

# The Role of Integrated Pest Management in the Green Revolution in Indonesia

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For centuries rice has been the major crop on which Indonesians depend for carbohydrate consumption. To meet increased consumption needs, due to the rapid population growth, the Indonesian government has introduced the Bimas (mass guidance) and Inmas (mass intensification) programs. Since these programs were launched, rough rice production increased substantially from 13.7 million tons in 1966 to 26.3 million tons in 1979 [3]. However, this increase does not meet the annual needs of the country because of the progressive population increase.

Rice yield in Indonesia was reported in 1979 to average 2.46 tons per hectare of rough rice. On the other hand, under experimental conditions yields of 6 to 9 tons have been produced. Demonstration plots yield 3 to 4 tons. One of the main reasons for the yield gap is epidemic outbreaks of pests and diseases. Other constraints are environmental factors such as drought and flood. For example, in 1967 and 1972, rice crops suffered severe droughts. In 1975 to 1977, severe brown planthopper damage occurred [26]. It has been demonstrated experimentally that average yield losses from insect pests ranged from 19.4 to 24.1 percent in 1975 [23].

In view of these problems, the government through its five year development plans gives the first priority to agriculture. This includes increased land area and crop intensification. In this paper only

pest management related to crop intensification will be discussed.

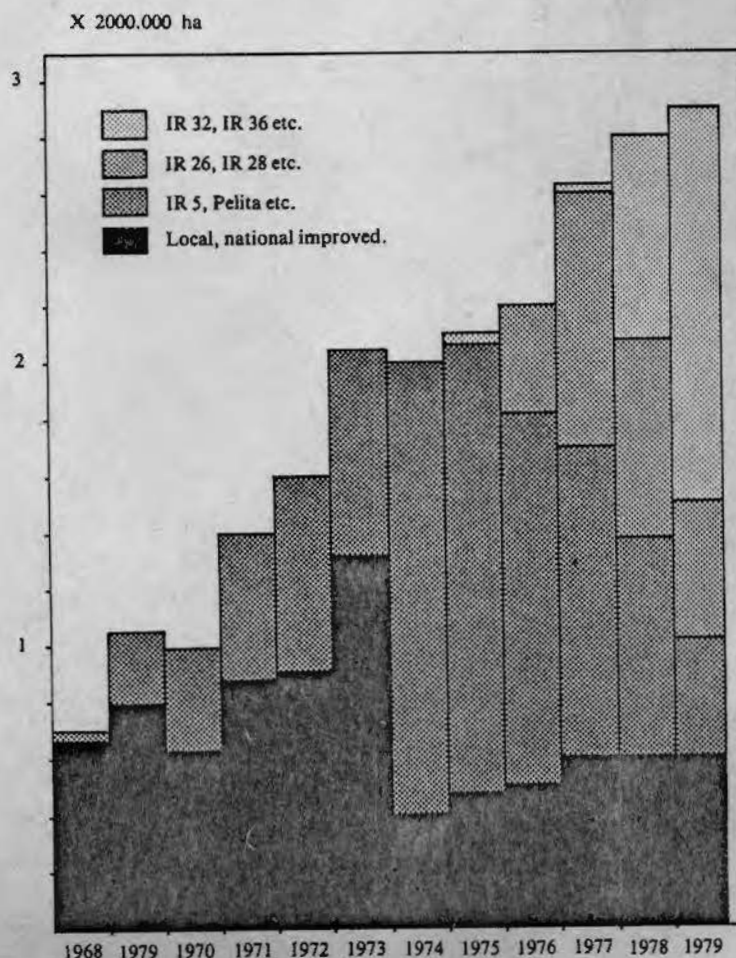
## Green Revolution Inputs

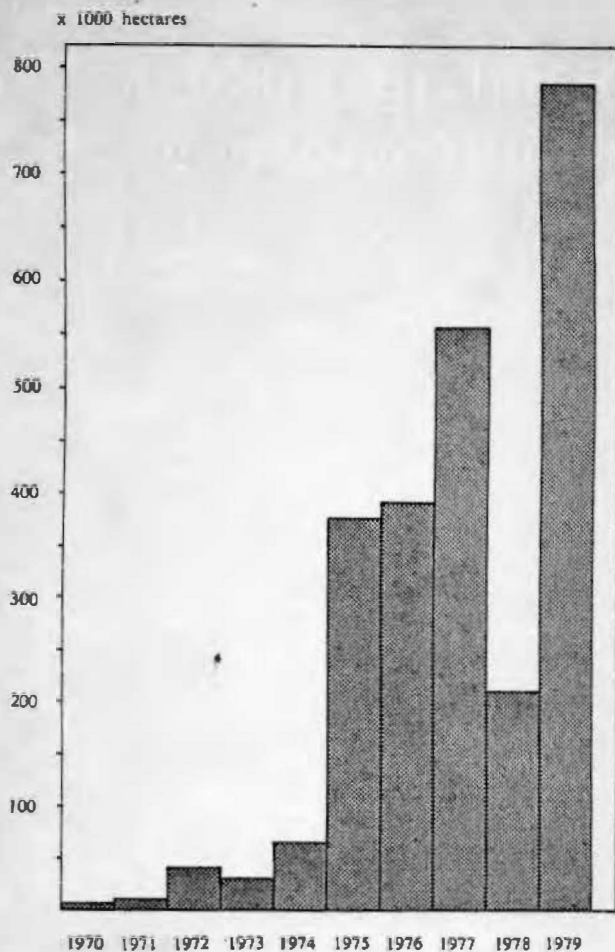
### High yielding varieties

The principle factor contributing to the development of the many traditional or local varieties has been the natural

selection of superior rice germplasm through the centuries, mostly by farmers. The major rice varieties grown by farmers prior to the introduction of high yielding varieties were among others

*Figure 1. The total area of susceptible and resistant rice varieties against BPH in the intensification program.*





*Figure 2. The total area infested by BPH with GSV and RSV.*

