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THE INSECT PEST COMPLEX AND RELATED PROBLEMS OF LOWLAND RICE CULTIVATION IN SOUTH SULAWESI, INDONESIA

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LIST OF ABBREVIATIONS

IRRI	International Rice Research Institute, Los Banos, Philippines
CRIA	Central Research Institute for Agriculture, Bogor, Indonesia
LPPM	Lembaga Penelitian Pertanian Maros or Maros Research Institute for Agriculture, Maros, South Sulawesi, Indonesia
IRTP	International Rice Testing Programme
GEU	Genetic Evaluation and Utilization
LSD	Least Significant Difference
dat	days after transplanting
wat	weeks after transplanting
dbh	days before harvest
dbt	days before transplanting
dbs	days before sowing
was	weeks after sowing
r.z.	root-zone
n.s.	not significant
DH	dead heart
WH	white head
R	resistant
MR	moderately resistant
MS	moderately susceptible
S	susceptible
insecticide G	granular
SP	soluble powder
EC	emulsifiable concentrate
SC	soluble concentrate
a.i.	active ingredient

These abbreviations are at least once explained in the text

1. INTRODUCTION

1.1 THE AGRICULTURE OF SOUTH SULAWESI

Grave concern about the future of the Indonesian peasant and his family, at present living near subsistance level, has been even more motivated by the fact that in the year 2000 the population of Indonesia will be between 206 and 238 million according to various assumptions (FREJKA, 1974). Another estimate by SOEMITRO (1975) gives an even larger population of 250 million by the year 2000, which is more than double the 120 million recorded in the 1971 census.

Indonesia is predominantly rural; 70 to 75 per cent of the human population is engaged in agriculture (ANONYMOUS, 1972a).
Population densities may be extremely high, as in Java with over 125 inhabitants per square kilometre, or extremely low as in West New-Guinea, with less than 10 inhabitants per square kilometre. Consequently, the socio-economics vary greatly from region to region. The population density of South Sulawesi, formerly known as South Celebes (Figure 1 and 2), is somewhat intermediate, although in itself again very varied in almost every respect.

The infrastructure of South Sulawesi is rather good, with many harbours and adequate roads. The human population will approach 7 million by 1978 with about 600,000 living in the capital Makassar. There are no other towns of over 100,000 inhabitants, which stresses the rural character of the area.

Over 75 per cent of the farmers have less than one hectare riceland. Most of them own their land and represent the typical subsistance farmer. A per capita consumption of 100 kg rice per year is assumed to be normal. A smallholder's total income usually comes from many sources. The farmer and his sons may be part-time labourers working in fields other than their own; his wife and daughters participate in many rice harvest and the various household

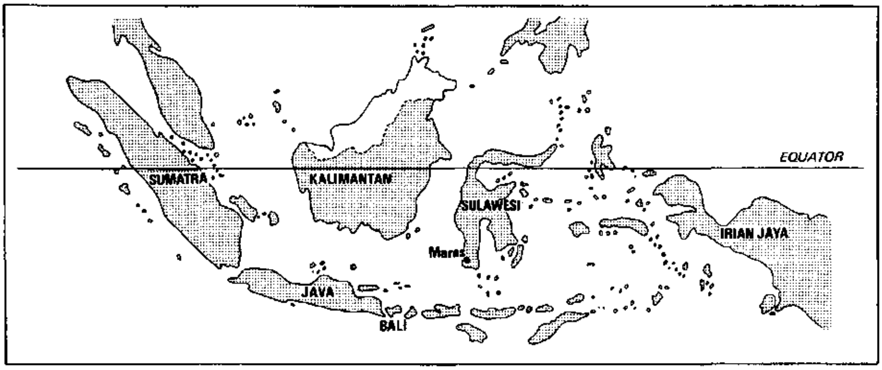
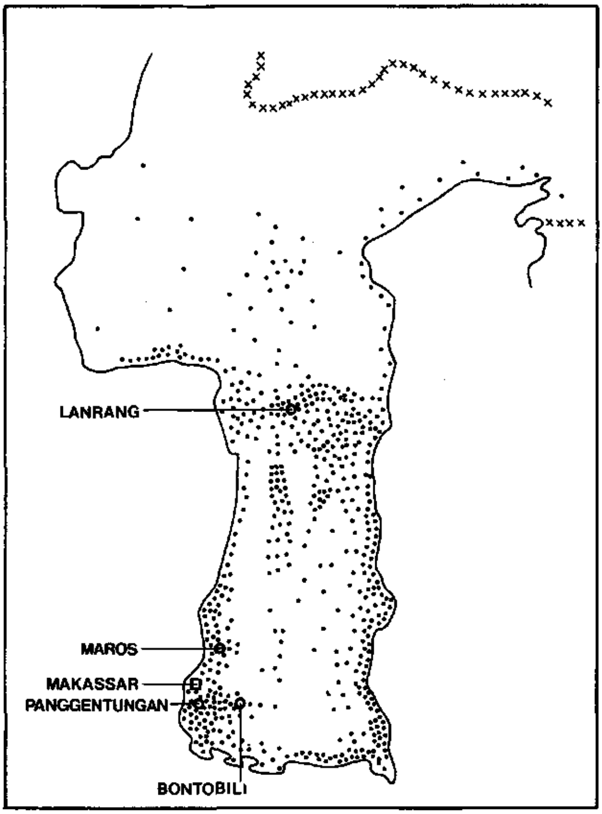


