ISSN: 2249-7137 Vol. 11, Issue 10, October 2021 Impact Factor: SJIF 2021 = 7.492

ACADEMICIA
An International Multidisciplinary Research Journal
(Double Blind Refereed & Peer Reviewed Journal)

DOI: 10.5958/2249-7137.2021.02224.2

THE BROWN PLANT HOPPER AS A RECURRENT DANGER TO HIGH-YIELDING RICE CULTIVATION

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ABSTRACT

The brown planthopper (BPH), Nilaparvatalugens, which erupted occasionally in tropical Asian rice in the sixties, became a great danger after the adoption of green revolution technology by farmers in the 1960s. In the 1980s and 1990s, management and regulatory reforms highlighted non-insecticide methods to prevent BPH epidemics. However, as main method for managing rice insect pests, pesticides have reappeared and recent planthopper outbreaks have occurred in record numbers in tropical Asian nations. Our examination of variables contributing to the epidemics shows that pesticides are mainly the most significant outbreak contributor in terms of their negative impact on natural enemies. BPH resistance to insecticides and particularly Imidacloprid enhanced the likelihood of outbreaks because farmers used increasing amounts of pesticide to fight resistant populations. Similarly, excessive use of nitrogen fertilizer in hybrid rice, in particular, has enhanced the epidemic risk. Other variables that are less established are causing outbreaks, however we explore the potential that high outbreak synchrony in geographically dispersed BPH populations may indicate a 'Moran effect' as a climate that favors the above-average growth in the populations of BPH. We further assume that BPH works as a meta population, and that recurrent outbreaks may thus constitute a natural occurrence which would need plant hoppers to return to the empty regions in order to maintain genetic interconnections between subpopulations. We finish by recommending a number of research and policy reforms to better understand the origin of BPH outbreaks and to create sustainable management methods to avoid repeat outbreaks.

KEYWORDS: *Fertilizers, Green Revolution, Insecticide, IRRI, Planthopper.*

1. INTRODUCTION

Starting in the 1960s, rice production in tropical Asia was developed from a low-yielding conventional system using farmers' rice lands produced with modest artificial input to a high yield scheme based on GM crops, synthetic fertilizers and synthesized insecticides. The first high-yielding rice variety for tropical farmers was IR8 created by the International Rice Research Institute (IRRI) and launched in the Philippines in 1966. IR8 generated 10 t ha−1 in favorable growth conditions compared to 1 t ha−1 for conventional rice. IR8 expanded rapidly throughout tropical Asia and helped substantially to rice output in regions facing food scarcity[1].

Technologies of the Green Revolution rapidly dislocated conventional techniques of rice production in several regions (Jennings, 1974). In the Philippines, within three years following the introduction of IR8 in 1966, 40 percent of Riceland was planted with enhanced cultivars. The Philippines' new-tech rice output grew an average of 12.4% each year from 1967–68 to 1971–72. Compared to conventional cultivars (160-200 days), new rice cultivars achieved maturity very fast. This meant that farmers using irrigation systems might harvest two or three plants of the same rice field per year. Monocultures in many irrigated regions of new high yielding cultivars emerged year round. Artificial fertilizers and pesticides were the high yield system's trademark characteristics. Genetically modified crops produced little better than conventional cultivars without fertilizers. Farmers viewed chemical pesticides as an insurance to preserve fertilizer and other investments. As seen in many Philippine regions, insecticide usage increases in high yield agricultural systems. About 60% of the Philippine farmers in the 1966 decade before IR8 was available were to use some pesticides; in the late 1970s about 70% of farmers who planted high-yielding rice varieties regularly used insecticidal treatments for rice. Researchers have discovered that farmers treat high yield rice (sowing seed beds and main crop) 1-10 times (average 1.4-3.2) in 40 different crops with pesticides, in the Philippine region of Nueva Ecija, the largest irrigated rice area of southeast Asia (comprising 64 distinct brands). The National Agricultural Research and Education Systems (NARES) and the green revolution-driven chemical corporations advised rice farmers with pesticides to increase crop yields and prevent catastrophic pesticide losses. Insect outbreaks, which paradoxically have frequently been caused by pesticides, have strengthened farmers' dread of insect pests and the necessity to use chemical substances. Even when breeders integrated pest resistance in high-yielding crops, farmers continued to treat rice regularly. Some governments have given low-cost pesticides to ensure that farmers spray rice crops frequently. In Indonesia, for example, government subsidies for pesticides amounted to 179 million dollars in 1986, which represented about 0.17% of the country's GDP and 0.8% of the government's overall expenses. Indonesian government spending on insecticides amounted to almost $1.5 billion between 1976 and 1987. However, few farmers have been taught to correctly apply pesticides. In the Philippines rice farmers questioned by researchers sprayed around 80% of pesticide treatments to the incorrect pest or when pests were not an issue. Due to inadequate application equipment, N 75% of the active component of a pesticide was found in the water of the rice fields instead of the target region. Despite the conviction of farmers that pesticides are needed to preserve the rice crop, many assessments have shown that insecticides are seldom required for successful rice production[2].