Bengawan, Syntha, and Sigadis just to mention a few. They developed through the rice breeding program of Indonesia from crosses between traditional local varieties and introduced varieties.

In 1968 Indonesia introduced the high yielding varieties IR8, IR5, C4-63, IR20 and IR22 from the Philippines. In 1971 the better eating quality varieties Pelita I/1 and Pelita I/2 were introduced in Indonesia and widely distributed. They have a growth duration of about 140 days and an ideal plant type for Indonesian conditions. In 1969, the high yielding varieties covered about 23 percent of the intensification program area.

By 1973 the area planted to the high yielding varieties increased drastically and by 1979 it reached 80 percent of the total areal of the intensification program (Figure 1). The rapid acceptance of the high

yielding varieties is a tribute to their superiority and to the willingness of the farmers to accept new technology.

The first group of introduced high yielding varieties had only a narrow genetic base. Therefore, they were more vulnerable to devastation by insect pests. For example, brown planthopper (BPH) outbreaks started after wide scale planting of the high yielding varieties Pelita, C4-63 and IR5, which were susceptible to both the insect and the grassy stunt and ragged stunt viruses, (Compare Figure 1 to Figure 2). The yield losses were estimated at about 0.7 million tons of rough rice in 1975 [17].

To cope with the BPH outbreaks, IR26 was introduced in 1973. This variety was resistant to the existing BPH biotype (biotype 1). The following year IR28, IR29, IR30 and IR34 were introduced.

They possessed the same dominant gene for resistance to BPH as IR26.

In 1975 they were officially released to farmers and gradually replaced the high yielding susceptible varieties (Figure 1). Through the Indonesian breeding program four other resistant varieties, Asahan, Brantas, Citarum and Serayu were released to farmers in 1978. They, likewise, had the same gene for resistance as IR26 but had better eating quality.

Although these resistant varieties were widely grown, BPH infestations continued to increase to about 568,000 hectares in 1977. This was due to the fact that more than 50 percent of the farmers still planted the susceptible varieties such as Pelita and C4-63.

