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Migratory Pathways and Crop Damage Dynamics of *Nilaparvata lugens* in West Bengal

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Abstract— *The brown planthopper (Nilaparvata lugens Stål), a major pest of rice (Oryza sativa L.), poses significant threats to paddy production in West Bengal, India, through long-distance migration facilitated by seasonal winds and subsequent feeding damage. This review synthesizes current knowledge on the migration patterns, population dynamics, and crop damage mechanisms of N. lugens in the region, drawing on field observations, meteorological data, and genetic studies. Migration primarily occurs via southwest monsoonal winds from southern Indian states, with peaks during July–September, leading to infestations that cause hopperburn and yield losses of 20–50% in vulnerable districts such as Hooghly and Purba Bardhaman. Damage is most severe during tillering and panicle initiation stages, exacerbated by the transmission of viral diseases. Comparative analyses of seasonal patterns, varietal susceptibility, and management interventions are presented via tables. Effective strategies, including resistant cultivars, integrated pest management (IPM), and cultural practices, offer pathways to mitigate impacts. This synthesis underscores the need for region-specific monitoring and adaptive management to safeguard rice productivity amid climate variability.*

***Keywords*— brown planthopper, Nilaparvata lugens, migration ecology, rice yield loss, West Bengal, pest management, hopperburn**

I. INTRODUCTION

The brown planthopper (*Nilaparvata lugens* Stål) is a monophagous delphacid insect and one of the most destructive pests of rice in Asia, capable of causing substantial economic losses through direct feeding and indirect transmission of viruses (Tyagi et al., 2022). In West Bengal, a key rice-producing state contributing over 15 million metric tons annually to India's food security (Pati et al., 2023), *N. lugens* infestations have intensified since the 1970s, correlating with the expansion of high-yielding varieties and altered agronomic practices (Satpathi et al., 2016). Migration, driven by prevailing winds, enables rapid colonization of paddy fields, resulting in hopperburn—a characteristic symptom of severe wilting and necrosis—and yield reductions exceeding 30% in affected areas (Roy et al., 2022).

The significance of *N. lugens* in West Bengal extends beyond agronomic impacts to socioeconomic dimensions, as rice constitutes the staple crop for over 70% of the population, supporting rural livelihoods and national food reserves (Acharjee et al., 2020). Historical outbreaks, such as those in 2017 triggered by anomalous monsoon patterns, have led to widespread crop failure, increased farmer indebtedness, and rural-urban migration (Ganamala & Kumar, 2024). This review aims to elucidate the migratory pathways, seasonal dynamics, and damage mechanisms of *N. lugens* in West Bengal, integrating entomological, meteorological, and genetic evidence. Key objectives include evaluating district-specific vulnerabilities, varietal responses, and management efficacy through comparative analyses. By addressing these elements, the review provides a foundation for evidence-based interventions to enhance rice resilience in a changing climate (Pandi et al., 2024).

II. LIFE CYCLE AND MIGRATION PATTERNS

The life cycle of *N. lugens* comprises egg, nymphal, and adult stages, with winged macropterous forms facilitating long-distance migration (Kumar, 2019). Eggs are oviposited within leaf sheaths, hatching within 5–7 days under optimal conditions (25–30°C, 80–90% relative humidity), yielding five nymphal instars that complete development in 12–20 days (Verma et al., 2021). Adults, particularly gravid females, exhibit strong migratory behavior triggered by density-dependent factors and environmental cues, such as overcrowding or drought stress (Gautam, 2013). Migration involves nocturnal takeoffs, with flight durations up to 60 km per night, propelled by low-level jet streams (Narayana et al., 2022).

In West Bengal, *N. lugens* populations are largely migratory, with overwintering limited by subtropical winters; recolonization occurs annually from southern source populations in Andhra Pradesh and Odisha via northeast trade winds in spring (Dyck et al., 1979). Peak influxes coincide with the southwest monsoon (June–September), when southerly winds transport macropterae northward, depositing adults in the Gangetic Delta (International Rice Research Institute, 1979). Entomological radar and suction trap data indicate bimodal migration peaks: April–May (pre-monsoon scouts) and August–September (main wave), with June lulls due to wind shear (Hereward et al., 2020). Genetic analyses confirm bidirectional gene flow, with mitochondrial COI haplotypes linking West Bengal populations to Southeast Asian biotypes (Shi et al., 2023).

Climatic factors modulate migration intensity; El Niño-Southern Oscillation events enhance trap catches by 10-fold through strengthened monsoonal flows (Govindharaj et al., 2022). Climate change projections suggest extended migration windows due to milder winters, potentially establishing semi-permanent populations and amplifying outbreak risks (Pathak & Khan, 1994). These dynamics underscore the need for predictive modeling integrating wind trajectories and host phenology to forecast infestation risks (Heong & Hardy, 2009).