FIG. 1. Map of Indonesia.

FIG. 2. Map of South Sulawesi with major rice-growing areas. Each dot represents 1,000 ha.



members may weave mats, catch fish, grow secundary crops, work as small traders or may be employed for certain periods of the year in Makassar or Pare-Pare. Since South Sulawesi has distinctly different growing seasons, whole families move to other regions to join the rice harvest there.

These various jobs give a certain amount of security throughout the year (SINAGA and COLLIER, 1975). Even so, a family often suffers from a shortage of food before each rice harvest, that is the period in which they are actually growing the rice and which is just the time when the farmer does not have the money to invest in his crop when he actually needs it most. This observation is of paramount importance. It explains why profitable inputs are not made. It also clarifies why farmers who are better off financially profit more from new developments than poorer farmers.

This situation applies more or less to most of rural Indonesia. To overcome some of the problems the Indonesian government has introduced the Bimas (mass guidance) and Inmas (mass intensification) programmes. Under the Bimas programme, farmers are allowed credit for the purchase of government-

TABLE 1. Hectares planted with various crops from 1968 to 1975 in South Sulawesi

	1968	1969	1970	1971	1972	1973	1974	1975
lowland rice[1]	518,494	500,487	522,802	461,088	405,544	596,510	523,537	540,759
upland rice	49,886	55,879	43,537	44,264	33,704	32,533	25,540	25,267
maize	313,803	321,383	211,709	194,547	379,953	226,381	179,236	163,811
cassava	39,878	49,077	40,882	33,674	43,583	44,885	36,692	31,454
sweet potato	11,998	13,126	13,407	11,707	14,452	11,841	10,866	8,410
groundnut	23,009	32,265	19,443	13,886	26,146	24,418	37,924	32,869
mungbean	20,795	39,771	28,911	30,067	45,043	27,855	28,235	27,454
soybean	5,055	10,473	4,967	4,458	7,145	7,370	9,810	6,853

supplied fertilizers and insecticides that has to be repaid later, normally after the harvest. The farmers involved have only to comply with certain instructions such as the rice variety, irrigation and time of application of fertilizers and pesticides. The Inmas programme is different in that the commodities have to paid for in cash at the time of purchase.
Optimal returns are the basis for the selection of farmers and areas for these programmes, which in practice means that the relatively better farmers have better chances to benefit from them. This is confirmed for Java by SAJOGYO (1973).

Apart from these activities, the Indonesian government has recently been heavily subsidizing the purchase of fertilizers and pesticides (see also Chapter 6).

South Sulawesi is a major rice-growing province, and one of the two provinces in the entire country that produces a rice surplus. Apart from rice, other food crops such as maize, cassava, sweet potato, groundnut, mungbean and soybean are exported to other provinces or abroad. Table 1 gives the areas planted with the main food crops and shows the overwhelming importance of rice. Soybeans are grown mainly by Javanese and Balinese transmigrants, and a large percentage of the groundnuts are shipped to Kalimantan and other parts of the archipelago.

Of the approximately 550,000 ha planted with rice, 50 per cent is rain-fed, 45 per cent is irrigated by various types of systems and 5 per cent is upland. Figure 2 shows the main rice-growing areas.

Table 2 gives the percentage of local tall varieties, locally improved varieties ((Bengawan, Sigadis, Remaja, Jelita, Syntha, Dara) and high-yielding varieties (IR5, IR20, IR26, C4-63, Pelita) of rice grown. There is a shift from the old locally improved varieties to the high-yielding varieties. The area with local tall varieties remains remarkably constant, because of preferred taste and cooking characteristics.