The resistant varieties were mainly accepted by the farmers in areas where previous rice crops were heavily damaged by BPH. For several seasons these resistant varieties did not show damage from BPH. However, in early 1977 some areas planted to the resistant varieties became susceptible to BPH. These events led to the idea of the development of a new biotype of BPH (biotype 2). Until now only two biotypes, biotype 1 and biotype 2, have been detected in Indonesia. Brown planthopper biotype 2 seems to be distributed widely in those areas where the biotype 1 resistant varieties had been widely planted. To overcome the epidemic of biotype 2 hoppers the government released IR32, IR36 and IR38 which are resistant to biotype 2. These varieties possess a recessive resistant gene. There is still a possibility that another biotype of the brown planthopper might develop in the future.

Recently, through the breeding program, Indonesia released two new varieties Cisadane and Semeru which are moderately resistant to all 3 biotypes of BPH. These varieties might give a lower selection pressure to the BPH populations than the highly resistant varieties previously released and might be effective to retard the development of other BPH biotypes.

## Nitrogen fertilizers

Since the government launched up the intensification program, the utilization of nitrogen fertilizers has increased significantly.

Prior to the intensification program (1967) the annual nitrogen input was only 19,000 tons. By 1968 nitrogen use had doubled and by 1969 it had increase by 7 folds (Figure 3). Recently, nitrogenous fertilizer input ranged between 30 to 88 kg N per hectare [8]. In well developed rice producing areas such as Java, Bali and Northern parts of Sumatra, rates are higher than in the other parts of Indonesia (about 92 kg N per hectare).

High fertilizer rates are favorable to the development of BPH populations [6]. That high levels of nitrogen have a stimulating effect on the population of most insect pests was earlier indicated by Glass [11]. Kiritani [15] gave several examples such as *Chilo suppressalis*, *Tryporyza incertulas*, *Nilaparvata lugens*, and *Chlorops oryzae*, the populations of which were stimulated following nitrogenous fertilizer applications.

High yielding varieties which are responsive to high levels of nitrogen application are widely grown by farmers. In 1974, 74 percent of the intensification areas were planted to these varieties (Figure 1). The irrigation systems in the areas have been much improved, enabling farmers to cultivate rice continuously and to increase the yearly nitrogen input (Figure 3). In these areas the agroecological conditions have changed from low tiller long duration local varieties to high tiller short duration improved varieties. This was favorable to the multiplication of BPH. As a result in 1975 there was a severe BPH outbreak.

## Insecticides

To achieve self sufficiency in food supplies, the need for adequate pest control measures has been recognized. The use of insecticides is considered an effective means for

protecting crops from insect damage. It provides rapid control of complex major agricultural pests. It had been demonstrated that proper protection using insecticides could increase the yield by 17 to 20.7 percent [19]. However, the economic and social conditions of subsistence farmers in Indonesia often render chemical control beyond their reach. Therefore, subsidized insecticide distribution was started even prior to the intensification program.

In 1968, tons of active ingredient of various insecticides were used. The leading insecticide was endrin followed by DDT, fenitrothion and phosphamidon [18]. Endrin was effective against a wide variety of major rice pests and gave a rapid and effective control. For this reason farmers depended on the use of these insecticides for crop protection. Soenardi [24] indicated that during the first 6 years of the intensification program, large quantities of insecticides were distributed through the Mass Guidance (BIMAS), largely diazinon (see Figure 4). The utilization of insecticides increased about 5 folds compared to 1968 (Figure 5).

In spite of the intensive use of insecticides, insect pests are still a major constraint in rice production. As an example, in 1975, serious outbreaks of BPH appeared in almost all the major rice producing areas.