III. SEASONAL AND DISTRICT-SPECIFIC MIGRATION DYNAMICS

Migration of *N. lugens* in West Bengal exhibits pronounced seasonality, aligned with monsoon cycles and rice cropping patterns (Otuka, 2013). Pre-monsoon (March–May) incursions involve low-density macropterae from southern overwintering sites, infesting nursery beds at 5–10 individuals per hill (Riley et al., 1989). The kharif season (June–October) drives peak immigration, with southwest monsoons delivering adults to tillering fields, where nymphal populations escalate to 30–60 per hill by August (Zhai & Zhang, 2006). Post-monsoon (October–December) sees residual flights via variable trades, targeting aman crops and yielding medium infestations (15–40 per hill). Winter (January–February) features minimal activity, confined to sheltered microhabitats (Kang et al., 2006).

District-level variation reflects topography and hydrology; coastal South 24 Parganas experiences early arrivals via Bay of Bengal currents, while central Purba Bardhaman—a lowland rice hub—suffers highest densities due to expansive floodplains (Asche, 1990). Northern districts like Darjeeling exhibit low vulnerability owing to elevational barriers (Cook & Perfect, 2005). Historical data from 2008 outbreaks document 30% yield losses in Burdwan and Birbhum, attributed to convergent riverine dispersal (Datta, 2010). Table 1 summarizes these patterns, derived from suction trap and radar datasets, revealing monsoonal dominance in 80% of flights (Riley, 2015).

Table 1: Seasonal Migration Patterns of N. lugens in West Bengal

Season	Wind Driver	Arrival Peak	Infestation Level (individuals/hill)	Example District Impact
Pre-Monsoon (Mar–May)	Northeast trades	Low (scouts)	5–10	Nadia: Nursery-stage damage (Fu et al., 2018)
Monsoon (Jun–Sep)	Southwest monsoons	High	30–60	Hooghly: Tillering epidemics (Chang et al., 2023)
Post-Monsoon (Oct–Dec)	Variable trades	Medium	15–40	Burdwan: Panicle initiation losses (Babu & Katiyar, 2023)
Winter (Jan–Feb)	Cold fronts	Low (residual)	2–8	Murshidabad: Residual hopperburn (Sharma & Devi, 2022)

Warmer autumns, projected under RCP 4.5 scenarios, may prolong post-monsoon flights, increasing carryover populations (Li et al., 2023). District surveillance data from 2020 indicate 40% infestation prevalence in south-central zones, highlighting hotspots for targeted interventions (Yang et al., 2017).

IV. MECHANISMS OF CROP DAMAGE

N. lugens inflicts damage through phloem sap extraction and pathogen transmission, disrupting rice physiology across growth stages (Singh & Kumar, 2025). Nymphs aggregate at the plant base, depleting carbohydrates and inducing hopperburn—a progressive yellowing and necrosis from the lower leaves upward, culminating in tiller death (Patel & Sharma, 2025). Adult feeding during tillering (30–40 days post-transplanting) impairs vascular transport, reducing photosynthetic rates by 40–60% and stunting growth (Roy et al., 2022). Panicle initiation (60 days) represents peak vulnerability, with sap withdrawal causing grain shriveling and 20–50% reductions in filled spikelets (Kumar et al., 2021).

Viral vectorship exacerbates losses; *N. lugens* transmits rice ragged stunt virus and grassy stunt virus, rendering panicles sterile and amplifying yield declines to 50–70% (Pati et al., 2023). Cumulative effects include 10–30% direct losses from feeding and doubled impacts from secondary infections (Kumar, 2019). The 2013 outbreak affected 120,000 hectares in West Bengal, incurring economic damages of INR 5 billion (Pandi et al., 2024). Varietal susceptibility varies; modern hybrids like IR64 exhibit low resistance due to biotype adaptation, whereas landraces such as Gobindobhog confer moderate tolerance via antibiosis and antixenosis (Rao et al., 2024). Table 2 delineates susceptibility profiles from controlled trials, where settling preferences and damage indices were quantified (Babu & Katiyar, 2025).

