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A Review on Brown Planthopper (*Nilaparvata lugens* Stål), a Major Pest of Rice in Asia and Pacific

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Authors' contributions

This work was carried out in collaboration among between authors. Author KI collected relevant literatures on brown plant hopper, analyzed and formulated the review. Author DD contributed his technical knowledge as research supervisor. Both authors read and approved the final manuscript.

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ABSTRACT

Rice (*Oryza sativa* L.) is the most important staple food in the world including Asia and Pacific. Millions of people around the world depend on rice due to the high calories and economic returns it provides. More than 100 species of insects including 20 economic pests are capable of causing notable damage to rice plants. Insect pests continue to pose threat to rice farming since rice plants serve as their host plants. Pests are major constraints to rice production and coexist with rice growth. Information on pest economic importance, description, biology, distribution, economic threshold level, population dynamics, monitoring and forecasting is a prerequisite. This review is focused on brown planthopper (*Nilaparvata lugens* Stål) which is an important economic rice pest that are prevalent in tropical rice growing regions. Brown planthopper (BPH) is a serious pest of rice and has tremendous impact especially in Asia-Pacific region. Understanding the biology and ecology of this pest will enhance the designing, formulation and utilization of effective control measures. The control strategies as stipulated by integrated pest management (IPM) should be eco-friendly with minimum use of synthetic pesticides while

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boosting the activities of natural enemies and other biological control agents. The control measures discussed in this paper are oriented towards the cultural and biological aspects of managing the pest.

Keywords: Nilaparvata lugens Stål; rice; Asia; pacific; integrated pest management; biological control.

1. INTRODUCTION

1.1 BACKGROUND OF BROWN PLANT-HOPPER

Rice (*Oryza sativa* L.) is the most important staple food in the world including Asia and Pacific. Millions of people around the world depend on rice due to the high calories and economic returns it provides [1,2]. Consumption of rice is steadily increasing with the changing demographic scenario in Papua New Guinea (PNG). Population boom, rural to urban migration, improved employment opportunities and shift in consumer preferences to staple foods like rice, flour and tinned fish has led to a decline in the consumption of indigenous vegetables in PNG [3]. Rice is becoming a staple food for most people in PNG because it is readily available in shops, possess high calories for energy, taste superb and produce sufficient quantities when boiled.

More than 100 species of insects including 20 economic pests are capable of causing notable damage to rice plants [4]. Insect pests continue to pose threat to rice farming since rice plants serve as their host plants [5]. Pests are major constraints to rice production and coexist with rice growth [6,7]. Information on pest economic importance, description, biology, distribution, economic threshold level, population dynamics, monitoring and forecasting is a prerequisite [8]. Partitioning of insect attacks on rice plants can be categorized into specific feeding guilds based on their feeding behaviour and preferences [9,10,11]. They can also utilize the plant parts to complete their reproduction cycle where oviposition and proceeding larval development feed on plant parts for food resources and thus damaging rice plants [12,13].

This review is focused on brown planthopper (*Nilaparvata lugens* Stål) which is an important economic rice pest that are prevalent in tropical regions. Brown planthopper is a serious pest of rice and has tremendous impact around the world and especially in Asia-Pacific region. Understanding the biology and ecology of this pest will enhance the designing, formulation and utilization of effective control measures. The control strategies as stipulated by integrated pest management (IPM) should be eco-friendly with minimum use of synthetic pesticides while boosting the activities of natural enemies and other biological control agents. The control measures discussed in this paper are oriented towards the cultural and biological aspects of managing the pest with a few mention of insecticides. IPM promotes the biodiversity of natural enemies in rice fields as they are the key component to success in biological control of pests [14,15]. The use of chemical insecticides, especially in the early crop season disrupts natural enemy activity therefore it has been recommended to minimize their applications [16]. IPM may not have a distinct definition, but it discourages the indiscriminate use of chemical pesticides and promotes biological techniques that use natural parasites and predators to control pests [17]. In contrary to the use of chemical insecticide which have become a traditional pest control practice, farmers should be well informed and be educated about the importance of biological control.