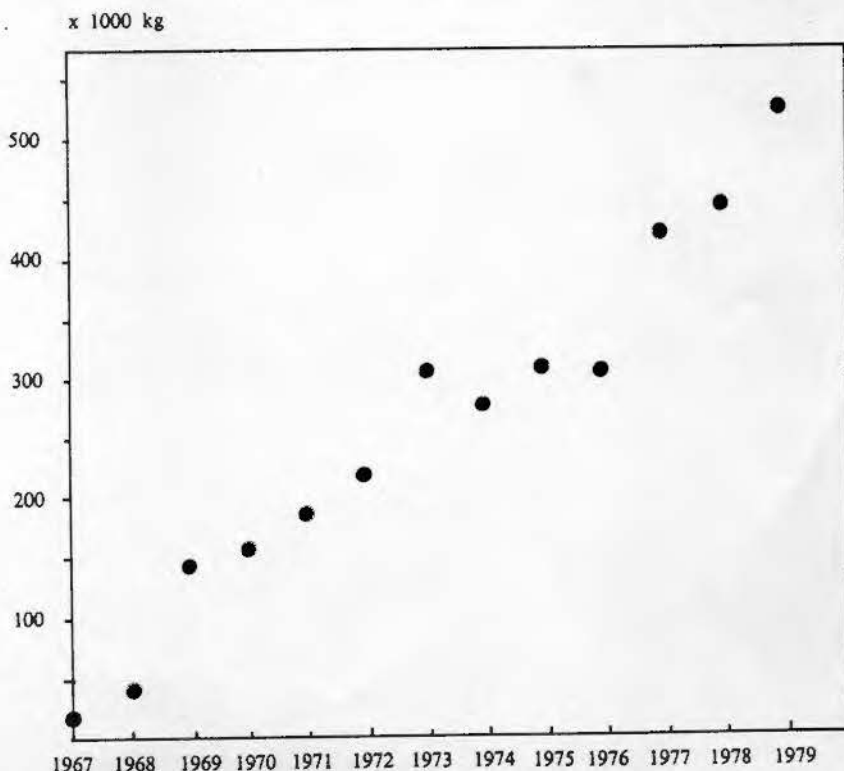
Factors complicating the use of insecticides in the BPH control were:

(a) Brown planthoppers are stem feeders, feeding at the base of the rice plant. Their location makes it difficult to reach them by insecticides. Insecticides provide only partial control and only a few insecticides can effectively control this pest [13].

(b) When farmers apply insecticides, they usually spray the top of the rice canopy. Therefore, insecticides do not effectively control BPH.

(c) Farmers commonly use knapsack sprayers that require high volume of water. This practice is laborious, so farmers frequently use less water and often underdose.

Figure 3. The amount of nitrogen fertilizer distributed to the farmers.



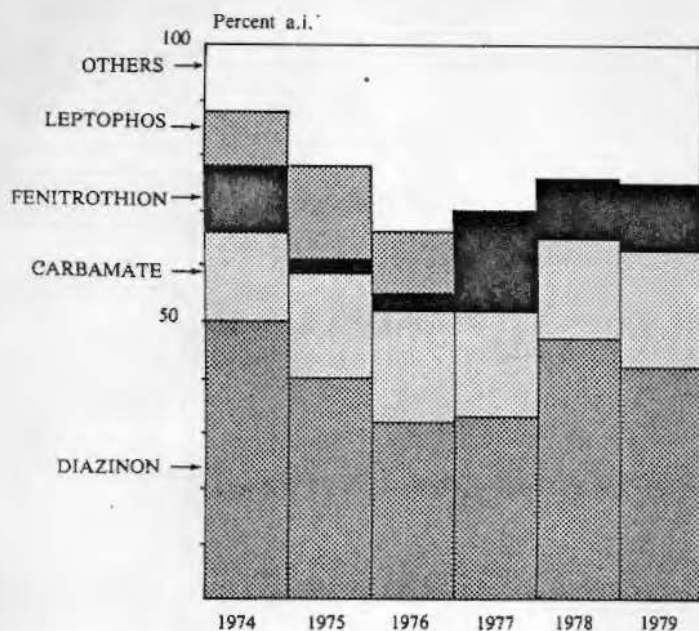


Figure 4. The composition of insecticides distributed to the farmers.

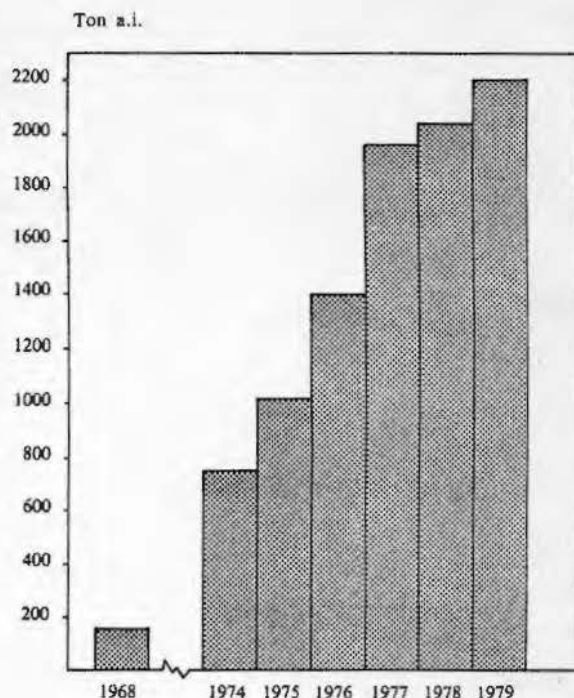


Figure 5. Total amount of insecticides distributed to the farmers.