TABLE 2. Percentage of local varieties, locally improved and high-yielding varieties of rice grown. South Sulawesi.

	1972/73	1973/74	1974	1974/75	1975	1975/76
Local tall varieties	38	35	26	39	32	38
Locally improved varieties	33	23	15	16	10	14
High yielding varieties	29	41	59	45	58	48

Source: South Sulawesi Extension Service

South Sulawesi does not have particularly rich soils. The alluvial coastal plains, however, are ideally suited to lowland rice, and some diluvial soil types are also rather good. Nitrogen deficiency is, of course, widespread and sulphur deficiency has recently been recognized as a major cause of poor yields even in coastal soils (MAMARIL *et al.*, 1977). Most upland crops suffer from serious shortages of nitrogen, potassium, phosphorus and sulphur. There is no longer any volcanic activity in South Sulawesi.

As in most tropical countries, rainfall determines which crops are grown and when. It is the all-important factor regarding cultivation of the soil, planting, weeding and harvesting. Temperature, sunshine and other meteorological factors are of minor importance except in a few predominantly mountainous areas. There are no typhoons.

Tabel 3 gives the total annual rainfall and number of relatively dry and wet months per district. A monthly precipitation of 200 mm is considered to be sufficient to grow a crop of lowland rice (OLDEMAN, 1977). Most districts have a wet and dry season and consequently two crops are often grown, a lowland rice crop during the wet season followed by a maize or pulse crop.

1.2. THE LOCAL AGRICULTURAL RESEARCH ORGANIZATION AND ITS FACILITIES

Because of the high agricultural potential of South Sulawesi, the Agricultural Research Station was established in Makassar, the capital of the province,

TABLE 3. Rainfall distribution in South Sulawesi.

Location	Annual rainfall mm	Months with less than 100 mm Number (months)	Months with more than 200 mm Number (months)
Sinjai (E)	2,378	4 (Aug.-Nov.)	4 (Apr.-Jul.)
Watanpone (E)	2,329	1 (Sept.)	5 (Mar.-Jul.)
Watansoppeng (E)	1,939	3 (Aug.-Oct.)	3 (Apr.-Jun.)
Sengkang (E)	1,642	3 (Aug.-Oct.)	2 (May-June)
Belawa (E)	1,560	3 (Aug.-Oct.)	2 (May-June)
Wajo (E)	1,228	5 (Mar.Jul.-Oct.)	0
Pare-Pare (W)	2,133	4 (Jun.-Sep.)	5 (Dec.-Apr.)
Pangkep (W)	3,545	5 (Jun.-Oct.)	6 (Nov.-Apr.)
Maros (W)	3,175	5 (Jun.-Oct.)	6 (Nov.-Apr.)
U. Pandang (W)	2,862	6 (May-Oct.)	4 (Dec.-Mar.)
Sungguminasa (W)	2,690	6 (May-Oct.)	4 (Dec.-Mar.)
Bili-bili (W)	3,340	4 (Jul.-Oct.)	7 (Nov.-May)
Malino (W)	4,230	4 (Jul.-Oct.)	7 (Nov.-May)
Palopo (N)	2,761	0	8 (Nov.-Jun.)
Rantepao	3,915	0	9 (Oct.-Jun.)
Makale (N)	2,337	2 (Aug.-Sep.)	6 (Dec.-May)
Enrekang (N)	2,191	2 (Aug.-Sep.)	6 (Dec.-May)
Rappang (N)	2,181	1 (Sept.)	3 (Apr.-Jun.)
Pinrang (N)	2,078	2 (Aug.-Sep.)	3 (Jan.Apr.May)
Majene (N)	1,727	3 (Jul.-Sep.)	2 (Dec.-Jan.)
Takalar (S)	2,027	6 (May-Oct.)	4 (Dec.-Mar.)
Jeneponto (S)	1,101	8 (Apr.-Nov.)	1 (Jan.)
Bantaeng (S)	1,374	4 (Aug.-Nov.)	2 (May-June)

Source: Meteorological Service of South Sulawesi.

shortly after the war. It supposedly served the needs related to soils, pests and diseases, plant varieties and various agricultural problems, of farmers and extension workers. In addition to the main office, there were three sub-stations: two for lowland rice in Lanrang and Panggentungan and one for upland crops in Bontobili. Lanrang and Bontobili are still used. Their locations are indicated in Figure 2. The rainfall patterns of Maros, Lanrang and Panggentungan are shown in Figures 3 and 4. In 1970, the Indonesian government requested the International Rice Research Institute (IRRI), with its headquarters in the Philippines, to assist in developing the station into a centre, to be located in Maros, for food crop research for Sulawesi, the Moluccas and possibly the whole of eastern Indonesia.

