FACTORS CONTRIBUTING TO BROWN PLANTHOPPER RESURGENCE

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There have been significant advances in noninsecticidal pest management. Insecticides, however, are still indispensable to rice farmers because they are effective, easy to use, and provide immediate results.

Synthetic organic insecticides provide effective insect control, but their widespread use has resulted in toxicity to natural pest enemies, toxic residues in plants and the environment, and insect resistance. Resurgence of some pests after insecticide application on rice is becoming common. Such an abnormal increase in the pest population after insecticide application often far exceeds the economic injury level.

Insecticide-induced pest outbreaks have been reported in walnut (Barlett and Ewart 1951), hemlock (McClure 1977), soybeans (Shepard et al 1977), and cotton (Bottrell and Rummel 1978).

Among the pests infesting rice, the brown planthopper (BPH) *Nilaparvata lugens* (Stål) has gained major importance in several Asian countries. Introduction of high yielding, BPH-susceptible rice varieties, use of high levels of nitrogen fertilizers, continuous cropping, staggered planting, and use of some insecticides are the reported causes for increased BPH populations. Throughout Asia, insecticide is an important component of BPH control, especially in countries where commercial, resistant varieties are not available.

Continuous use of insecticides has resulted in BPH resistance to insecticides in Taiwan (Lin et al 1979), Japan (Nagata 1979), and the Philippines (Heinrichs 1979). After application of insecticides, BPH resurgence was reported in Bangladesh (Alam and Karim 1977), India (Varadharajan et al 1977, Chandy 1979), Indonesia (Oka 1978, Soekarna 1979), the Philippines (IRRI 1979), and the Solomon lslands (Stapley et al 1979). Most of the hopperburned fields reported or observed in India, Indonesia, Philippines, and Sri Lanka received insecticides before the outbreak.

Detailed investigations have been made in the past few years on the insecticide-induced BPH resurgence in rice (Chelliah 1979; Chelliah and Heinrichs 1980; Chelliah et al 1980; Raman 1981; Heinrichs et al 1982a, b; Reissig et al 1982a, b).

FACTORS CONTRIBUTING TO RESURGENCE

Research indicates that a variety of factors contribute to BPH resurgence. The

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degree of resurgence is dependent on the method, timing, and number of insecticide applications and the level of varietal resistance to BPH.

Suppression of natural enemies

Suppression of natural enemies following intensive broad-spectrum insecticide application was suggested as an important factor for BPH resurgence in rice (Kiritani 1972, 1975; Kiritani et a1 1971; Kobayashi 1961; Miyashita 1963). Dyckand Orlido (1977) reported that reduction in the population of the mind predator *Cyrtorhinus lividipennis* after regular spraying with methyl parathion caused BPH resurgence. However, extensive field studies conducted later did not show adequate evidence that reduction in the *C. lividipennis* population caused the resurgence (IRRI 1978, Chelliah 1979).

Reissig et a1 (1982b) indicated that when BPH resurgence occurred in the field, the population of the most important predators such as spiders *C. lividipennis* and *Microvelia atrolineata* could not increase to a sufficient level to suppress the increasing BPH population. Their investigations further indicated that when resurgence-inducing insecticides were applied in the field, they stimulated BPH population growth regardless of their relative toxicity to natural enemies. Natural enemy destruction was a minor factor (Chelliah 1979, Heinrichs et a1 1982).

Insecticide-induced plant growth

Heinrichs et a1 (1979) reported that, in rice, paddy water application of granular formulations of carbofuran, isazophos, ethoprop, and acephate significantly increases plant height. Spraying rice plants with methyl parathion induced tillering (Chelliah 1979). Recently, Raman (1981) reported that foliar application of deltamethrin and methyl parathion resulted in increased number of tillers and leaves and increased plant height. The phytotonic effect (healthy, green plants) of certain insecticides may attract more macropterous hoppers immigrating into rice fields. The alighting followed by increased feeding, reproduction, and longevity would increase BPH resurgence.