(d) The spraying practices conducted by farmers are on a calendar based schedule without any consideration of the presence of insects in their fields.

(e) When there are insects in the rice fields, most farmers will apply any insecticide available in the market.

(f) Plant protection equipments and insecticides are not readily and timely available to farmers [24].

Other disadvantages associated with the use of insecticides are the adverse effects on non-target organisms, the development of pest populations resistant to insecticides and resurgence of insect pests after insecticide application [18]. Population increases of BPH in outbreak from following insecticidal treatments have been recorded in several places [3]. No doubt that one of the contributing factors was resurgence of BPH after chemical treatment. Chelliah [4] demonstrated

that several insecticides applied at sublethal rates will cause resurgence. In the routine field evaluation of insecticides at CRIA Indonesia, it was observed that after repeated applications of certain insecticides, a dramatic increase in BPH populations occurred, with low populations in the control plots [21]. Insecticides induced BPH resurgence have also been reported in other Asian countries [18].

Insecticides have a number of serious limitations, but when used properly in an ecologically sound and acceptable practice, they are indispensable to integrated pest management.

## Change in Pest Status

Since the introduction of high yielding varieties, a distinct change has occurred in the pattern and dimension of insect pests in most tropical and subtropical rice growing countries.

Prior to 1929 the major insect pests were white rice borer, followed by yellow rice borer, rice seed bug, black rice bug, army worm and case worm [9]. Soenardi [23] pointed out that since the start of the intensification program through 1975, the major insect pests were rice stem borers. They contributed to the highest yield loss followed in descending order by BPH, rice gall midge and grass-hopper. The adoption of the high yielding varieties brought about abrupt changes in cultural practices that subsequently changed the composition of the insect fauna in rice fields.

Prior to 1948 [10] the white rice borer was primarily found along the northern coastal area of Java. But in 1969 the yellow rice borer was found to be the dominant species followed by striped rice borer [22]. During the last five year period rapid increases in BPH populations occurred in all the major rice areas.

The other important pests in succeeding order were rice stemborers, rice seed bug, rice leaf folder, rice gall midge, black rice bug and army worms.

Kiritani [15] concluded that the damage from BPH may be comparable to a locust plague in its magnitude of space and intensity. When a high population density of BPH occurs, extensive feeding damage causes wilting and drying of the rice plants resulting in a total loss of yield (hopperburn). The insect may also transmit diseases such as grassy and ragged-stunt virus that can further reduce crop yields [16].

The brown planthopper, *Nilaparvata lugens*, was not major pest until 1975. Occasional outbreaks of leafhoppers and planthoppers were recorded on 50 to 150 hectares in Java [14]. Large scale damage was reported suddenly in the early 1970s in Java and subsequently in north Sumatra in 1972 and 1973 [17]. Acreage of rice fields attacked by BPH increased year by year. The main outbreak areas were mainly planted to high yielding varieties susceptible to BPH (Figures 1 and 2). These varieties were continuously planted in irrigated areas with heavy doses of nitrogen fertilizers applied throughout the year (Figure 3) [19]. Starting in 1975 BPH replaced rice stemborers as the major pest. BPH, that causes dramatic crop losses is now considered the most threatening insect pest by both entomologists and laymen. Mochida [17] estimated

grain losses due to heavy infestation of BPH to be about 81 billion Rupiahs (US \$ 195 million) in 1977. Most of the damage occurred in South East Asia. Information on loss of rice in Asia were reviewed by Dyck and Thomas [5].