1.1 The Brown Planthopper (BPH) Revolution:

An unexpected issue with the rice green revolution was the recurrent brown planthopper outbreak (BPH). This bug is made from grown rice, numerous wild Oryza and the herb Leer-siahexandra Swartz. Diagnostic indicators and the study of genetic distance using RAPD – PCR showed the potential of BPH sibling species between the population of rice and Leersia. BPH eats into the vascular tissue of plant leaf blades and leaf sheaths and ingests the sap by inserting its styles. Populations concentrate at the base of the plant and following canopy closure achieve maximum density. Heavy infestations may cause rice plants, known as the "hopperburn," to dry and wilt completely. The pest also transmits ragged stunt virus and grassy stunt virus to plant diseases. BPH in tropics can complete around twelve generations per year, while in temperate regions only 3 generations per year. Around the Red River Delta of Vietnam is the northern geographical limit of winter breeding for the species. In Asian tropics and subtropics, it occurs throughout the year and extends its scope to the north when rice becomes accessible in temperate regions of China, India, Japan and Korea (Perfect and Cook, 1994). Weather-facing migration guarantees that part of the migratory population reaches a distance of several hundred km. However, BPH does not live in temperate regions during winter. BPH infestations in temperate settings are caused by annual migration from tropical Asia and China. Return migrations of BPH populations (north-south) were examined across China and India throughout the fall. Such movements may assist to explain how in the southern overwintering populations migrants are sustained over a great distance[3].

Planthopper epidemics in rice happened hundreds of years before the Green Revolution in the 1960s, according to experts. Outbreaks reportedly occurred about 18 AD in Korea and 701 AD in Japan. After the discovery in 1670 of whale oil as an insecticide, followed by slaked and bitter lime, leafhoppers and planthoppers were said to have been flourishing in Japan. Confirming early claims such as BPH epidemics poses taxonomic issues, since N. lugens species were not identified until 1854. However, before 1966, the year when IR8 was adopted, Fiji, Japan, Korea, Solomon Islands, Taiwan and perhaps more nations verified BPH occurrences. The most significant epidemics occurred in temperate regions, including Japan and Korea, before the green revolution. Tropical outbreaks were usually limited and happened seldom[4].

In 1977 IRRI organized an international meeting to address the danger posed by BPH outbreaks to the new high-yield tropical rice in order to evaluate the issue and to establish prioritized re-search and training initiatives for improved control of the pest. The conferences concluded that the intensification of rice crops and their related technologies had caused major changes to the rice environment, promoting BPH epidemics, especially in irrigated regions where farmers grow 2 or 3 rice crops year. The constant rotation of mono-crops across wide regions offered numerous BPH habitats that allowed the population to breed almost all year round and increased the reproductive capacity of the plague due to the excessive use of nitrogen fertilizer. The frequent use of pesticides worsened the issue by eliminating natural enemies which controlled the populations of BPH. The conferences stressed the need of creating rice cultivars that are genetically resistant to BPH while recognizing that the pesticide is able to adjust to the resistant cultivars. IR26 was the first high yield rice cultivar with BPH resistance introduced in 1974 by IRRI[5]

1.2 IPM Solution:

The IRRI (1979) emphasizes integrated pesticide control as a management approach to avoid outbreaks of BPH. A term established by the Environmental Quality Council from the former integrated pest control term, IPM utilizes several techniques for preventing pest populations from reaching harmful levels. IPM combines pest-resistant cultivars, fertilizer management, agronomic practices that conserve and increase the impact of predators and other natural biological control products and, when necessary, the cautious use of pesticides based on need rather than on prophylactic treatment instead of relying on one single pest control technique.

