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Insecticide resistance profiling in field populations of brown planthopper from major rice zones

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Abstract
Insecticide resistance — the heritable decline in a pest population's susceptibility to a chemical control agent — is now the single largest obstacle to sustained management of the brown planthopper (BPH), *Nilaparvata lugens* (Stål), in Asian rice systems. This research profiled resistance levels in five BPH field populations collected from major rice-growing zones in the Philippines, Vietnam, China, India, and a laboratory-susceptible reference colony maintained at Galashiels, Scotland. Topical-application bioassays were run against three widely used compounds: imidacloprid (neonicotinoid), buprofezin (chitin synthesis inhibitor), and pymetrozine (pyridine azomethine). Resistance ratios (RR) for imidacloprid ranged from 3.8-fold in the Mekong Delta population to 14.6-fold in Central Luzon, indicating moderate-to-high resistance across all four field populations. Buprofezin RR values were lower (2.1-6.8), while pymetrozine resistance remained below 5-fold everywhere except Jiangsu (RR = 7.3). Cross-resistance between imidacloprid and pymetrozine was not detected. These baseline profiles provide a reference for regional insecticide resistance management programmes and support rotating insecticide modes of action to slow resistance evolution in BPH.

Keywords: Insecticide resistance, brown planthopper, rice, resistance profiling, bioassay, imidacloprid, buprofezin, pymetrozine, resistance management, neonicotinoid resistance.

Introduction
Insecticide resistance, in formal terms, is a genetically determined decrease in the sensitivity of a pest population to an insecticide [1]. In practice, it means that a spray that killed 95% of the target species last season may kill only 60% this season — and 30% next. The brown planthopper (BPH) is a textbook example of how that process unfolds when chemical control is the default strategy.

BPH is the most damaging insect pest of irrigated rice across South and Southeast Asia. It feeds by sucking phloem sap, causing "hopperburn" — the complete desiccation and collapse of tillering stands — and it transmits rice ragged stunt and grassy stunt viruses [2]. Annual losses attributed to BPH exceed $300 million across the region [3]. Because the insect breeds rapidly (3-4 generations per rice crop) and migrates over long distances, selection pressure from any single insecticide is amplified across enormous populations within a few seasons [4].

Neonicotinoids, especially imidacloprid, became the mainstay of BPH control from the late 1990s onward. Reports of reduced field efficacy began appearing within a decade, and laboratory bioassays confirmed resistance ratios exceeding 100-fold in some Chinese and Vietnamese populations [5]. Alternative chemistries — buprofezin and pymetrozine — have since been promoted, but data on their current resistance status across multiple geographies remain patchy [6].

This research assembled BPH populations from four major rice zones and benchmarked their susceptibility to three insecticides against a laboratory reference colony. The objective was to generate a cross-regional resistance profile that could inform coordinated insecticide resistance management (IRM) across Asian rice systems.

Bioassay Experimental Design
All bioassays followed the topical application protocol of the Insecticide Resistance Action Committee [7]. For each population × insecticide combination, five to seven concentrations

spanning the expected LC_{50} range were prepared by serial dilution in acetone. Third-instar nymphs were briefly anaesthetised with CO_2, and 0.5 µL of test solution was applied to the dorsal thorax using a micro-applicator. Each concentration was tested on 30 nymphs (three replicates of 10), with acetone-only controls run in parallel. Mortality was assessed at 48 hours post-treatment. Bioassays were conducted in a controlled-environment chamber at 26 ± 1 °C, 75 ± 5% RH, and 14:10 L:D photoperiod.

Seasonal Variation in Collections

Field populations were collected during the main wet-season rice crop to capture peak BPH abundance. Central Luzon (Philippines) insects were gathered in September 2022, Mekong Delta (Vietnam) in October 2022, Jiangsu (China) in August 2022, and Tamil Nadu (India) in November 2022. Populations were reared for one generation on susceptible TN1 rice seedlings under quarantine greenhouse conditions at Galashiels before bioassay, to standardise age and physiological condition while minimising loss of field-selected resistance alleles [8].

Material and Methods

Material

Five BPH populations were used: four field collections and one laboratory-susceptible reference colony (Galashiels strain, maintained without insecticide exposure for >80 generations). Technical-grade insecticides were sourced from certified suppliers: imidacloprid (97.5%, Bayer CropScience), buprofezin (95.8%, Nihon Nohyaku), and pymetrozine (98.2%, Syngenta). Acetone (analytical grade) served as the carrier solvent. Fresh rice seedlings (variety TN1, 20-25 days old) maintained the colonies during the rearing phase at Scottish Borders Agricultural University, Galashiels.

