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Pesticide-Induced Resurgence in Rice Planthoppers

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Rice is a cereal grain and in its domesticated form is the staple food of over half of the world's population, particularly in Asia countries. Planthoppers are monophagous and serious pests of rice. It causes hopper burn symptoms by sucking sap from phloem tissue. Their population resurgence was first reported in the early 1960s, caused mainly by insecticides that indiscriminately killed beneficial arthropods and target pests. Major resurgence causing species in rice are as follows: BPH - *Nilaparvata lugens* (Stal), WBPH - *Sogatella furcifera* (Horvath), and SBPH - *Laodelphax striatellus* (Fallen) Suppression of natural enemies following intensive broad-spectrum insecticidal application; the increased feeding rate of BPH at sub-lethal doses of some resurgence inducing insecticides; stimulation of growth and reproduction by the pest following insecticidal application; changes in the nutrient contents of the plant following insecticidal application are important factors contributing to a resurgence in BPH.

The resurgence may be induced via alterations of resistant or nutritious substances in treated host plants, possibly including allelochemicals, due to alterations in crop plant physiology. Pesticide-induced rice susceptibility may benefit BPH feeding, survival, and reproduction. Ripper (1956) first time recognized the resurgence problem in plant protection. Later, Chellaiah (1986) defined that resurgence refers to an abnormal increase in pest population following insecticide treatment, often far exceeding the economic injury level. Populations may be increased by the application of insecticides which kill both the pests and their natural enemies.

Types of resurgence

Primary pest resurgence: The target pest population responds to a pesticide treatment by increasing to a level at least higher than the population level observed before the treatment.

A: Both the majority of Pests & Natural enemies were killed

B: Plant pests re-colonize first

C: Pest unrestrained by NES then increase to a level greater than A.

Table 1 Resurgence of insect pest

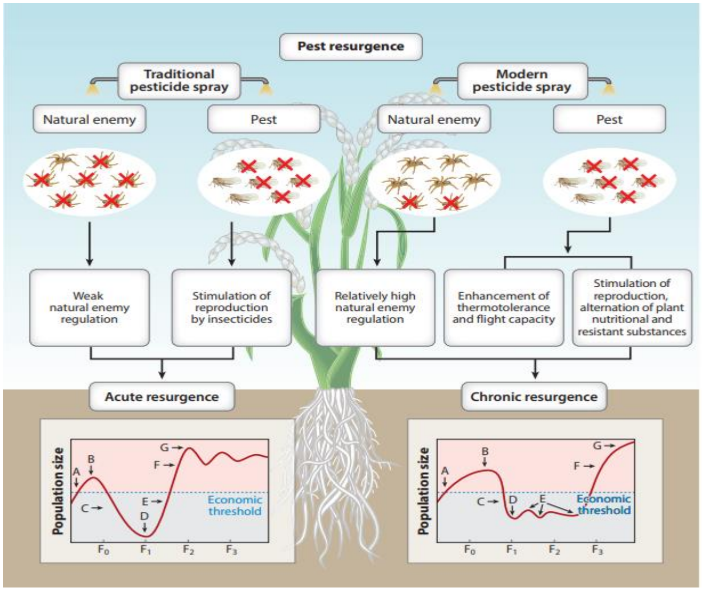
S.No.	Crop	Insect pest	Reference
1.	Rice	BPH- *Nilaparvata lugens* (Stal, 1854)	IRRI, 1969
		WBPH- *Sogatella furcifera* Fennah, 1963	IRRI,1972
		GLH- *Nephotettix sp.* (Distant)	Kobayashi, 1975
		LF- *Cnaphalocrocis medinalis* (Guenee, 1854)	Chelliah & Heinrichs, 1980
2.	Sugarcane	Scale- *Melanspis glomerata* (Green)	David and Easwaramoorthy,1987
		SLH- *Pyrilla perpusilla* (Walker, 1851)	Verma,1981
3.	Sorghum	Aphid- *Rhopalosiphum maidis* (Fitch, 1856)	Mohan *et al.*, 1987
4.	Brinjal	Aphid- *Myzus persicae* (Sulzer, 1776)	Subbarami reddy *et al.*, 1987
5.	Chilli	Yellow mite- *Polyphagotarsonemus latus* (Banks, 1904)	David,1987
6.	Cotton	Whitefly- *Bemisia tabaci* (Gennadius, 1889)	Jayaswal and singh, 1984
		Aphid- *Aphis gossypii* Glover, 1877	Natarajan *et al.*,1987
		Spider mite- *Tetranychus cinnabarinus* Dufour,	Patil,1987

Secondary pest resurgence: This occurs when a non-target pest is present. It is injurious when a secondary pest population increases in a crop treated with a pesticide to control a primary pest population.

