RESISTANCE MANAGEMENT OF BROWN PLANTHOPPER, NILAPARVATA LUGENS, IN INDONESIA

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ABSTRACT

In the 1970's and early 1980's, during rice production intensification in Indonesia, the brown planthopper, *Nilaparvata lugens* Stal, became a major pest of rice and seriously threatened Indonesia's rice self-sufficiency. Factors that contributed to the increasing problems of brown planthopper were: injudicious use of pesticides which caused pest resurgence, the elimination of natural enemies and the development of resistance; breakdown of host plant resistance, and; lack of integration of different pest management tactics. In 1986, because of the increasing problems with brown planthopper, the Indonesian government declared Integrated Pest Management (IPM) the national rice pest management strategy and banned 57 pesticides for their use on rice based on expert advice. Although this IPM program is highly effective, brown planthopper will continue to adapt to pesticides and resistant rice varieties used in the current IPM program. Therefore, in order to develop a sustainable rice IPM program, pesticide and host plant resistance management strategies need to be implemented.

THE BROWN PLANTHOPPER PROBLEM

In the 1970's and early 1980's one of the major goals of rice production in Indonesia was to reach self-sufficiency [1]. Through a rice production intensification program Indonesia became rice self-sufficient by 1983. This was primarily achieved by combining high pesticide and fertilizer input with the use of high yielding rice varieties that were resistant to insect pests [1,2].

The intensification of rice production, however, caused increasing pest problems [1,2,3]. During this period, the brown planthopper, *Nilaparvata lugens* Stal, became a major pest of rice in Indonesia. This insect causes both direct damage to rice by feeding on the rice plants, causing 'hopperburn', and indirect damage by transmitting grassy stunt, a mycoplasma [4]. The brown planthopper was first reported as a rice pest in Indonesia in 1969, and in subsequent years there was a dramatic increase in brown planthopper populations and losses in rice yield due to damage caused by this insect [2, see Fig. 1]. From the period 1977 to 1979 alone, over 2 million hectares of rice were lost due to brown planthopper damage [1,2]. Since 1979 damage caused by brown planthopper decreased, however, brown planthopper outbreaks in 1984 and 1986 reduced rice yields nation-wide [2,3].

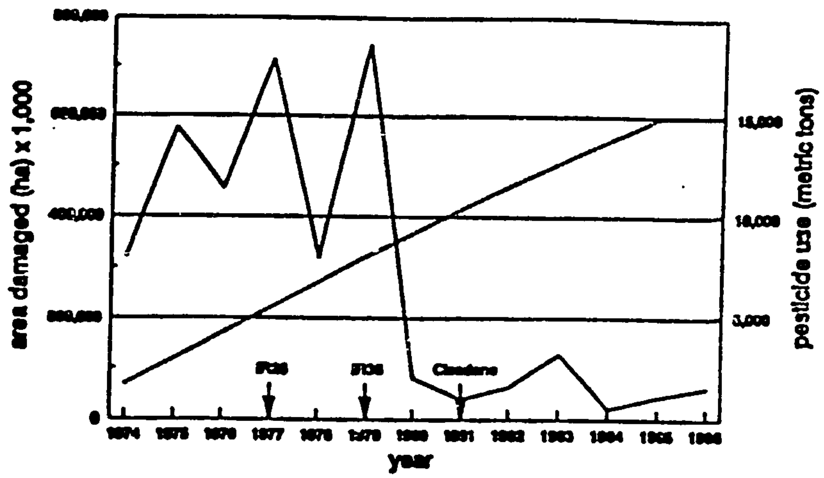

Figure 1. Economic damage caused by brown planthopper, N. lugens, (—) and the use of pesticides (—) and release of resistant rice varieties (IR26, IR36, Cisadane) for its control in Indonesia.

Strategies for controlling brown planthopper in the 1970's and early 1980's depended mainly on the use of brown planthopper resistant rice varieties and insecticides, although the use of some cultural practices were suggested to overcome the brown planthopper problem [2,5, see Fig. 1]. However, the unilateral dependence on resistant rice varieties and insecticides, to which brown planthopper was able to adapt, and the lack of integration of different pest management strategies caused brown planthopper to become a major pest in this period. The following factors contributed to the increasing brown planthopper problem;

1) Inappropriate cultural practices: the lack of crop rotation and staggered planting provided a continuous food source for brown planthopper [2,5]. Nitrogen fertilizers trigger ovipositional response in brown planthopper, and increased use of fertilizers

during the rice production intensification program led to dramatic population increases [5]. Although resistant rice varieties were available, many farmers planted old, brown planthopper-susceptible, varieties because of better taste.