To combat the BPH threat, the International Rice Research Institute in collaboration with national research institutes of Asian countries developed rice varieties resistant to BPH. In 1975 resistant varieties with one dominant resistant gene (Bph-1) were released in Indonesia. By the end of 1976 biotype 2 hoppers appeared in North Sumatra [19]. Similar phenomena were observed in Aceh, East Java and Bali in 1977 [19]. This development proved to be due to biotype 2 of BPH.

In the affected areas biotype 1 resistant varieties were replaced by varieties that possessed one recessive gene resistant to biotype 2 hoppers. These varieties are still holding up but are threatened by the development of other biotypes to which they might be susceptible.

Rice stemborers are generally considered the most serious rice pest. Six species of rice stemborers are identified in Indonesia. They are the yellow rice borer, *Tryporyza incertulas*, the white rice borer, *T. innotata*, the striped rice borer, *Chilo suppressalis*, the dark headed rice borer, *C. polychrysa*, the sugarcane internodal borer, *C. auricilia*, and the pink borer, *Sesamia inferens*.

Prior to 1970, the predominant species in Indonesia was the white

rice borer. Since the intensification program, farmers in the major rice growing areas started to grow two rice crops a year and the white rice borer became less important. However, in South Sulawesi the white rice borer is still the predominant species [12]. In some regions in Java the white rice borer is still important. Its main locations are in areas with only one rice crop a year. However, this borer could disperse and infest the two crop areas.

Pink borer and the dark headed rice borer populations could be abundant in areas where sugarcane and maize are planted adjacent to rice fields or when rice is planted after these crops.

Striped rice borer is generally abundant in higher altitude areas, but occasionally it occurs in lower areas, especially at the heading stage of the rice crop.

The rice seedbug, *Leptocorixa* spp., generally occurs in sporadic localized areas. It is frequently more abundant outside Java. In South Sulawesi it is considered a major pest [12].

The rice gall midge, *Orseolia oryzae*, is not distributed over all of Indonesia. It is present in South Sumatra, Java, Bali and Lombok. Its infestation does not occur over large areas like BPH. In specific locations it may contribute an important role in the yield losses of rice. Prior to 1961 the rice gall midge was considered a minor pest.

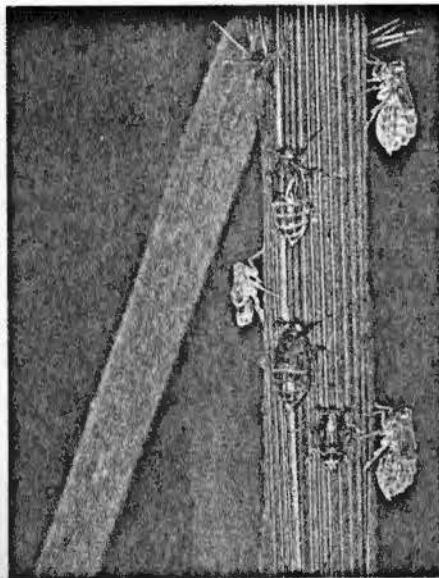


Figure 6. The brown planthoppers (BPH, *Nilaparvata lugens*) are easily seen on the upper plant parts during severe infestations. (Left photo)

Figure 7. Brachypterous BPH on a rice stem.

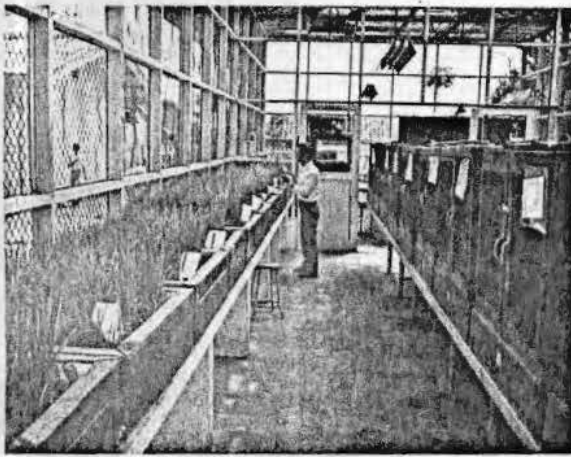


Figure 8. Mass rearing of the rice gall midge (*Orseolia oryzae*) in the glass house for a continuous supply of test insects.