2. IMPORTANCE OF BROWN PLANT-HOPPER

Brown planthopper (Homoptera: Delphacidae: *Nilaparvata lugens* Stål) is one of the most destructive pests of rice in widely distributed in Asia and Pacific region. Brown planthopper (BPH) has occurrences in China [18,19], India [20,21], Sri Lanka [22,23], Bangladesh [24, 25], Thailand [26,27], Vietnam [28,29], Malaysia [30,31], Korea [32,33], Japan [34,35], Indonesia [36,37], Philippines [38,39], Fiji [40], Papua New Guinea [41,42], and Solomon Islands [43]. Fig. 1 shows the distributional locations of BPH occurrences in Asia and Pacific region. BPH increasingly exhibit resistance to insecticides and adaptation to resistant varieties, so they threaten rice production thus food security [44]. BPH outbreaks occur when the population of Arthropod Natural Enemies (ANEs) decreases, either by natural events such as floods and drought or agronomic practices, or by excess use of fertilizers and pesticides [45].

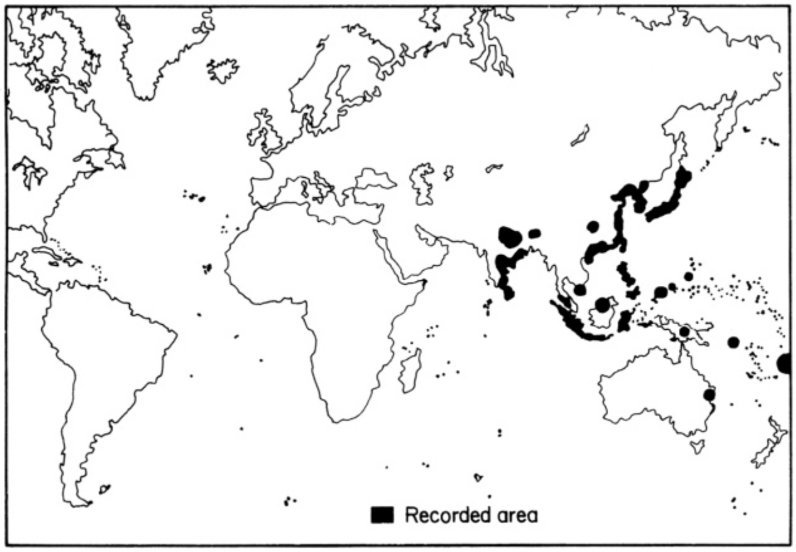

Fig. 1. Blacken areas show the distributional location of brown planthopper, *Nilaparvata lugens* (Stål) [46]

They can be secondary pests serving as herbivores but favourable environmental conditions may trigger their outbreak as major pests of rice [46,47]. High arthropod biodiversity in rice fields are derived from sufficient species richness of predators and parasitoids which can suppress outbreaks of BPH [48,45]. Heong [45] stated that BPH outbreaks became negligible when insecticide use decreased as it boosted arthropod biodiversity and population [49,48]. The use of urea fertilizer as source of nitrogen can also lead to outbreaks by increasing the fecundity [50,51]. With the risk of synthetic insecticides and nitrogenous effect, biological control should be investigated further.

3. DAMAGE ASSESSMENT OF BROWN PLANTHOPPER IN RICE

BPH as major pest in rice can lower the grain yield by impeding the development and growth of rice plants. Their feeding depends on host quality where they extract their food resources through sucking of plant sap and oviposit their eggs in stems [52]. The feeding, oviposition, larval development and transmitted diseases of Grassy Stunted Disease and Ragged Stunted Disease coherently favour BPH as a destructive pest of rice [53, 54, 55]. A severe infestation occurred in Southern Vietnam from 2005 to 2006 where more than 485,000 ha of rice fields were affected by viral diseases seemingly transmitted by BPH and other insect vectors which amounted to loss of US$120 million [56]. Thus the impact of BPH is measured in terms of economic threshold level that can be correlated to yield loss. The main objective of modern pest management program is to suppress or maintain pest population below an economically and ecologically tolerable level [57,58,59,60].