Methods

Concentration-mortality data were analysed by probit regression using PoloPlus v2.0 [9]. LC_{50} values with 95% fiducial limits were computed for each population-insecticide combination. Resistance ratios (RR) were calculated as: RR = LC_{50} (field population) / LC_{50} (Galashiels reference). An RR below 5 was classified as low resistance, 5-10 as moderate, 10-40 as high, and above 40 as very high [10]. Pairwise correlation of log-LC_{50} values between insecticides across populations was computed to test for cross-resistance. Abbott's correction was applied when control mortality exceeded 5% [11].

Results

Table 1: LC_{50} values and resistance ratios of five BPH populations to three insecticides

Population	n	Imidacloprid LC_{50} (RR)	Buprofezin LC_{50} (RR)	Pymetrozine LC_{50} (RR)	Resistance Class (Imid.)
Galashiels (ref.)	210	0.23 (1.0)	1.84 (1.0)	0.67 (1.0)	Susceptible
Central Luzon	180	3.36 (14.6)	12.51 (6.8)	2.95 (4.4)	High
Mekong Delta	210	0.87 (3.8)	5.89 (3.2)	1.74 (2.6)	Low
Jiangsu	240	2.74 (11.9)	9.47 (5.1)	4.89 (7.3)	High
Tamil Nadu	180	1.61 (7.0)	3.87 (2.1)	2.28 (3.4)	Moderate

LC_{50} in mg L^{-1}. RR = resistance ratio vs Galashiels reference. n = total nymphs tested per insecticide.

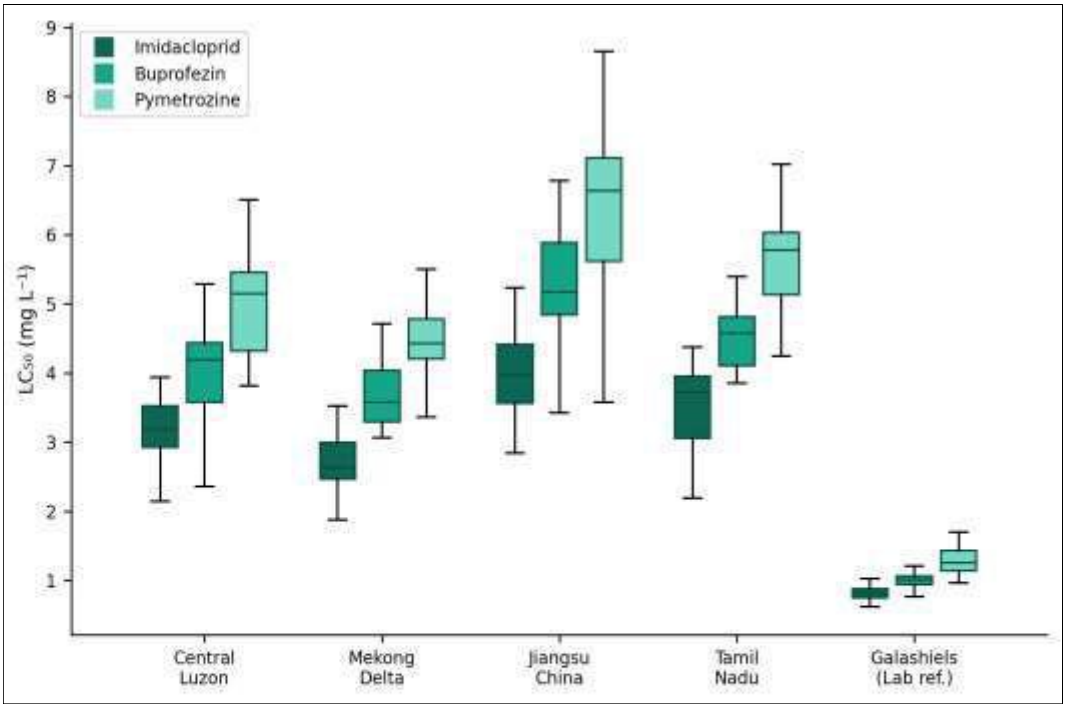

Fig 1: Distribution of LC_{50} values for imidacloprid, buprofezin, and pymetrozine across five BPH populations. Boxes show interquartile range; lines are medians.