The masterplan for Maros was submitted in late 1971 and the purchasing of land and building construction started in late 1972. The Maros facility was officially opened in 1973 as LPPM, Lembaga Penelitian Pertanian Maros or Maros Research Institute for Agriculture, to some extent a branch of the Central Research Institute for Agriculture in Bogor.

As part of a five year programme, the Dutch government granted IRRI funds to provide for the services of two staff members, a training programme and additional equipment. And in 1972, through its bilateral programme, the Netherlands stationed an entomologist at Makassar and later at Maros. At the end of the bilateral programme in 1974 the entomologist from Maros joined the IRRI outreach programme in Indonesia with the same tasks and duties.

The Maros Research Institute has impressively expanded its activities during the past five years. It now consists of five research departments: Agronomy, Soils, Varietal Improvement, Plant Pathology and Entomology. All departments have a wide range of research activities both in field experiments all over the province and in the institute's own laboratories. IRRI provides three scien-

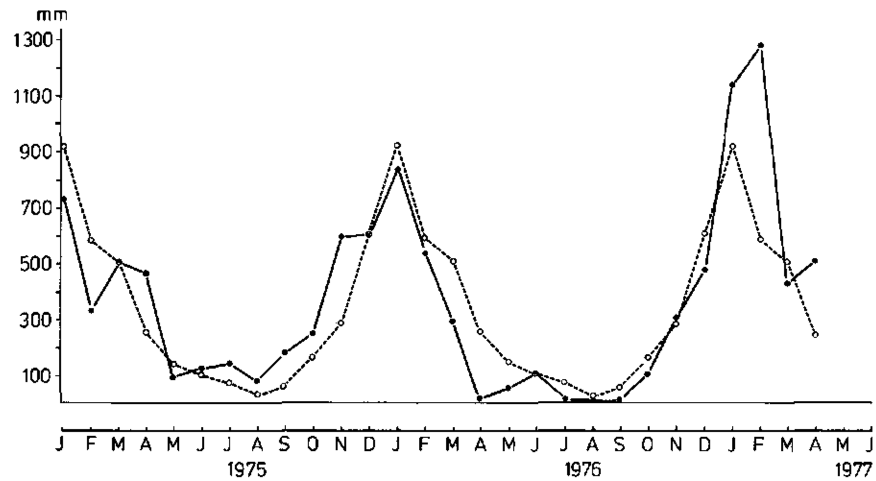


FIG. 3. Monthly rainfall (mm) at Maros during 1975, 1976 and early 1977 with the average monthly rainfall from 1964–1976 (broken line).

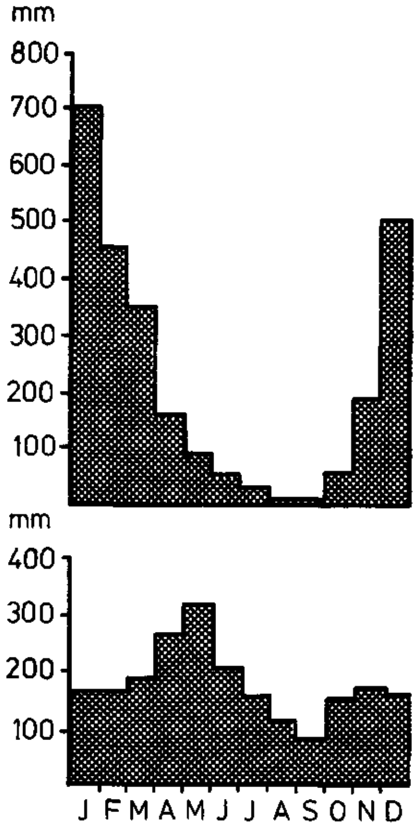


FIG. 4. Average monthly rainfall (mm) in Panggentungan (top) and Lanrang (bottom) from 1964–1976.

tists to assist in implementing these programmes. The research is adapted to the specific problems and the LPPM maintains close linkages with the South Sulawesi Agricultural Extension Service.

The quality and quantity of the research have increased over the years, and this is recognized by the extension service and by the farmers who sometimes flood the institute with visits and requests for information.

Unfortunately, the LPPM has not extensively published the results of its research activities. Most of the information is stencilled and distributed within the LPPM and rarely reaches the outside world. Only the Entomology Department has been able to print and publish most of the data (see Appendix).