The incremental returns should exceed incremental costs of control which is expressed in terms of Economic Threshold Level (ETL) of pest in rice [61,62]. To determine ETL, it requires a quantitative study of various pest-crop interactions. ETL has many factors which include; pest species (biotype) behaviour, pest developmental stage, pest age structure, pest dispersion, pest population density, pest infestation period, pest population dynamics, crop variety (susceptible to pest attack), plant stage (time of attack, tolerance, compensatory capacity), site of attack (on plant and field), crop management practices, species competition, natural enemies and weather (abiotic factors) [63]. Economic variables such as price of crop products, cost of control measures, and data on pesticide efficiency and efficacy are also important variable included in ETL [63,61]. A proposed simple model for calculating ET value is as follows: ET = (Cost of Control) ÷ (yield x % Yield reduction x Price of crop x Efficiency of control x Pest survival coefficient) x (critical factor) [64].

Yield loss of rice plants in relation to BPH population have been studied by caging and artificially infesting rice plants at various growth stages over a fixed period [65, 64, 66]. The results showed that plants differ in BPH infestation at different growth stages with booting as the most sensitive stage followed by milking, maximum tillering and the soft seedling stage. The yield loss threshold at booting stage (panicle initiation) is 2-3 BPH/hill and 4 BPH/hill at maximum tillering stage [63]. To justify BPH ETL prior to application of control measures, simple random sampling and monitoring is a pre-requisite [67, 68]. Cheng [64] recommended 30-50 rice hills to be sampled in the field to meet a 20% precision level. ETL works efficiently with sequential sampling plan [69].

4. MORPHOLOGY, MIGRATION AND IMPACT OF BROWN PLANTHOPPER

In Japan, BPH (*N. lugens)* is considered as a pest of economic importance among *Sogatella furcifera* (Horv.) and *Laodelphax striatella* (Fall.) [70]. BPH differ from its sister sub-order, Sternorrhyncha, which include aphids, whiteflies and scale insects [71]. Adult is brownish black with yellowish brown body (4-5mm) and has a distinct white band on its mesonotum and dark brown outer sides. The adults can exist as dimorphic, macropterous and brachypterous (Fig. 2). Macropterous adults (long-winged) have normal front and hind wings, whereas brachypterous forms (short-winged) have reduced hind wings [71]. A prominent tibial spur present on the third leg distinguishes *N. lugens* from other two genera, *Afrokalpha* and *Nethokalpa* [72]. Macropterous forms (usually female) are adapted for long distance flights and are known to migrate thousands of kilometres across land and sea [73, 74]. These forms are the first to arrive at newly planted fields and began colonization. The adults mate on the day of emergence and gravid females start laying eggs thereafter while adults may live up to 25 days [71].

BPH are Homopterans of Delphacidae family that possess a prominent sucking mode of feeding that draws sap from phloem in stems of rice plants [76]. Due to the continuous sucking of phloem sap, plants turn yellow, dries up quickly and soon a wide area of rice plants turn brownish resulting in ‘hopper burn’, and yield loss [77]. These outbreaks are exacerbated by viral diseases; Grassy Stunted Disease and Ragged Stunted Disease transmitted by BPH as the vector [53, 54,55]. The plant damage caused by these viral diseases can sometimes supersede the attack of vector [78]. Fig. 3 shows the symptoms of viral diseases that are transmitted by BPH.