2) Pesticides: three major factors contributing to the failure of chemical control have been the resurgence of brown planthopper after insecticide applications, the elimination of natural enemies of brown planthopper due to broad spectrum chemicals, and the development of insecticide resistance in brown planthopper. Resurgence, a significant increase in brown planthopper populations after insecticide treatment, was observed in Indonesia since 1979 as well as elsewhere in Southeast Asia [1,2,3,6,7]. Studies on the effect of insecticides on populations of brown planthopper on central Java indicated that all the major groups of insecticides (carbamates, organophosphates, and pyrethroids) caused brown planthopper resurgence [3,8]. These studies also indicated that the use of broad-spectrum insecticides eliminated natural enemies of brown planthopper, allowing the pest to reach damaging levels. Brown planthoppers were effectively controlled by natural enemies if no disruptive insecticides were used. The excessive use of insecticides during the rice production intensification program caused high selection pressure on brown planthopper populations, resulting in the development of insecticide resistance. Populations of brown planthopper from Java were reported to be resistant to organophosphates, carbamates, and pyrethroids [9,10], and resistance levels were related to patterns of insecticide use [10].

3) Breakdown of host plant resistance: in order to overcome the increasing problems with brown planthopper, more effort was put into the propagation and distribution of brown planthopper-resistant rice varieties in Indonesia. As early as 1967, varieties resistant to brown planthopper had been identified at the International Rice Research Institute, Los Banos, Phillipines [11]. In Indonesia, IR26 and other resistant varieties containing the Bph 1 gene, were introduced in 1977-1978 [3, see Fig. 1]. However, host plant resistance was easily broken down by brown planthopper, and resistance to these varieties did not last for more than 2 cropping seasons (less than one year), after their introduction [1]. After 1979, brown planthopper outbreaks could be controlled by the introduction of varieties containing the bph 2 gene, such as IR36 and Cisadane [3]. However, this narrow base of host plant resistance made the rice production system vulnerable to brown planthopper outbreaks. The acreage of rice fields damaged by brown planthopper increased from 19,000 ha in 1984 to 60,000 ha in 1986 [3, see Fig. 1]. The ability to breakdown host plant resistance has been related to the development of 'biotypes', based on the observations that laboratory cultures of brown planthopper obtained from field populations and selected on host plants containing different resistant genes led to the development of strains capable of

surviving host plant resistance [12]. Although some authors speculate that the occurence of biotypes in the field may even eventually lead to sympatric speciation [13], other workers conclude that biotypes are simple genetic variants rapidly selected with no mating barriers [14,15]. The ability of brown planthopper to quickly breakdown host plant resistance as well as to develop resistance to insecticides indicates that this insect is highly adaptive to selection pressure exerted through different means on the population. Researchers start to realize that control of brown planthopper solely based on the use of pesticides or resistant varieties will not be effective in the long term.

INTEGRATED PEST MANAGEMENT OF BROWN PLANTHOPPER

Based on the findings that natural enemies can effectively control brown planthopper if no disruptive insecticides are used, pilot studies were conducted in the early 1980's to implement pest control based on the conservation of natural enemics as part of a new Integrated Pest Management approach [2,3,8]. Integrated Pest Management (IPM) is a philosophy of pest control that utilizes the "best set" of management strategies, tactics and tools to limit pests below an economic threshold with mimimum environmental and socioeconomic impacts [16]. Various tools, tactics, and strategies were developed and evaluated in order to implement a more sustainable rice production system (see Fig. 2). The rice IPM strategy emphasized the use of insecticides only when needed and the use of locally acceptable resistant rice varieties. An important aspect of this program was the training of extension personnel and farmers to diagnose and monitor pest problems in the field and to make decisions accordingly. Results of these pilot studies demonstrated the feasibility of the IPM approach for larger areas of rice production in Indonesia.