1.3. PRIORITIES WITHIN THE ENTOMOLOGICAL RESEARCH PROGRAMME

In 1972, at the onset of the Dutch-supported IRRI project in South Sulawesi, the main problems were fairly obvious. Insects, notably stem borers, caused great losses to the rice crop.

The use of insecticides had already proved successful and the station had a research programme to further reduce rice yield losses by means of insecticides. Due to the lack of both qualified personnel and funds, the research programme remained limited to insect control by chemicals.

Information on ecology and phenology of the pest insects was virtually non-existent.

The establishment of the relative importance and the extent of damage caused by the various insect species were thought to be of prime importance. It was felt by everyone concerned, that an expansion and diversification of the research activities were urgently needed. An insect pest management programme should not depend solely on the use of insecticides but, of course, neither should they be excluded.

The task of the Dutch entomologist was to help formulate a more varied research programme and to assist in its impletation.

The present report reflects the results of such a more balanced research programme. It may form a basis of an integrated control of lowland rice insect pests in South Sulawesi.

2. THE RELATIVE IMPORTANCE OF THE VARIOUS INSECT PESTS, THE NATURE OF DAMAGE INFLICTED AND SHIFTS IN THE PEST COMPLEX POSSIBLY BROUGHT ABOUT BY RECENT MODIFICATIONS OF AGRICULTURAL PRACTICES

The insects attacking rice can be grouped into major and minor pests. The classification of the rice insects of South Sulawesi (Table 4) is subjective. Major pests are those which frequently cause a very distinct economic damage. Minor pests comprise those insects which are often found but cause less serious damage.

An attempt has been made to list and discuss the insects according to the sequence in which they normally appear during the growing season from transplanting to harvest (Table 4 and Figure 5). Insects attacking rice seedlings in the seedbed are of little importance, and are usually easily dealt with by the farmer. Insect species that only damage rice occasionally are not discussed in detail.

Scientific and common names are in accordance with the nomenclature in PAWAR'S (1974) checklist. Information on geographical distribution can be found in PATHAK (1975).

2.1. THE MAJOR AND MINOR INSECT PESTS OF LOWLAND RICE IN SOUTH SULAWESI

The insect pest complex of rice in South Sulawesi is distinctly different compared to its neighbouring islands. The brown planthopper has attained alar-

TABLE 4. The major and minor pests of lowland rice.

Major	
Tryporyza innotata (Walker)	white rice borer
Cnaphalocrosis medinalis (Fabricius)	rice leaf folder
Leptocorisa oratorius (Guenee)	rice seedbug
Minor	
Hydrellia philippina Ferino	whorl maggot
Nymphula stagnalis (Zeller)	caseworm
Oxya spp. and other	short-horned grasshoppers
Chilo suppressalis (Walker)	striped rice borer
Sesamia inferens (Walker)	pink borer
Spodoptera spp.	armyworms
Sogatella furcifera (Horvath)	white-backed planthopper
Nephotettix virescens (Distant)	green leafhopper
Nilaparvata lugens (Stal)	brown planthopper
Conocephalus sp.	long-horned grasshopper
Nezara viridula (Linnaeus)	green stinkbug

ming proportions in Luzon, Mindanao, Sumatra, Java and Bali but not yet in Sulawesi, although it is widespread throughout the island. The gall-midge is similarly alarming in Sumatra and Java, but has not yet been recorded in Sulawesi and the Philippines.

Tryporyza incertulas is the predominant stemborer almost everywhere in South-East Asia, but in South Sulawesi, *Tryporyza innotata* is predominant, and *T. incertulas* is practically absent.

The tungro virus, carried by the green leafhopper, has recently been disastrous in Sulawesi but less so in the Philippines. It has been reported from Kalimantan and Sumatra, but not recently from Java and Bali, where conditions were at least as favourable.

Grassy stunt virus, transmitted by the brown planthopper, has been widespread in the Philippines, Bali, Java and Sumatra, but has not been recorded in Sulawesi.

2.2. The insect pest complex in relation to the growth stages of the rice plant

The insects have segregated into larger or smaller groups, independent of their taxonomic characteristics, to feed on certain plant families, plant genera, parts of a plant, etc. It is generally accepted that specialization enables phytophagous insects to exploit the plant kingdom more fully and efficiently by reducing excessive interspecific competition (Painter, 1951; de Wilde, 1964). This specialization can be less advanced as in polyphagous grasshoppers feeding on leaves of grasses and cereals, or be more advanced as in some monophagous aphids or leafhoppers feeding on the vascular bundles of only one plant species.