Feeding rate

The feeding rate of the BPH was observed to be significantly increased at sublethal doses of resurgence-inducing insecticides. Chelliah and Heinrichs (1980) observed that, in rice plants sprayed with three resurgence-inducing insecticides *viz* deltamethrin, methyl parathion, and diazinon, the BPH feeding rate was higher than that of the check by 61, 43, and 33% respectively. They further reported that, although the first two insecticides induced plant growth, the improved growth did not compensate for the higher rate of BPH feeding leading to hopperburn of these plants much earlier. Subsequent studies by Raman (1981) showed that other resurgence-inducing insecticides such as quinalphos, cypermethrin, fenthion, permethrin, and fenvalerate also increased the BPH feeding rate.

Influence on BPH biology

Chelliah (1979) and Heinrichs et al (1982) demonstrated that BPH population increase after insecticide application was due to stimulation of hopper reproduction.

In laboratory studies, Raman (1981) observed that the BPH reproductive rate was enhanced when the hopper was feeding on rice plants sprayed with deltamethrin, methyl parathion, quinalphos, cypermethrin, permethrin, and fenvalerate. The increased reproduction might be due to the action of insecticide residues or their metabolites, chemical changes in the host plant receiving insecticides, or a combination of these factors. Reduction in the length of the nymphal stage resulting in a shortened life cycle and increased adult longevity resulting in a longer oviposition period were additional factors contributing to resurgence (Chelliah 1979).

Changes in the nutrient content of the rice plant

Mani and Jayaraj (1976) reported that a low concentration of calcium and high levels of nitrogen and phosphorus in insecticide-applied plants contributed to resurgence of the blue leafhopper *Zygina maculifrons* (Motch). However, in chemical analyses of major and minor nutrients in rice plants protected with insecticides, Chelliah and Heinrichs (1978) did not find any marked BPH resurgence. This area needs further investigation because other nutrients in the plants might provide nutritional evidence on BPH resurgence.

Effect of sublethal doses

To save money, farmers are using low insecticide doses. This practice, combined with the short residual toxicity of many commercial insecticides, will often cause the BPH to be exposed to sublethal insecticide doses. Chelliah (1979) reported that low doses of resurgence-inducing insecticides increased the reproductive rate of the BPH and reduced the nymphal duration, eventually leading to resurgence.

Insecticide classes and resurgence

Insecticides causing resurgence include some synthetic pyrethroids, organophosphates, and carbamates. No single class of insecticide has been identified to be free from resurgence-inducement (Chelliah 1979, Reissig et al 1982b).

Insecticide rates

Insecticide rates had distinct influence on the degree of BPH resurgence. Heinrichs et al (in press) observed that deltamethrin at 30 g ai/ha induced significantly high BPH population compared with 20 and 10 g ai/ ha. With methyl parathion, resurgence rate was highest at 750 g ai/ ha compared with 500 and 250 g ai/ha (Table 1).

Timing and number of application

The timing and number of insecticide applications ultimately govern BPH resurgence. Foliar sprays applied at 50 and 65 DT (days after transplanting) resulted in a high BPH egg and subsequent nymphal population, reaching a peak at 80 DT (Heinrichs et al 1982).

Method of insecticide application

Heinrichs et al (1982) found that foliar spraying induced more BPH resurgence than root zone placement and broadcasting (Table 2).

Table 1. *N. lugens* **population in field plots of rice variety IR22 treated with 3 rates of deltamethrin and methyl parathion as foliar sprays (Heinrichs et al, in press).**

Insecticide[a]	Rate (kg ai/ha)	*N. lugens*/hill[b] (no.)
Deltamethrin	0.03	850 a
	0.02	220 bc
	0.01	210 bcd
Methyl parathion	0.75	360 b
	0.50	145 cd
	0.25	112 cd
Check	–	60 d

[a]Insecticides were applied with a knapsack sprayer at 20, 35, and 50 days after transplanting (DT). [b]Sample means of *N. lugens,* taken at 68 DT, followed by a common letter are not significantly different at the 5% level.