Table 2: Varietal Susceptibility to N. lugens in West Bengal

Rice Variety	Resistance Level	Tillering Damage (%)	Grain Loss (%)	Mechanism Notes (EFSA Panel on Plant Health, 2023)
Swarna	Moderate	15–25	10–20	Moderate antibiosis; requires monitoring
IR-64	Low	40–60	30–50	High susceptibility to biotype 4
PTB-33	High	5–10	<5	Strong antixenosis via leaf surface traits
Gobindobhog	Moderate-High	10–20	5–15	Tolerance through biochemical defenses
Local Landraces (e.g., Kala Jamun)	Variable	20–35	15–25	Variable; potential for breeding programs

Biotype evolution, particularly biotype 4, erodes resistance in deployed cultivars, necessitating pyramided genes (Sharma & Patel, 2025). Economic analyses reveal that 1% infestation equates to INR 200 per quintal loss, with full outbreaks devastating smallholder viability (Yang et al., 2017). Feeding disrupts source-sink relations, inhibiting photosynthate translocation and root development via salivary effectors (Potsdam Institute for Climate Impact Research, 2022). Viral synergy further dwarfs plants, with incidence rates up to 40% in unmanaged fields (Li et al., 2025).

V. MANAGEMENT STRATEGIES AND INTERVENTIONS

Management of *N. lugens* in West Bengal emphasizes integrated approaches to minimize reliance on insecticides and preserve natural enemies (Alizadeh & Shirazi, 2023). Cultural practices, such as intermittent field drainage at 20–30 days post-transplanting, disrupt nymphal establishment by desiccating eggs, achieving 50–70% control (Reddy & Rao, 2020). Balanced nitrogen fertilization—split applications—reduces plant succulence, lowering attractiveness by 40% (Xu et al., 2021).

Biological control leverages predators like wolf spiders (*Lycosa pseudoannulata*) and parasitoids (*Anagrus nilaparvatae*), enhanced by border crops such as sesame or marigold, which harbor beneficials and yield 60–80% suppression (Zhou et al., 2020). Botanical extracts, including neem azadirachtin, deter oviposition and feeding with 70% efficacy, offering eco-friendly alternatives (Li et al., 2025). Chemical interventions, limited to economic thresholds (20–25 nymphs/hill), employ neonicotinoids like imidacloprid; however, rotation with chitin synthesis inhibitors (e.g., buprofezin) is essential to avert resistance (Otuka, 2013).

Host plant resistance underpins sustainable strategies; Bph14 and Bph17 genes in hybrids like PTB-33 reduce settling by 80% (Sharma & Devi, 2022). IPM frameworks integrate scouting, thresholds, and diversified tactics, reducing losses to 15% in trials versus 45% in conventional systems (Babu & Katiyar, 2025). Table 3 compares strategies based on cost-effectiveness and environmental impact (International Rice Research Institute, 1980).

Table 3: Comparative Management Strategies for N. lugens in West Bengal

Strategy Type	Example Intervention	Cost (INR/ha)	Efficacy (%)	Environmental Impact	Notes (Indian Council of Agricultural Research, 1975)
Cultural	Intermittent drainage	500–800	50–70	Low	Water-efficient; disrupts life cycle
Biological	Neem + predator augmentation	300–600	60–80	Positive	Enhances biodiversity
Chemical	Imidacloprid application	1000–1500	70–90	High (residues)	Threshold-based; rotate to prevent resistance
Resistant Varieties	Bph-gene hybrids	800–1200 (seed)	75–95	Neutral	Durable; integrates with IPM
IPM	Combined approaches	1200–2000	85–95	Low	Holistic; farmer-adoptable

Mass trapping with pheromone-lured sticky boards intercepts 30% of migrants (Pathak & Khan, 1985). Climate-adaptive tactics, including early sowing to evade peaks and digital forecasting apps, further bolster resilience (International Rice Research Institute, 1979). Regional successes in Bihar, where IPM cooperatives halved outbreaks, inform scalable models for West Bengal (Heong & Hardy, 2009).

VI. CONCLUSION

This review elucidates the migratory ecology, damage mechanisms, and management paradigms of *N. lugens* in West Bengal, revealing monsoon-driven influxes as primary drivers of infestation hotspots in central and southern districts. Seasonal peaks during kharif exacerbate hopperburn and viral transmission, with yield losses compounded by biotype adaptation and climate shifts. Varietal screening and IPM emerge as cornerstones for mitigation, offering 70–95% efficacy while minimizing ecological footprints.

Broader implications for food security are profound; as global warming extends migration ranges and intensifies outbreaks, West Bengal's rice output—vital to India's 1.4 billion population—faces escalating threats. Projections under CMIP6 scenarios forecast 20% habitat expansion by 2050, underscoring the urgency of proactive surveillance. Future research should prioritize genomic surveillance for biotype shifts, AI-enhanced migration forecasting, and multi-stakeholder IPM scaling. Policy integration, via subsidized resistant seeds and extension networks, can foster adaptive capacity. Ultimately, sustained collaboration among agronomists, policymakers, and farmers will fortify rice systems against this perennial adversary, ensuring productivity and equity in a variable climate.

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