The rice plant, *Oryza sativa*, is a host for insects as diverse in their feeding habits as polyphagous grasshoppers and the virtually monophagous *Sogatella furcifera*, the white-backed planthopper.

Moreover, any stage of the rice plant from grain to mature plant, and practically every plant part, is subject to attack.

Figure 5 shows the insect spectrum of South Sulawesi attacking the various plant parts of three plant stages of rice: an early vegetative stage, an advanced vegetative stage and a maturing, generative stage. Seedlings still in the seedbed may be attacked by any insect species also affecting later vegetative stages (except the whorl maggot, *Hydrellia philippina*).

Insects attacking the submerged roots of the rice plants, such as the *Lissorhopterus* weevils of the America's are conspicuously absent in South-East Asia.

2.3. The nature of damage inflicted

2.3.1. Hydrellia philippina, *the rice whorl maggot*

There is no record of the rice whorl maggot from South Sulawesi prior to 1972. Its existence was established by van Halteren and Shagir Sama (1972).

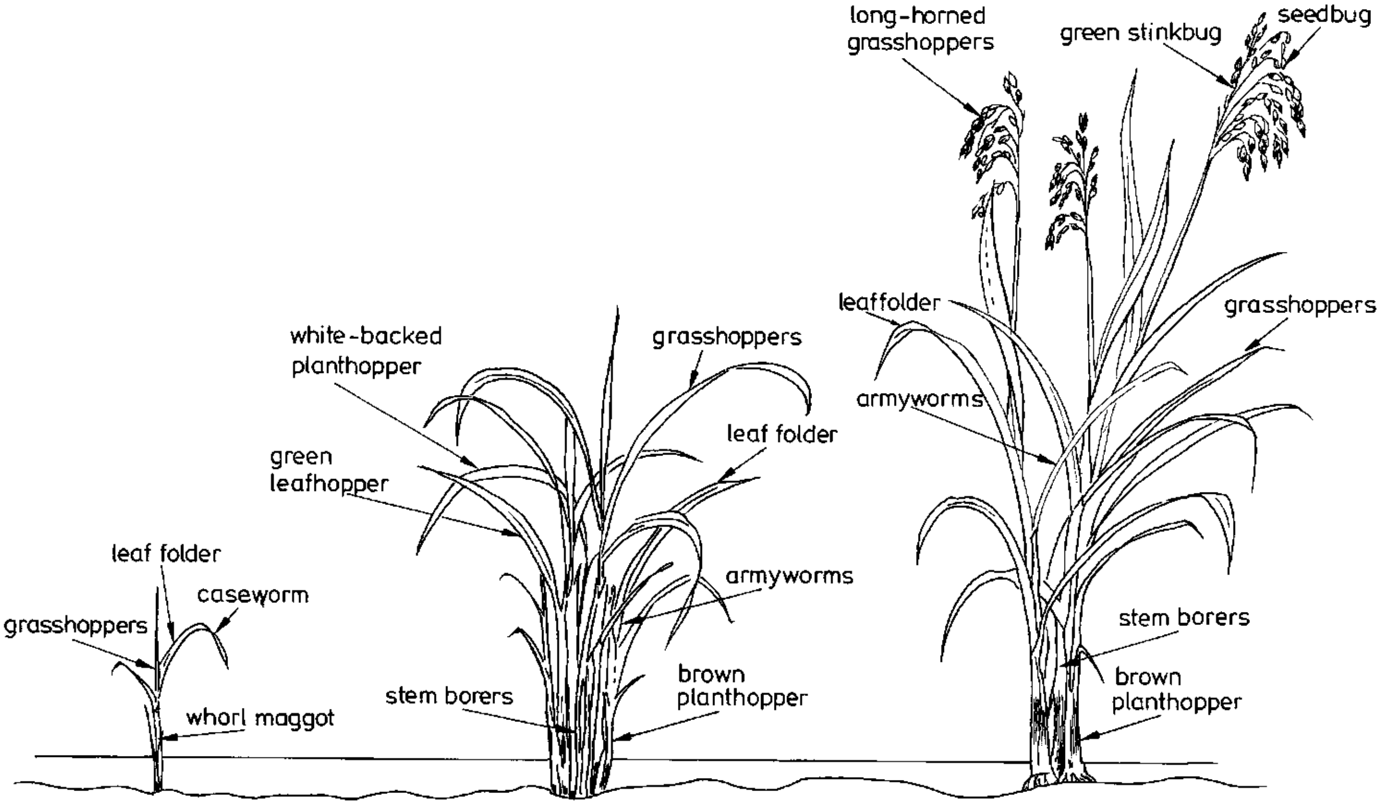


FIG. 5. Three stages of the rice plant with the insect spectrum of South Sulawesi attacking the various plant parts.