Influence of insecticide on nymphal and adult stages

The reproductive rates of BPH exposed to insecticide-sprayed plants during nymphal or adult stage or both varied significantly (Chelliah 1979). The reproductive rate was significantly higher when the BPH was exposed to plants sprayed with resurgence-inducing insecticides at the fourth- and fifth-instar stage as well as at the adult stage (Table 3).

Genetic resistance of rice varieties

In BPH management, resistant rice varieties, planted over large areas in Asia, play an important role. Reissig et a1 (1982a) demonstrated through a field experiment that the extent of BPH resurgence after insecticide application decreased as varietal

Table 2. Influence of method of carbofuran application on BPH population and degree of hopperburn[a] (Heinrichs et al 1982).

Application method	BPH (no./hill)	Hopperburned hills (%)
	Experiment 1[b]	
Root zone	87 b	14 b
Broadcast	44 b	4 b
Foliar spray	149 a	97 a
Check	120 b	8 b
	Experiment 2[c]	
Root zone	1196 ab	19 a
Broadcast	541 bc	16 a
Foliar spray	2456 a	25 a
Check	123 d	18 a

[a]In a column, means followed by a common letter are not significantly different at the 5% level. [b]Root zone application made 5 days after transplanting (DT) at 1.0 kg ai/ha; broadcast application at 1.0 kg ai/ha and foliar sprays at 0.5 kg ai/ha, both at 5, 25, 45, and 72 DT. BPH population and hopperburn were recorded at 78 and 92 DT, respectively. [c]All applications made at 0.75 kg ai/ha 25, 45, and 72 DT. BPH population and hopperburn were recorded at 71 and 84 DT, respectively.

Table 3. Resurgence of BPH as influenced by exposure of different nymphal stages and adult to insecticide-sprayed rice plants.

Stage at exposure[a]	Nymphs hatched[b] (no.)				
	Methyl parathion	Deltamethrin	Diazinon	Perthane	Check (water spray)
First instar to adult	336.7 c	363.3 d	291.7 a	140.3 b	225.3 a
Second instar to adult	375.3 c	386.0 cd	297.0 a	169.0 ab	225.0 a
Third instar to adult	422.3 b	407.3 bc	309.7 a	178.3 ab	262.0 a
Fourth instar to adult	438.0 ab	448.3 ab	334.3 a	192.7 a	241.7 a
Fifth instar to adult	450.3 ab	461.7 a	316.7 a	188.3 a	236.3 a
Adult	472.7 a	484.3 a	315.3 a	188.7 a	252.7 a

[a]Insecticide sprayed on plants aged 20, 30, and 40 days. Insects were released on plants 10 days after third spraying. [b]From eggs laid by 2 females in 7 days. In a column, means followed by a common letter are not significantly different at 5% level.

resistance increased. Populations in insecticide-treated plots compared with untreated plots were 74- 50- and 5-fold for susceptible, moderately resistant, and resistant varieties, respectively. Resurgence-causing insecticides should not be used indiscriminately on moderately resistant varieties because they contribute to a BPH population increase above economic injury levels and accelerate the biotype selection process.

CONCLUSION

Investigations have indicated that many factors are involved in inducing BPH resurgence. Some insecticides contribute to a favorable environment in the rice ecosystem for the BPH to alight, feed, and survive. This stimulates BPH reproduction leading to a high population buildup and severe damage.

Rice production in Asia is being limited by insecticide-induced BPH outbreaks. To prevent outbreaks, a more natural pesticide management program must be adopted. National programs must thoroughly evaluate candidate insecticides to identify those causing BPH resurgence.

Although identifying insecticides that induce resurgence is important in an insecticide evaluation program, their use for increasing field population of rice insects in varietal screening is also valuable.