A: Pesticide is applied to suppress pest A but also kills natural enemies that feed on pest 2

B: Pest 2 is free from the regulation of natural enemies. So, pest B becomes a major problem.

Conceptual framework of chronic and acute resurgence of planthoppers



Acute resurgence is linked to rapid planthopper population growth in the absence or weakening of natural enemies following traditional insecticide applications. Chronic resurgenc**e** after the application of modern pesticides is characterized by delayed population growth due to the presence of natural enemies. At point A, the population exceeds the economic threshold; at point B, pesticide is applied; at point C, there is rapid population decline due to pesticides; at point D, the lowest population level before reproduction starts; at point E, reproduction leads to population growth, which is unchecked in acute resurgence but limited by natural enemies in chronic resurgence; at point F, there are large resurgent populations; and at point G, severe economic losses occur.

The subsequent resurgence involved two mechanisms, the loss of beneficial insects and insecticide-enhanced planthopper reproduction. In this review, we identify two forms of resurgence, acute and chronic. Acute resurgence is caused by traditional insecticides with rapid resurgence in the F1 generation. Chronic resurgence follows the application of modern pesticides, including fungicides and herbicides, with low natural enemy toxicity, coupled with stimulated planthopper reproduction. The chemical-driven syndrome of changes leads to later resurgence in the F2 or later generations.

Factors influencing pesticide induced resurgence of insect pests

Host plant factors

- Influence plant hormone
- Pesticide induce susceptibility in rice crop to planthopper
- Resistance level of plant
- Influence rice physiology and biochemistry

Natural enemies

- Mortality of natural enemies
- Reduction in competitive pest species
- Reduction in natural enemies service

Pesticides related factors

- Insecticide type
- Timing and number of insecticide application
- Sub-lethal doses of insecticide
- Method of application
- Insecticide rate

Pest related factors

- Altered survival of different stage of target pest
- Stimulation of feeding & reproduction of target pest

Resurgence within the planthopper guild

✓ **Impacts of pesticide application on natural enemies**

Rice agroecosystems are complex, consisting of predators, parasites, parasitoids, herbivores, and detritivores. Many of these creatures perform essential ecological services. Herbivorous pest insects have natural enemies, particularly predators and parasitoids.

❖ Agricultural chemicals challenge to natural enemies in two ways:

- By killing some individuals and in surviving individuals
- By sharply reducing their abilities to search for and locate pest eggs, larvae, pupae and adults

Pesticides effect on natural enemies

Natural enemies	**Pesticide**	**Effect**	**Refence**
Cyrtorhinus lividipennis	Butachlor, Disopropyl S-benzyl phosphorothiolate, Triazophos and Deltamethrin	High mortality, Reduction in prey consumption	Cheng *et al.*, 1999 Xu *et al.*, 2000
Lycosa pseudoannulata	Chlorpyriphos, Abamectin	More lethal	Cheng *et al.*, 1999
Pirata subpiraticus	Bisultap, Methanidophos and Buprofezin, Triazophos and Pymetrozine, Butachlor, Oxyfluorfen, Oxadiazon, and Metolachlor	Functional response less to prey, Negative effect on egg development	Li *et al.*, 2000
Anagrus nilaparvatae	Pymetrozine. Imidacloprid, Triazophos and Deltamethrin	Reduction in foraging capacity, Survival & parasitism	Liu *et al.*, 2010

A) Pesticides kill natural enemies

Indirect effects on natural enemies

❖ Fecundity
❖ Predation
❖ Population growth
❖ Reproduction
❖ Prey searching efficiency and feeding behaviour

B) Reduction of natural enemy services due to pesticide exposure

In addition to mortality, biocontrol services of surviving natural enemies decline substantially after exposure to agricultural chemicals. Sublethal concentrations of triazophos, and deltamethrin were decreased *C. lividipennis* consumption rate by 18–35%. Bisultap and buprofezin treatments reduced the spider functionality by 60 %

C) Pesticides influence parasitoid behavior and fecundity

Parasitoid foraging capacity is influenced by sublethal doses of insecticides. Some other insecticides do not disrupt parasitoid foraging. *Anagrus nilaparvatae* have lost host eggs finding capacity. Wasps reduce the parasitoid foraging capacity

Population characteristics of planthopper resurgence

Following the administration of resurgence-associated insecticides, planthopper populations will be lowered for about 3 days before rapidly rebounding due to increased growth and development of survivors. Insecticide interactions with other parameters, such as rice variety, fertilization timing, and dosage, all have an impact on rebounding populations. In general, the interactions between pesticide sprays and rice variety, as well as pesticide sprays and fertilization, altered planthopper development periods in WBPH, from early nymph to late nymph and adult.