According to the taxonomists the whorl maggot is identical to the Philippine species, *Hydrellia philippina* Ferino (Diptera: Ephydridae) (D. L. DEONIER, USA, personal communication, 1976).

Eggs are deposited singly on the leaves of newly transplanted seedlings. Normally, there is only one maggot per seedling but several more may be found (Andres, 1975; Schuiling, 1977). The maggots feed on the central whorl. The feeding symtoms become evident when the leaves unfold. The leaf margins are damaged and adjacent parts are yellow. Heavy infestations cause a stunting of the plant. The symptoms are most severe at 3 to 4 weeks after transplanting.

Although often one hundred percent of the hills are affected in South Sulawesi, farmers and extension workers consider the pest ever insignificant. There is no common name, and no control is ever practised. In the Philippines however, it is considered to be rather important (V. A. DIJCK, IRRI, 1975, personal communication) and in view of this quite a lot of attention was paid to this insect in Maros.

2.3.2. Nymphula stagnalis, *the rice caseworm*

This insect, often erroneously recorded as *Nymphula depunctalis* (Gwen) (Lepidoptera: Pyralidae), can be found in most young paddy fields but as a rule in very low numbers only. Occasionally, the pest builds up over larger areas during the first few weeks after transplanting.

The larva wraps itself in a case after cutting off a leaf tip. Head and thorax protrude from this case which is filled with water. The entire leaf tissue is consumed except for the upper epidermis, leaving characteristic transparant patches. If caterpillar numbers are high the field attains a whitish appearance. Fields normally recover after an attack, but growth will be delayed and extra weeding necessary.

2.3.3. Tryporyza innotata *and other stemborers*

The borers *Tryporyza innotata* (Walker), *Chilo suppressalis* (Walker), *Chilo polychrysus* (Meyrick), *Tryporyza incertulas* (Walker) (Lepidoptera: Pyralidae) and *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae) are found in South Sulawesi.

T. innotata is the predominant species and of paramount economic importance. *Ch. suppressalis* and *S. inferens* are minor pests and *Ch. polychrysus* and *T. incertulas* are unimportant.

After hatching, the stem borer larva moves into a leaf sheath and, some time later, bores into the stalk. Feeding often results in a severing of the apical parts from the base. If the plant is still in its vegetative stage, the youngest, still folded leaf dies off and this condition is called 'dead heart' (DH). If the larva has not damaged the growing point, the tiller recovers and produces a new leaf. If the growing point is destroyed, the entire tiller will die. The plant may be able to compensate for some lost tillers by producing new ones in the early stages of vegetative growth.

Smaller larvae may eat away a leaf sheath and cause the leaf blade to shrivel and die which, from a distance, resembles dead heart. On the other hand, a tiller may be damaged without showing a dead heart because the apical parts have not entirely been severed from the base. If an attack occurs in the generative stage, and the developing or emerged panicle is severed from its base it will not produce grains. These panicles remain straight and turn whitish. This condition is called 'white head' (WH). The plant cannot compensate white head losses. If a stem is not completely cut, the panicle may not become a white head but will bear only poorly filled grains.

Although pockets of affected hills can be numerous, these pockets are evenly distributed throughout a rice field.

Stem borer damage is of considerable importance almost every growing season in South Sulawesi and is occasionally devastating.

Tryporyza innotata only feeds on rice. *Chilo suppressalis* primarily has rice as host plant, but also survives on some grasses (*Echinochloa* spp., *Panicum* spp.) (PATHAK, 1975). *Sesamia inferens* feeds on grasses and cereals.

2.3.4. Spodoptera mauritia *(and other Spodoptera spp.), armyworms*

Although no thorough investigation has been done on the armyworm complex in South Sulawesi, there is no doubt that the rice-swarming caterpillar, *Spodoptera mauritia* (Boisd.) (Lepidoptera: Noctuidae) is the predominant species. Though generally of little significance, the species occasionally seriously attacks rice nurseries as well as rices after transplanting. The Noctuid *Mythimna separata* (Walker) has also been found damaging rice. *Spodoptera litura* (Fabr.) has not been observed attacking rice, but feeds vigorously on *Monochoria vaginalis*, an important weed in lowland rice fields and could therefore even be considered beneficial.