Brown planthopper

When screening to identify BPH-resistant rice varieties, the pest's unpredictability can cause high expenditures without desired results. Researchers are using resurgence-inducing insecticides to maintain BPH populations for varietal screening work. Insecticides that work well for this purpose include the synthetic pyrethroids deltamethrin and cypermethrin and organophosphates such as methyl parathion, diazinon, azinphos ethyl, and quinalphos (Heinrichs et al 1978).

Leaffolder

Optimum field populations of the leaffolder *Cnaphalocrocis medinalis* are also essential for objective varietal screening. Phorate 10G application along with adoption of closer plant spacing and a higher dose of nitrogen fertilizer promoted plant growth and heavy leaffolder infestation (Velusamy and Chelliah, unpubl.). The leaffolder population was built up on susceptible plants located around the experimental field. The moths later moved to the test entries, providing a high level of infestation.

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DISCUSSION

RENDELL: Have any studies been made on the surface structure of the rice plant in relation to resurgence in inducing insecticides? I noticed from the pattern of BPH honeydew spots on filter paper that with resurgence-causing insecticides the insects stayed stationary, but in nonresurgence-causing insecticides the insects moved around.

CHELLIAH: No studies on the surface morphology of the rice plant have been made in this area. In this study however, hoppers, whether on resurgence or nonresurgence-inducing insecticide-treated plants, were highly sedentary.

SAXENA: Have you considered that BPH resurgence may be induced by insecticidal effects on pathogens?

CHELLIAH: No studies have been carried out.

LOWE: Has resurgence been found with pests other than BPH and leaffolder?

CHELLIAH: The whitebacked planthopper populations exhibit resurgence from methyl parathion, diazinon, and deltamethrin.

BATEMAN: Has leaffolder resurgence been caused by insecticides other than phorate G?

CHELLIAH: Yes, by carbofuran G.

LIM: Road dust is known to stimulate spider mite populations. Have you studied dust formulations for their potential to stimulate resurgence?

CHELLIAH: No, we have tested only granule and emulsifiable concentrate formulations, because they are most commonly used in the areas where resurgence has been reported.

DANDI (comment): In Indonesia, we also have found that BPH resurgence does not appear to be related to depressed natural enemy numbers nor to resistant varieties. We still do not know the cause of resurgence. However, laboratory experiments have shown that sublethal doses of insecticides cause resurgence of the armyworm *Spodoptera litura.*

SANCHEZ(comment): The mango hopper in the Philippines undergoes population explosions during the mango blossoming period, supporting the observation that improved nutrition may cause resurgence.

CHELLIAH (comment): Yes, the mango hopper is known to breed only during the mango blossoming period.

PERFECT (comment): We must be cautious about our interpretations leading to conclusions that resurgence in BPH is not related to natural enemy numbers and does not occur on resistant varieties. Field trials carried out in small plots may give biased results because natural enemies can quickly reinvade from neighboring plots. Predator-prey ratios, rather than actual numbers, are better indicators of natural enemy effect because many natural enemies are density dependent.

Evidence also shows that BPH numbers increase up to fivefold on resistant varieties. This increase does not lead to hopperburn but has serious implications for the development of biotypes that can attack resistant varieties. Therefore, resurgence-causing insecticides jeopardize resistant varieties.

LITSINGER: A number of people have failed to demonstrate resurgence in their countries. What is your recipe for inducing resurgence in BPH?

CHELLIAH: To induce resurgence, there must be a population to begin with. One can set out lights to attract hoppers, use high levels of nitrogen fertilizer, and time fertilizer application when the hoppers are adults.

ISHIKURA: In parts of Japan, farmers use two insecticide applications on rice for stem borer, one in midsummer, when temperatures are high, and the second in the fall, when temperatures are cool. BPH resurgence in Japan has been noted after the midsummer application during hot weather but not during cool periods. Temperature therefore may be important.

CHELLIAH: (comment) In the tropics, where resurgence has been reported, temperatures are always high and relatively constant. Therefore, we have not considered this factor.

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