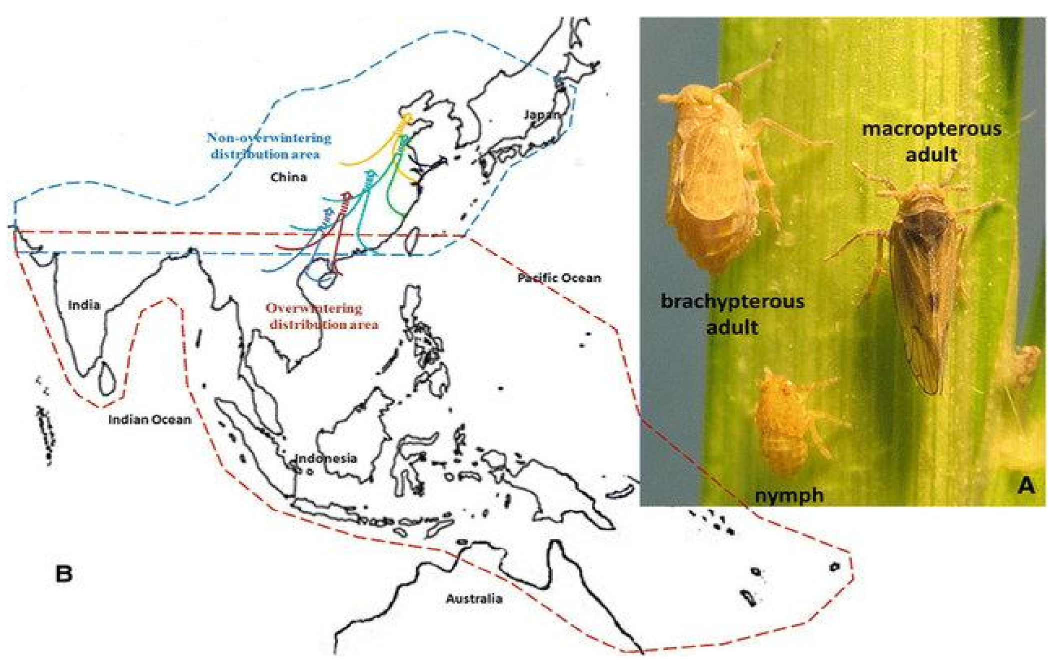

Fig. 2. Long-winged (macropterous) form (A), short-winged (brachypterous) form (A) and worldwide distribution and possible migratory routes (B) of BPH [75]

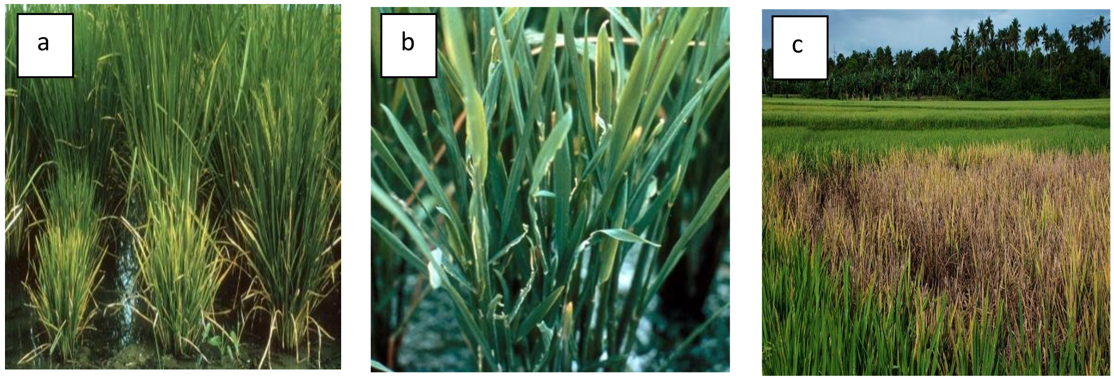

Fig. 3. BPH transmits the grassy stunt (a) and ragged stunt (b) viral diseases as it feeds on the phloem sap of rice stems, and in severe cases, a 'hopper burn' (c) occurs (source: www.knowledgebank.irri.org).