Influence of pesticides on physiology and biochemistry of rice plants

Pesticides influence on rice physiology and biochemistry

Oxalic acid (OA) is a dicarboxylic acid that acts in rice resistance to BPH. OA content is higher in planthopper-resistant rice varieties compared to susceptible ones. Some insecticides, such as triazophos and imidacloprid, lead to reduced OA content in rice. Buprofezin, imidacloprid, and decamethrin lead to higher amounts of sugars and free amino nitrogen, which benefits pests. Increase in the malondialdehyde (MAD) content in imidacloprid treated plant facilitate BPH feeding.

Pesticides influence rice gene transcription profiles

Some pesticide-induced changes indirectly influence gene expression in rice. Specific expression of genes encoding plant lipid transfer protein, lignin peroxidase, and flavonol-3-o-methyltransferenase will change after the application of chemicals. These chemical synthesis pathways play an important role induced resistance of plants which is affected by chemical application.

Pesticides influence plant hormones

Pesticide-induced changes in plant hormones have the potential to drive changes at the whole-plant level. Cytokinins including zeatins riboside (ZR) play a vital regulation role in the growth, development, physiology and biochemistry of rice plants.

Pesticide-induced susceptibility to planthoppers

Pesticide-induced susceptibility (PIS) as reduced rice resistance to planthoppers following pesticide application. PIS facilitates planthopper feeding, survival, and fecundity and may thereby promote resurgence. Applications of bisultap, imidacloprid, JGM, butachlor, bentazone, metolachlor, bensulfuron-methyl, and acetochlor are led to increased damage levels of rice plant infested by Planthoppers.

Mechanisms of planthopper resurgence at the guild level

Physiological and biochemical effects of agricultural chemicals on planthopper reproduction

JH titers in insect bodies are regulated by JH production in corpora allata and the amount of JH esterase. The increased hormone titers are due to reduced levels of active JH esterase. Triazophos, deltamethrin & jinggangmycin treatments led to increased (45-50%) JH-III titers in BPH females. Imidacloprid, triazophos and deltamethrin treatments led to increased protein contents particularly vitellogenin in BPH ovary and fat body. Amounts of lipids, fatty acids & soluble sugar were higher in adults that developed from nymphs treated with various concentrations of deltamethrin, triazophos and imidacloprid.

Flight muscle changes associated with pesticide induced brown planthopper reproduction

Planthopper migratory capacity and distance are closely related to resurgence. Transmission electron microscopy shows that the diameters of female muscle myofibrils are larger at days one (by 31% and two (by 21%) PE following TZP treatment. Similarly, sarcomere lengths and mitochondrial volumes were larger. These TZP-induced changes are supported by increases in energy metabolites. TZP, imidacloprid, and deltamethrin treatments led to enhanced flight speed and distance.

Proteomic analysis of pesticide actions

Pesticide exposure leads to substantial changes in protein and gene expression in planthoppers in a species- and pesticide type-related manner. TZP-treated unmated BPH males versus untreated unmated males & TZP-treated unmated males versus treated mated males showed 16 differentially expressed proteins in the treated males compared to their untreated counterparts, 10 increases and 6 decreases. Act-5C Protein, which acts in flight muscle isoforms, sperm individualization, and mushroom body development, was upregulated 19-fold. Spermatogenesis associated protein 5 and testis development protein NYD-SP6 were upregulated 3.1 and 5.5-fold, respectively. These proteins are involved in spermatogenesis & they enhance male contributions to BPH reproduction & increased fecundity.

Analysis of gene functions

The discovery of specific genes acting in pesticide-induced planthopper reproduction emerged from the targeted knockdown of selected genes that reduced or eliminated the pesticide-induced influences on reproduction. Some specific genes have been identified. Hydroxysteroid dehydrogenase-like protein 2 and long chain fatty acid coenzyme A ligase act in the carbendazim and triazophos- induced SBPH reproductive increases. Fatty acid synthase (FAS), adipose triglyceride lipase, acetyl-CoA carboxylase (ACC) and EST-1 participate in jinggangmycin-induced stimulation of BPH reproduction. Acyl-coenzyme A oxidase mediates triazophos-induced BPH reproductive stimulation.

Pest comeback in planthoppers, particularly the brown planthopper, is owing to the use of traditional insecticides such as organochlorines, organophosphates, carbamates, and pyrethroids, which cause insecticide-induced mortality of natural enemies. Sublethal dosages of most pesticides induced planthopper reproduction and nutritional alterations via a number of physiological and molecular pathways. As a result, a balance should be established between chemical and biological control of rice planthoppers. Chronic resurgence, in comparison to acute resurgence, poses new dangers to world rice supply. Further investigation on the physiological and molecular processes of chronic planthopper comeback could reveal research areas that can help in addressing these new threats.

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