In 1980, the Food and Agriculture Organization of the United Nations (FAO) provided technical support for tropical Asian nations to start a large programme for rice IPM to improve economically and ecologically sound pesticide management. Between 1980 and 1989, the programme underlined pesticide monitoring, resistance of host plants, wise use of pesticides, natural enemies of pests and demonstrations on the ground that offered farmers first-hand experience with IPM techniques and environmental ideas. There was a working group headed by designated NARES in each component. In the mid-1980s, the Indian, Philip-pine and Indonesian governments proclaimed national IPM strategies. Indonesian authorities have prohibited 57 pesticides suspected to promote BPH breakdown and have also ceased subsidizing pesticides. The change in policy to restrict pesticides saved the Indonesian government approximately 100 million dollars per year and decreased the import of pesticides by two thirds. The FAO initiative cost about US$650,000 in Indonesia between 1985 and 1988.

FAO-IPM highlighted intensive on-farm training at farm schools (FFS) in order to enable rice farmers to adopt IPM with little technical support. The IPM programme educated farmers in several nations from 1980 to 2002. Data from Malaysia and Myanmar is not available, but FFS-trained N2 million rice farmers from 1989 to 2000 in the other eleven countries. According to academics, just 1-5% of all farmer's homes in these nations were for FFS-trained farmers. More than 90 percent of all FFS graduates included six of the nation’s participating in the FAO programme.IPM educated farmers decreased their usage of secticide by 50–80% while maintaining or increasing their rice production. The biggest effect was in Indonesia, where approximately 1.5 million farmers were trained in IPM. In combination with IPM training and pesticide regulations, the usage of insecticide on rice by IPM-trained farmers in the Java province has dropped 75 percent.

In 1991, IRRI started its complementary Pesticide Reduction Program (FPR) to address farmers' misunderstandings regarding leaf-keeper controls. IRRI studies have shown that leaffolters seldom affect the production of rice when untreated; nevertheless, rice farmers believe that if not managed, such insects would lead to significant yield losses. Surveys revealed that most insecticidal treatments were targeted at leaffolders during the first 30–40 days of rice cultivation. In the first 30–40 days of FPR trials, the participating farmers sprayed insecticide spray to the majority of their crops as they typically (usually 1–3 times) but left a section (around 1100 m2) of each crop unprocessed. During harvest, the farmer determined yields from both sides and then compared the findings with adjacent farmers who had carried out similar studies. Participating farmers typically experienced economic advantages immediately when they stopped early treatments and became ambassadors when they disseminated a message of "no spray" to other farms. In some regions, government authorities have started supplementary media efforts utilizing radio, TV, printed and other communication channels to urge more farmers to discontinue rice pesticides early in the season. FPR initiatives at many places in Southeast Asia eradicated rice without loss of production of 50-80 per cent of pesticide usage. The biggest effect occurred in the Vietnam Mekong Delta. Surveys found that the average number of pesticide springs per rice crop was decreased from 3.1 to 1.0 between 1992 and 1997. The FPR initiatives have reduced pesticide usage by 50 percent in approximately 2 million rice fields across the Delta[6].

1.3 Hormesis Caused by Insecticide:

Not only can insecticides enhance the probability of pest breakout by disturbing natural enemy activities, they may also encourage the growth of pesticides via hormesis. Researchers demonstrated that in adults with BPH who evolved from the nymphs, sublethal dosages of methyl parathione and decamethrin had been given topically to 5th Instar BPH nymphs. Sublethal dosages of certain pesticides enhance female fertility of BPH by promoting changes in nutrients of rice crops. Researchers discovered that the reproductive stimulation caused by pesticide differed in rice cultivars, insecticides and the application rate of insecticides. Sublethal uses of deltamethrin insecticide resulted in substantially more brachypterous adults of (flightless) BPH compared to imidaclopride or triazophos in sublethal treatments. The greatest reproductive rate of BPH occurred on triazophos-treated plants. Treatments for both susceptible BPH (TN1) and resistant rice crops of all pesticides were tested at increased soluble levels of sucrose in 3rd and 5th-star nymphs and adults from the nymphs fed on insecticide treated rice plants. Adults from nymphs that have been feed on treated plants had substantially higher levels of crude fat than adults from non-treated plant-fed nymphs. In BPH-susceptible cultivars, reproductive stimulation due to pesticide treatment was more apparent.