In 1961, 70,000 hectares of rice fields in Central Java were heavily infested by this insect [23]. In 1969 it dispersed into West Java, but infested area decreased to 40,000 hectares. In 1973, 11,000 hectares in East Java were heavily infested. Soenarjo and Hummelen [25] recorded that in 1975 about 230,000 hectares of rice fields in West and East Java were damaged by the rice gall midge. In the subsequent year about 330,000 hectares were infested in West and Central Java. Since genetic resistance to gall midge has been identified, Central Research Institute for Agriculture (CRIA) attempts to develop varieties resistant to the pest.

The rice leaf folder, *Cnaphalocrosis medinalis* is not considered a major pest. However, at the Pusakanegara experimental station of CRIA, it occurs every season causing leaf damage ranging from 15 to 50 percent.

In the intensification program, new and modern technology has been implemented. Cultural practices have changed along with time. The pest status of several species may also change and minor pests may replace the major ones. Therefore, attention should be paid to the minor pests such as striped rice borer, white backed planthopper and leaf folder.

Kiritani [15] indicated that intensive use of synthetic insecticides in Japan and Taiwan decreases the incidence of the yellow rice borer whereas the striped rice borer become more important. In general, the striped rice borer is present in the major rice areas of Indonesia but is considered a minor pest. If insecticides are used intensively to control the yellow rice borer, striped rice borer may become important as it has occurred in Japan and Taiwan.

In 1973 white backed planthopper infestations were recorded for the first time in South Sulawesi [12]. In 1977 an outbreak of white backed planthopper occurred on a farm in Bali. The infested varieties were resistant to biotype 1 of BPH. Outbreaks of the

white backed planthopper were also observed in West Java, Palembang and Kalimantan in 1978. In Subang, West Java, they attacked IR26. Another outbreak was observed in North Sumatra in 1979.

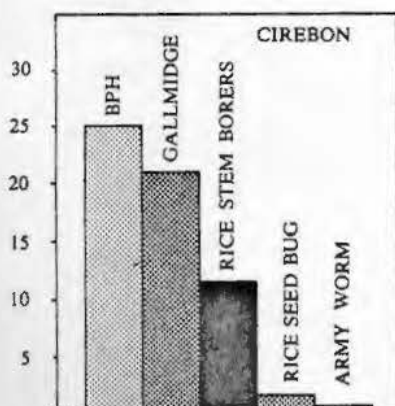
Reviewing the outbreaks, Dyck *et al.* [7] noted that outbreaks of the rice leaf folder occurred in Korea in 1971, and in India in 1967. Yield reductions in some fields reached 74 percent. Chatterjee and Rao [2] concluded that the outbreaks were due to the reduction in abundance of natural enemies caused by insecticidal applications. In Indonesia, the rice leaf folder, had not been reported even as a minor pest prior to intensification. Starting in 1977 it became the fourth most important pest [1].

## Implementing Integrated Pest Management

The green revolution in Indonesia is an integral part of the intensification program. Its major components are high yielding varieties, high rates of fertilizer application and plant protection. The inputs are modified from year to year. But in general the introduction of modernized practices has not been given adequate attention to crop protection which is a major component of agricultural development programs. Unless measures are taken to protect the food crops against insect pests, rice self sufficiency will be a mere panacea.

Integrated pest management offers a solution to these difficult problems. Success in integrated pest management depends on the development of an effective system

x 1000 Ha



x 1000 Ha

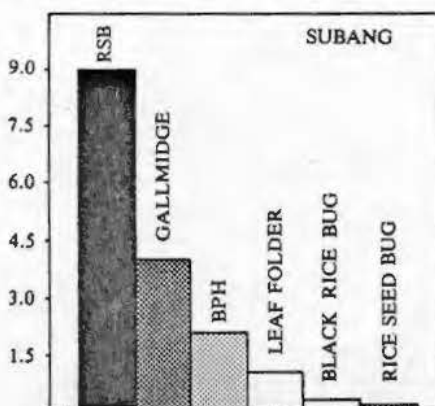


Figure 9. Total area damaged by insect pests in Cirebon and Subang district, 1974 - 1979.

of utilizing new and existing pest control techniques. Implementation requires highly effective information delivery systems. To achieve this, it is necessary that pest management personnel receive training in a wide range of subjects. The Directorate of Plant Protection has organized several training courses on this subject. In 1977 they trained 400 agricultural high school graduates assigned as scouts to conduct regular surveillance of insect populations in the major rice growing areas, particularly concentrating on BPH.