Because of the increase in damage caused by brown planthopper in the mid 1980's (see Fig. 1) and the availibility of an IPM alternative, the Indonesian Government declared on November 5, 1986, by Presidential Decree 3 (Inpress 3/1986) IPM the national pest control strategy for rice [1,2]. The Indonesian legislation was based on expert advice from the Indonesian (Gadjah Mada University, Yogyakarta, and Central Research Institute for Agriculture, Bogor) and international (International Rice Research Institute and Food and Agricultural Organization, Phillipines) rice research community. The Presidential Decree emphasized that insecticides should only be used when control thresholds in effect were reached (5 brown planthoppers/tiller), thus mandating a monitoring strategy. The decree banned the use of 57 insecticides on rice because of their implication on brown planthopper resurgence. Only four compounds

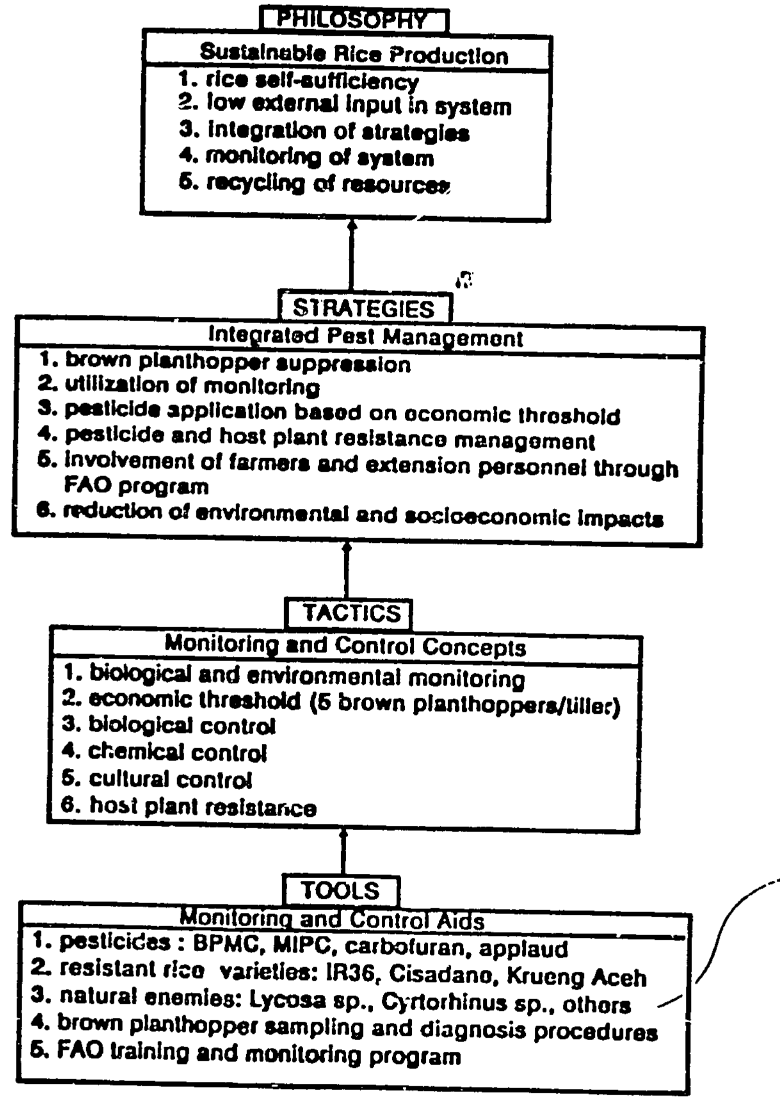

Figure 2. Tools, tactics, strategies, and philosophy of Integrated Pest Management of brown planthopper, *N. lugens*, in Indonesia.

were allowed for rice pest management, the carbamates MIPC, BPMC, and carbofuran and the insect growth regulator buprofuzin (Applaud^{R}). The use of brown planthopper resistant rice varieties was also required. An appropriate cropping system, including synchronous planting, rotation with non-rice crops, and a considerable free rice crop period was recommended. In order to implement this program, the Presidential Decree stated that extension personnel and farmers should be trained to conduct IPM of brown planthopper.