The findings of this research show that theoretical applications of sublethal insecticide may enhance BPH migratory ability since the plant-humpers gain more fat and sugar for flight when fed rice plants treated with insecticide than if fed on untreated rice plants. Researchers discovered that Philippine rice farmers frequently use pesticides in large quantities and apply sprays at rates below the insecticide manufacturers advised in order to save time and money. In addition, since BPH populations develop near the base of the rice plant over time, the closed canopy may protect them from spray droplets. Study findings indicate that farmers' use of the sublethal rates of particular pesticides may both improve BPH's reproductive capacities and raise theoretically the risk of BPH outbreaks even when these insecticides did not damage natural enemies[7].

1.4 Resistance to Insecticides:

BHC genetic resistance emerged approximately 15 years after the pesticide was sprayed on the country's rice in 1967 in BPH populations in Japan. In the late 1960s and 1970s, researchers discovered resistance to BPH in the experimental farm of IRRI in the Philipines and resistance to organophosphorus or carbamate insecticides in Taiwan in the 1970s. BPH resistance to organochlorine, organophosphorus, carbamate and pyrethroid pesticides was recorded in many Asian nations in the earlies 1990's. Until recently, resistance reports were mostly produced in temperate regions in BPH populations. Widespread usage of neonicotinyl chemicals in tropical and temperate regions has increased problem resistance. Laboratory testing in China, India, Japan, Indonesia, Malaysia, Taiwan, Thailand and Vietnam have demonstrated imidacloprid resistance in 2008 in populations with BPH. The use of imidacloprid in order to manage BPH was reported by rice growers in many countries. BPH imidacloprid resistance has caused particularly severe difficulties for Chinese rice growers.

From 1996 to 2006, 42 field samples of BPH from eight Chinese provinces were tested for imidacloprid resistance. Most of the BPH populations remained sensitive to imidacloprid between 1996 and 2003 except in Guilin where there was modest resistance in 1997. However, BPH populations from several regions showed high to very high levels of resistance in 2005. Within a just 2 years, the Nanning population grew by N 200 in resistance. BPH acquired N 800-fold resistance to imidacloprid in other places, particularly in southeast China. In several rice-growing regions with each BPH generation, farmers sprayed to avoid the emergence of the plague. The extended residual activity and excellent effectiveness of Imidacloprid make it a favorite insecticide for BPH treatment in many regions. Trends indicate that continuing extensive usage of pesticide in China and in other countries exacerbates the genetic resistance issue in BPH populations.

As BPH migrates over vast distances, it appears that the frequent influx of immigrants from regions of low pesticide use will slow down resistance to insecticides. In China, however, imidacloprid has been used extensively to reduce BPH both in the emigration region and in immigrant areas. Imidacloprid was also extensively utilized in Southeastern Asia where rice-year-round population BPH developed and in the next year it became the main source of northbound mid-gration for China. Therefore, when imidacloprid resistance develops, resistant BPH migrants may transmit their imidacloprid resistance over vast distances rapidly[8].

The issue of resurgence and subsequent outbreaks of BPH may be exacerbated by pesticide resistance, since farmers must use increasing amounts of insecticide to fight resistant populations. In addition, as stated, researchers have shown that imidaclopride foliar sprays for rice may enhance lipids and soluble sugar in BPH nymphs and adult plant feed. BPH populations that have survived treatments of imidacloprid may potentially travel across typical distances and thus serve as a particularly significant conduit for the transmission of the imidacloprid-resistance alone into other regions.

1.5 Usage of Fertilizers in Rice:

Crossing two inbred lines, the hybrid rice created occupies considerably more Asian Riceland. Hybrid rice currently accounts for 60% of the Chinese rice. Although hybrid seeds may cost twice as much as non-hybrid seeds, farmers' earnings may be much greater since hybrids produce 16–20 percent more than their income parents. Larger crop populations and frequent breakouts in farmers' fields of hybrid rice have been observed. The thick canopy of the hybrids, resulting from more robust vegetative growth, seems to make it easier to migrate or disperse insects. The hybrid plants are more effective at absorbing nitrogen and using nitrogen than their inbred parent lines. The increased intake of nitrogen and the efficiency of hybrid usage may lead to more nitrogen accessible for BPH and other pests. In addition, the total absence of or poor genetic resistance of hybrids makes plants more vulnerable to insects. The major hybrid rice varieties are vulnerable to WBPH in China, and only approximately 12% of newly created varieties have had resistance to BPH in field testing.

