are essential next steps. By shifting from reactive, calendar-based spraying to proactive, knowledge-intensive IPM, Basmati-producing regions in India and Pakistan can achieve resilient, high-quality production that meets both domestic food security needs and stringent global trade standards securing farmer livelihoods while preserving the ecological integrity of the rice agroecosystem for future generations.

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