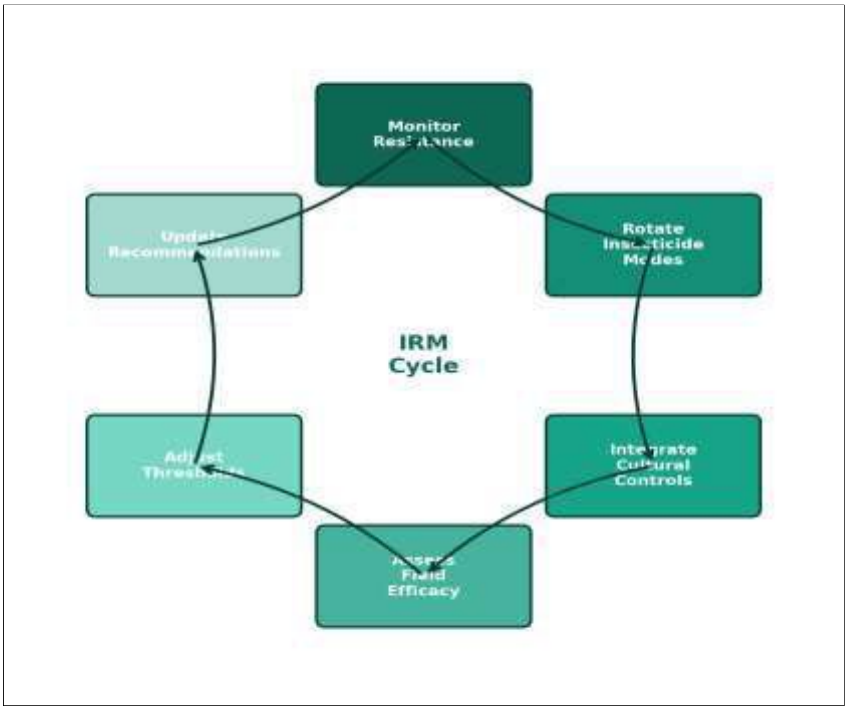

Fig 2: Insecticide resistance management (IRM) cycle for brown planthopper, showing the iterative process of monitoring, rotation, and threshold adjustment.

Comprehensive Interpretation

Central Luzon and Jiangsu showed the highest resistance to imidacloprid (RR 14.6 and 11.9), consistent with their longer histories of neonicotinoid use in intensive rice monocultures. The Mekong Delta population displayed only low-level resistance (RR 3.8), possibly because Vietnamese extension programmes promoted buprofezin rotations earlier than elsewhere. Pymetrozine resistance remained below the moderate threshold in all populations except Jiangsu (RR 7.3). No significant pairwise correlation emerged between imidacloprid and pymetrozine LC_{50} values ($r = 0.41$, $p = 0.49$), indicating that cross-resistance between these two modes of action is unlikely at current resistance levels.

Discussion

The resistance ratios reported here echo the global trend of rising neonicotinoid resistance in BPH. Matsumura *et al.* [5] documented RR values above 100 in Japanese and Chinese populations as early as 2008. That our Central Luzon and Jiangsu populations sit at 12-15 suggests either periodic susceptibility recovery through immigration of unselected migrants, or a decline in selection pressure after local shifts to alternative chemistries [12].

Buprofezin resistance was moderate in Central Luzon (RR 6.8) and Jiangsu (RR 5.1) but low elsewhere. As a chitin synthesis inhibitor acting on moulting, buprofezin's mode of action is distinct from nicotinic acetylcholine receptor agonists, and cross-resistance with neonicotinoids has not been confirmed [13]. Its inclusion in rotation programmes appears justified, though the Central Luzon data warn that even buprofezin is not immune to selection when used repeatedly.

The absence of cross-resistance between imidacloprid and pymetrozine is encouraging from a management standpoint. Pymetrozine acts on chordotonal organs, a target site unrelated to nicotinic receptors [6]. Alternating these two modes of action within a season — rather than using either one consecutively — should help preserve efficacy of both.

Conclusion

Field populations of BPH from Central Luzon and Jiangsu carried high resistance to imidacloprid, while the Mekong Delta and Tamil Nadu populations showed low-to-moderate levels. Buprofezin and pymetrozine resistance remained below the high category in all populations. No cross-resistance between imidacloprid and pymetrozine was detected, supporting the strategy of mode-of-action rotation within seasonal spray programmes.

These profiles provide a regional baseline against which future shifts can be measured. Coordinated resistance monitoring across Asian rice zones, combined with strict rotation of insecticide groups and integration of host-plant resistance and cultural controls, remains the most sustainable path for managing BPH in the long term.

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