5. BIOLOGY OF BROWN PLANTHOPPER

As described by Mochida and Okada [71], BPH eggs are usually laid in groups at lower part of the rice plant, especially in sheaths and also in leaf blades. But the sizes and sites of egg-groups depend upon the growth stage of the rice plant. When the adult population is high, eggs are found in the upper parts of rice plants. The egg stage is about 7 to 11 days in the tropics. The nymphal stage is 10 to 15 days via five instars. The pre-oviposition period averages 3 to 4 days for brachypterous females and 3 to 10 days for macropterous females t constant temperatures of 20–33°C [71]. Pre-oviposition period of migratory macropters were prolonged by approximately 1 month [79]. Duration of each stage depends on temperature and cultivars. In the greenhouse each female lays about 100 to 200 eggs. The adults and nymphs usually stay on the lower parts of rice plants. However, when the population is very high—in Java more than 500 per hill— they are observed to swarm even on flag leaves, the uppermost internodes of panicles, and panicle axes [71]. In tropical lowlands, *N. lugens* may have 2 to 8 generations during one rice cropping season with five generations on a single rice crop in Japan [80], five or six generations in China [81], and four or five generations in Java [82]. The seasonal occurrence of *N. lugens* in the tropics depends on availability and longevity of standing rice plants. In many rainfed paddy fields in Java, rice is absent during the dry season. BPH is less abundant during dry season when rice plants are absent, but present in some irrigated fields even in dry season [82].

6. ECOLOGY OF BROWN PLANTHOPPER

Rice (*Oryza sativa* L.) is the most preferable host plant of BPH [83]. Other plants have been observed to serve as alternative habitat for the insect [40,84]. A few alternate hosts identified includes *Eleusine coracana*, *Leersia hexandra*, *L. japonica* Makino, *Saccharum officinarum* L., *Zea mays*, *Zizania latifolia* Turcz., and *Zizania longifolia* [85,86,87,88]. The continuous availability of rice plants including ratoon rice with absence of fallow period increases the population density of BPH [89,90,43, 91, 92,38]. Rice stubble also provides a reservoir, refugia or even a suitable breeding point for BPH therefore stubble management is recommended as a control measure [86,93,94,95,96]. Extensive rice fields with dense plant stand and availability of non-rice plants in the vicinity are presumed to positively affect pest population [97, 98, 99, 22,38].

Abiotic factors can also influence BPH development and population dynamics, including outbreaks in rice field. This includes mean temperature, rainfall and relative humidity. Temperatures between 25 and 30°C are considered optimal for egg and nymphal development of BPH [89,93,100]. The rate of development increases as temperature increases. A humid environment (70 to 85% relative humidity) is preferred by *N. lugens,* and is conducive to its development and population increase [97,28,101,99,102,26,46]. A relatively warm and high humidity environment favors the outbreak of this pest [103,89,102]. It was suggested that typhoons could reduce BPH numbers [38] and the limited air movement within the microhabitat could increase populations

[28,101]. The dense canopy produced by high-tillering varieties, close spacing and high fertility, combined with continuously flooded fields, produces a microclimate that favours multiplication of BPH [99, 46,104].

7. BIOLOGICAL CONTROL OF BROWN PLANTHOPPER

Biological control may involves the use of natural enemies such as predators, parasitoids and entomopathogens to lower BPH population in rice field. BPH population was low, partly due to presence of predators such as mirid bugs (*Cyrtorhinus* spp., *Tytthus parviceps*) [105, 106]. Predatory spiders, aquatic bugs (*Microvelia* spp.), coccinellid beetles (Coccinellidae), ground beetles (Carabidae) and rove beetles (Staphylinidae) also suppress BPH population [90,107]. *Cyrtorhinus lividipennis* which is a predator of both eggs and larvae of BPH apparently prevents the increase of the BPH population in drilled rice fields [40,108,109]. At least 19 species of hymenopterans Eulophidae, Mymaridae (*Anagrus* sp.), and Trichogrammatidae (*Oligosita* sp.) are egg parasites of BPH [110]. Sixteen species belonging to Hymenoptera (Dryinidae), Strepsiptera (Elenchidae), and Diptera (Pipunculidae) were identified as parasites of BPH nymphs and adults [110,111,112].

Low pest damage was observed under unsprayed irrigated rice fields since it encourages more natural biological control that kept planthoppers and other potential pests in check [113, 114]. Insecticide application in tropical rice are the most likely cause of pest problems since they lower the population of natural enemies and encourage pest resurgence [108, 9,115]. Bae and Pathak [103] speculated that an infection of *Entomophthora* spp. helped reduce pest density, but Hinckley [40] concluded that fungi caused less pest mortality than predators and parasitoids.