Presidential Decree 3 resulted in effectively controlling brown planthopper and improving rice pest management in Indonesia. The number of insecticide applications dropped from 4.5/ha in 1986 to 0.5/ha in 1988 [1]. This resulted in a reduction of insecticide costs to the farmers from 7,500 rupiah/ha in 1986 to only 2,200 rupiah/ha in 1988, even though insecticides were more expensive due to a reduction in government subsidy compared with 1986. The rice yield increased from 6 tons/ha in 1986 to 7.5 tons/ha in 1988. Throughout the introduction of IPM in Indonesia, an extensive training program of field personnel, extension workers and farmers was put in place.

RESISTANCE MANAGEMENT OF BROWN PLANTHOPPER

Although the current rice IPM program in Indonesia emphasizes the integration of various tools for pest control, resistant rice varieties as well as insecticides remain important components of the overall IPM strategy. The availibility of only 4 insecticides (MIPC, BPMC, carbofuran, and buprofezin) and 3 major brown planthopper-resistant rice varieties (IR36, Krueng Aceh, and Cisadane) for brown planthopper control, imposes a substantial selection pressure on populations of this pest. Because of the propensity of brown planthopper to quickly adapt to selection pressure exerted on populations by resistant host plants or insecticides, as indicated by strains of brown planthopper able to breakdown host plant resistance or to develop insecticide resistance, the application of resistance management is necessary. We define resistance management as a strategy within an IPM system that seeks to limit the selection for resistance alleles to major population suppression strategies such as host plant resistance and insecticides. Through resistance management one seeks to prolong the life of a pesticide or resistant host plant variety by preventing, delaying or reverting resistance development to the pesticide or ability to breakdown host plant resistance by the pest. The goal of resistance management is to implement a sustainable IPM system which allows for long term control of a pest or pest complex. Because of the importance of managing resistance in brown planthopper for overall pest control in rice, a strategy of resistance management of brown planthopper has been developed as an initial step to implement a resistance management program in Indonesia. Figure 3 shows the different tools, tactics, and strategies of such a resistance management program.

Pesticide resistance management

An important requirement for a resistance management program is the ability to detect resistance in a population at a sufficiently early stage to reduce selection pressure. Through resistance monitoring one attempts to measure changes in the frequency or degree of resistance in time and space in a pest species. Resistance monitoring is therefore essential for the evaluation of strategies, validation of tactics, and implementation of an ongoing IPM program.

Insecticide resistance in brown planthopper in Indonesia has been mainly observed through field failure of insecticides [10]. Because of the importance of detecting resistance at an early stage, resistance monitoring techniques have been currently developed as initial steps in resistance management of brown planthopper. Toxicity bioassays, including topical application of insects, dipping of insects, and exposing insects to insecticide residues seem appropriate assays for evaluating the efficacy of pesticides. However, disadvantages of such toxicity bioassays are that only one insecticide can be tested per insect, relatively large numbers of insects are needed, and results are only known after 24 or 48 hrs. More recently biochemical assays have been developed for various insects such as aphids and mosquitoes in which the activity of detoxification enzymes can be measured in individual insects which is an indication of resistance to a certain insecticide [17,18]. Advantages of such biochemical tests are that they provide information about resistance frequencies within populations, require fewer insects, and are more sensitive and less time consuming than toxicity bioassays [19]. Studies on the biochemistry of resistance in brown planthopper from Java showed that esterases are important in conferring resistance to organophosphates, carbamates, and pyrethroids [9,10]. Therefore, biochemical assays were developed for the detection of esterase activity in individual brown planthoppers, using either a microtitre plate assay and an ELISA reader or a portable photometer set-up. The latter allows for the detection of resistance levels in populations of brown planthopper in the field. These biochemical assays are simple and easily transferred to relatively untrained field personnel and seem useful tools for resistance monitoring.