1.6 Cultivars Impact On BPH:

The development of better rice cultivars with resistance to insects and diseases is an important goal of rice breeding. High-yielding cultivars with BPH resistance, other insects and diseases greatly contributed to the rice production in tropical Asia. IRRI is the world's leading rice breeding institution and has provided rice producing nations with thousands of enhanced breeding lines. An estimated 50% of the world's rice acreage is planted in IRRI or its progeny[9].

IRRI began a rice breeding effort for BPH resistance shortly after researchers discovered pest resistance to rice sources in 1967. Many Asian nations have begun similar programmes. Bph1 and bph2 were the first two resistance genes. Twenty-one BPH resistance genes from farmed and wild Oryza species have already been discovered. The production of rice with a lasting resistance to BPH is a significant problem, given the history of the pesticide adaptation to resistant crops. Pesticides adapted to IR26, the first high producing BPH-resistant cultivar, within two to three years after distribution to farmers. For a relatively brief period, several BPH-resistant cultivars have remained viable. Although certain BPH-resistant cultivars, in particular IR36 and IR64, have shown increased durability, BPH continues to be a nemesis for plant breeders[10].

In addition, scientists have discovered many BPH toxins from non-rice sources which have promise for transgenic rice plants specially built to withstand BPH in addition to the natural sources of BPH resistance in O. sativa and its natural relatives. As far as we know, no transgenic rice types are being cultivated commercially although many modified kinds for marketing have been authorized. Plant breeders are particularly interested in Galanthusnivalis agglutinin (GNA), a transgenic rice plant that expresses the use of snowdrop lectin in plant hoppers. Transgenic GNA plants showed resistance to BPH and WBPH as well as green leafhoppers (Nephotettix sp.). GNA plants are the closest to marketing among the transgenic rice plants available.

2. DISCUSSION

Climate change predicts that interaction and combined effects of high temperature and humidity, drought, salt and submergence will have negative consequences on rice production. How BPH, other pests, natural enemies and ternate progeny are affected by such abiotic stressors is unclear while little study has given insight. In laboratory experiments, BPH eggs and adults' survival was reduced at temperatures of 35°C compared to 25–30°C. In addition, greater temperatures impacted BPH instars and populations differently, owing to their differing intracellular symbiotic death rates. The greatest rice pest fauna has moved from stem borers to dops, cycadellids and, more recently, to rice bugs and migratory populations of dops, such as BPH and WBPH, in Japan in the last half-century. In Japan, the average surface temperature increased by 1.0°C from 1961 to 2000. Researchers have forecast that global warming may benefit natural enemies by increasing the number of generations of their prey. However, some research has indicated that unique reactions to increasing temperatures may result by changing their phenologies, distribution ranges or migratory patterns in distinctions between pests and enemy population.

The assessment of reactions to large-scale impacts such as climate re-inquires information on local population dynamics in spatial scaling. Due to a hazy database of past outbreaks in tropics, it is difficult to test the idea that the climate may have caused a Moran effect for BPH populations in recent years. Data consistently documented over extended periods at representative sites is needed. During 1957–2009, researchers investigated the connection between ENSO occurrences and BPH outbreaks at the mid and lower levels of the Yangtze River. In the years and outbreaks of La Niña, they found no obvious connection. BPH epidemics occurred, however, primarily in the EI Nino and three years following El Nino.

3. CONCLUSION

It is tempting to infer that inputs controlled by humans like pesticides or insecticides in conjunction with nitrogen fertilizers, for example, were fully responsible for the simultaneous tropical rice BPH epidemics in various parts of Asia soon after and even more recently. However, less visible natural governance elements may have produced an environment which favors a rise in pest populations that is higher than normal regardless of their human contribution. The high overall synchronization in BPH's geographically segregated populations may show that a "Moran effect" like the climate had an important impact. Researchers have anticipated that autocorrelation in population fluctuations will equate to autocorrelation in environmental noise, if population synchronization is driven by an environmental variable such as temperature. His prediction anticipated that all impacted populations would be subject to the same linear density regulation on a logarithmic scale and that the correlation in fluctuations between two population populations would always be the same regardless of the starting population sizes. Spatial correlations of ecological factors, generated, for example, by comparable temperatures, were originally proposed as sync agents for the size fluctuations of spatially separated populations. The Moran effect may play a significant role in driving sync in a number of ecological processes, irrespective of size. Natural enemies and BPH-resistant cultivars should be anticipated to have less influence on regulation of the density of the BPH in such an environment which will allow for more rapid BPH growth and natural enemy destroying pesticides would therefore have an above average negative impact.

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