8. RESISTANCE RICE VARITIES

Initial studies on varietal resistance to the BPH was done by the International Rice Research Institute (IRRI). IRRI has developed and documented efficient mass-screening techniques for assessing and evaluating different rice germplasms worldwide [116]. The varieties ASD7 and Mudgo were resistant in the Philippines [117], Japan [118], Korea [119], Taiwan [120], Thailand [121], and Indonesia [122] however they were susceptible in India [104]. The different reactions could be due to the presence of different populations of BPH in different locations and countries. In the future, the sources of resistance so far identified should be retested against the different biotypes to tackle the development of biotypes capable of surviving on the resistant plants. Four major genes that impart resistance to the BPH were identified in the rice germplasm at International Rice Research Institute (IRRI). When resistant cultivars (IR26, IR28, IR29, IR30, and IR34) with the *Bph 1* gene were released, BPH problems almost disappeared in farmers' fields in some countries of Asia [123,124, 125, 126]. Furthermore, they were at first resistant but after about 2 years became susceptible to the BPH in the Solomon Islands, Philippines, and Indonesia [124]. The factors associated with BPH outbreak include cropping of high-yielding susceptible rice cultivars, high application of nitrogenous fertilizers, continuous irrigation, excessive insecticides, high plant density, extensive rice fields, and continuous rice cropping high yielding susceptible cultivars [46,51,127]. Using of resistant varieties with horizontal resistance is better than those with vertical resistance.

9. CULTURAL CONTROL

Cultural control is the most simplified method of control perhaps as old as agriculture itself [117]. Unlike insecticidal control, cultural control may not give immediate results but it provides a first line of defense against pest attack and orients from ecological and economical concepts [128]. Insects can survive on alternate hosts but does not multiply well as they do on rice plants [129]. Fallowing period when rice is not grown thus helps in reducing the population of insect pests [117]. Rotating rice plants with other annual crops or fallowing between two rice seasons disrupts the life cycle and population build-up of the pest [130]. Rotating with non-host plants such as soybeans, mung bean, sweet potatoes and marigold flowers can reduce population of insect pests [131,132]. Integration of crop rotation with resistant varieties (IR26, IR28, IR30) should further lower the population and impact of BPH [129,117]. A concurrent planting with secondary non-host plants should be utilized and extensively [90,129,117].

10. CHEMICAL CONTROL AND PEST RESISTANCE

In most rice growing regions, chemical control is still a common method of controlling BPH [16, 133]. Due to intensive and indiscriminate use of insecticides, this pest has gradually developed resistance to most of the chemical insecticidal classes [134]. These major classes of synthetic insecticides include organophosphates, carbamates, pyrethroids, neonicotinoids, insect growth regulators, and phenylpyrazoles [68,135]. The neonicotinoid insecticide, imidacloprid, was introduced into Asia to control BPH in the early 1990s [136]. Resistance to this insect neurotoxin become widespread in field populations across Asia region between 2005 to 2012 [137]. As a result, imidacloprid was suspended in 2006 followed by subsequent banning of fipronil and buprofezin in 2009 and 2013 [134]. Insect resistance to insecticide chemicals involves the mutations of detoxifying enzyme genes and amino acid mutations of targeted genes [138,139]. Since then, pymetrozine, thiamethoxam, flufiprole, nitenpyram, dinotefuran, sulfoxaflor and chlorpyrifos have been introduced and widely used in controlling this pest in China [19]. Monitoring and early detection of shifts in resistance or susceptibility status is important for prompt adoption of alternative control measures of this pest [68].

11. CONCLUSION

Brown planthopper (*Nilaparvata lugens* Stål) is one of the important economic pest of rice that is prevalent in Asia and Pacific regions. It is a serious pest that is considered a threat to rice production in the Asia-Pacific region. Understanding the ecology and biology of this pest is a prerequisite for developing and implementing effective control measures. The control strategy that has been proven effective against brown planthopper is integrated pest management (IPM). IPM programs are usually eco-friendly and oriented towards minimum use of synthetic pesticides. The objective of reducing pesticides is to boost the activities of natural enemies and other biological control agents. Integration of host resistance, biological and cultural control are therefore recommended to manage brown planthopper.

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DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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