The availability of resistance monitoring techniques may allow for effective resistance management of brown planthopper in Indonesia in the future. The following strategies supported by laboratory data and/or field experience have been generally considered useful in managing resistance in arthropods [20] and will be evaluated for brown planthopper during the development and implementation of a

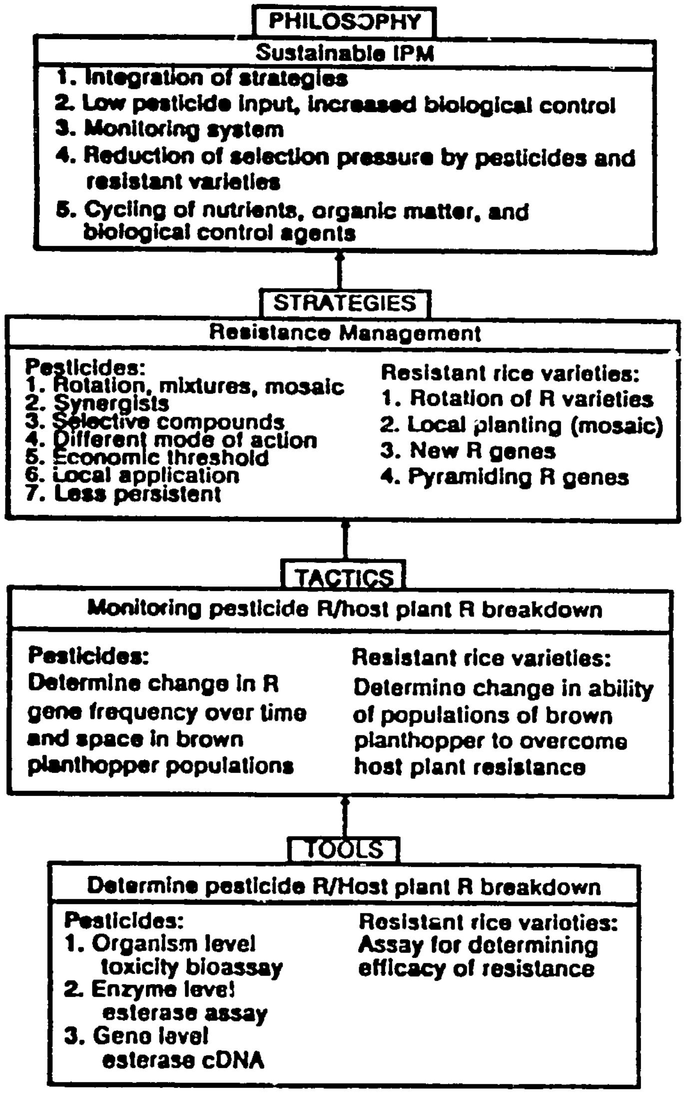

Figure 3. Tools, tactics, strategies, and philosophy of Resistance Management of brown planthopper, *N. lugens*, in Indonesia.

resistance management program: local rather than areawide insecticide applications; treatments only when the economic threshold is reached; use of less persistent insecticides; mixtures, rotations or mosaics of applications of the carbamates MIPC, BPMC, carbofuran and the insect growth regulator buprofezin; use of synergists; use of selective compounds to protect natural enemies; use of compounds with different mode of action.

Host plant resistance management

Regarding host plant resistance management, monitoring for the ability to breakdown the resistances of different resistant varieties in field populations of brown planthopper under standardized conditions will be an essential component. Strategies that may reduce the speed at which brown planthopper will break down host plant resistance are the following: rotation of resistant varieties, i.e. rotation of different resistant genes; more local than areawide planting of a certain resistant variety, i.e. host plant mosaic; pyramiding existing resistant genes from different varieties into a new variety; introduction of new convential selected resistant genes (laboratory biotypes of brown planthopper may be useful for genetic screening of new resistant varieties). Biotechnology also offers the possibility of creating new resistant varieties, but there is no reason *a priori* to assume that these exotic genes could not be overcome by brown planthopper biotypes.

Future perspectives

Because of the great demand for rice, rice production in Indonesia will continue to be based on high-input intensive farming. As part of the current IPM program, the use of insecticides as well as resistant rice varieties will therefore continue, thus selection pressure will continue and brown planthopper populations will eventually adapt. However, it is hoped that the integration of insecticide and host plant resistance management strategies will result in stable control of brown planthopper in Indonesia. Because, brown planthopper is a highly adaptive species, we believe that continuous monitoring and strategy alteration will be necessary for brown planthopper management. In our view, resistance management is therefore an essential strategy within a sustainable IPM approach to brown planthopper management.

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