Surveillance is an essential component of pest management programs. It is designed to detect the level of population density of insects and give an early warning to the extension workers or farmers. Its aim is early detection of infested areas that potentially could develop into an outbreak.

As described in the preceding section, the BPH populations increased drastically in 1975. From a number of direct control tactics available for use in integrated pest management, the use of pest resistant varieties is compatible with virtually all other control methods. It is practical and inexpensive for the farmer and also presents no environmental pollution hazards. Varietal resistance is a major component in our integrated pest management. Subsequently, the government initiated the release of resistant varieties. One major disadvantage associated with the use of resistant varieties is the development of biotypes of BPH that can overcome the acquired resistance. But the advantages outweigh the disadvantages.

Soon after the release of varieties resistant to BPH, a new biotype may develop after a few years. Therefore, the use of pest resistant varieties should be integrated with the other components of the integrated pest management.

In the surveillance program developed by the Directorate of Plant Protection, identification of new biotype(s) of BPH through a

*bioassay* method suggested by Oka [20] has been practiced throughout the major rice growing areas.

To educate farmers and extension workers on the implementation of integrated pest management and its benefits, the Directorate of Plant Protection conducted demonstration trials at several pilot projects. These projects have been designed for special problem areas in which major insect pests are endemic.

Excluding the brown planthopper, the pest composition in each project area is as follows:

- (a) Simalungun, North Sumatra: yellow rice borer, rice seed bug and black rice bug.
- (b) Karawang, West Java: yellow rice borer, rice gall midge and black rice bug.
- (c) Bantul, Central Java: yellow rice borer, rice gall midge and rice seed bug.
- (d) Jember, East Java: yellow rice borer, rice seed bug and rice gall midge.
- (e) Sidrap, South Sulawesi: white rice borer, green leafhopper and rice seed bug.

In the pilot projects, the integrated pest management components are:

- *Resistant varieties*,
  - IR26, IR28, IR29, IR30, IR34, Asahan, Brantas, Citarum and Serayu are varieties resistant to biotype 1 and biotype 3 of BPH.
  - IR32, IR36 and IR38 are resistant to biotype 1 and biotype 2 of the BPH.
  - Semeru and Cisadane are moderately resistant to all three biotypes.
- *Cultural control involves crop rotation, simultaneous planting and sanitation by destroying the rice stubbles.*
- *Insecticides*  
The application of insecticides is based on the economic threshold of insect pests. The economic thresholds for each

major insect are:

- 10 percent dead hearts for rice stemborers or 2 egg masses per square meter for yellow rice borer.
- 20 brown planthoppers per hill at the early stage of rice plants.
- 2 rice seed bug per square meter.
- 5 percent silvershoots for rice gall midge.

It is evident that the composition of the pest species varies from location to location. Even in two nearby districts the predominant species may be different. As an example, in Subang district, West Java, the predominant pest species are rice stemborers. Whereas in the nearby Cirebon district, the major pests is rice gall midge (Figure 6). Halteren [12] stated that in South Sulawesi, the major rice pests are the white rice borer, the rice leaf folder and the rice seed bug.

Due to the differences in insect problems in various locations, it is essential that the implementation of the integrated pest management be location specific.

To illustrate the differences in implementing the integrated pest management, two districts located in West Java described previously will be used as an example.

In Cirebon the major pest is rice gall midge, that occurs seriously every year. But the incidence of rice stemborers occurs only occasionally. Hence the implementation of the integrated pest management should be the use of resistant variety to control the rice gall midge, whereas insecticides will only be used if the economic threshold of the rice stemborers has reached its limit. However, in Subang, where the rice gall midge does not occur every year, the use of resistant variety should not be recommended. Large scale use of resistant varieties may stimulate the development of new biotypes. Therefore, the occurrence of both rice gall midge and rice stemborers should be controlled by the use of insecticide which is effective to both insects.