2.3.5. Nilaparvata lugens, *the brown planthopper*

The brown planthopper, *N. lugens* (Homoptera: Delphacidae) is a minor pest in South Sulawesi but could develop into a major pest. Both the fully-grown insect and the larvae suck juices from the vascular bundles. If insect numbers are moderate, sucking results in yellowing and wilting of the plants. Hopperburn, the desiccation and browning of plants caused by high population densites of the hoppers, has been observed in various locations in South Sulawesi, but only on a limited scale. Rice can become hopperburned almost overnight if large numbers of larvae hatch simultaneously. A flowering rice field might look healthy but may never mature.

Hopperburn is often irregular and patchy because of the crowding behaviour of *N. lugens*. The brown planthopper prefers older plants and feeds on the lower plant parts. Rice is the major if not the only host plant (PATHAK, 1975).

In addition, the brown planthopper is the vector of Grassy Stunt Virus (OU, 1972), which has been disastrous in some areas of Indonesia, but has not convincingly been reported from Sulawesi.

2.3.6. Sogatella furcifera, *the white-backed planthopper*

Sogatella furcifera (Homoptera: Delphacidae) is of virtually no importance. Only once was a minor outbreak observed causing a field to yellow (Panggentungan, substation LPPM, 1973). In contrast to the brown planthopper, *S. furcifera* tends to feed on slightly higher places and prefers younger plant stages. Rice is the only host plant.

2.3.7. Nephotettix *spp., the green leafhoppers*

Nephotettix virescens (Distant) and *Nephotettix nigropictus* (Stal) (Homoptera: Cicadellidae) are common leafhoppers in South Sulawesi. The former feeds mainly on rice, the latter has, besides rice, a wide range of host plants, mainly wild grasses. Adults and larvae both feed on the vascular bundles of leaf sheaths and on leaf blades.

The leafhoppers move to newly transplanted hills from neighbouring fields or from adjacent grasses. They can be found on rice plants up to flowering but tend to prefer the younger plant stages.

Nephotettix populations are rarely high enough to inflict serious direct damage. There is only one report on direct damage (RAO et al., 1976) from South Sulawesi). *N. virescens* is, however, of paramount importance as the vector of the tungro virus (see Chapter 8).

2.3.8. Cnaphalocrosis medinalis, *the rice leaf folder*

Cnaphalocrosis medinalis (Lepidoptera: Pyralidae), is an insect of intermediate economic importance in South Sulawesi. The yellow to green caterpillar folds the rice leaves, normally longitudinally, into a case and feeds on the inside. In young hills, several leaves are used for one case, in older plants one leaf is big enough to accomodate a caterpillar. Feeding results in long transparant or whitish streaks. In severe outbreaks, so many leaves will be affected that the field attains a whitish appearance and the photosynthetic ability is seriously reduced.

Although rice is the major host plant, the leaf folder is also a pest of maize, sorghum and other cereals.

2.3.9. Leptocorisa oratorius, *the rice seedbug*

The seedbugs so far collected from maturing rice proved to be *Leptocorisa oratorius* (Heteroptera: Alydidae) (Identified by Dr. W. Dolling, British Museum). If a more systematic collecting were to be conducted, other related species would probably be found as well.

Both adults and larvae are destructive and of major importance, especially during the dry season and in mountainous areas.

The bug normally feeds on the seeds of cereals and grasses but can also be found feeding on peculiar substrates such as rotten cadavers and avocado flowers. When rice fields start blooming, the bugs come from weeds or neighbouring rice fields. They insert their stylets into the endosperm of a seed, preferably in the milky stage, but they are also prepared to feed on seed in the dough stage. Infested grains may remain empty, fill only partially or develop a brown spot, depending upon the stage of development of the rice grain at the time of attack. During insertion of the stylets, bacteria and fungi are also introduced. Damage inflicted is thus twofold: loss of yield and loss of grain quality.

The population density of the bug in a given field strongly depends on the surrounding area (see also CORBETT, 1930; van der GOOT, 1949; ROTHSCHILD, 1970).

Rice maturing early in the season attracts a great many seedbugs. With more rice coming into bloom, the population increases and spreads over a large area. The late-maturing fields are often seriously infested again. Adult bugs are continually on the move, which also contributes to considerable fluctuations in the population.

2.3.10. Nezara viridula, *the green stinkbug*

The polyphagous green stinkbug, *N. viridula* (Heteroptera: Pentatomidae), is a pest of minor significance in South Sulawesi. It apparently is more common on elevated paddies than in coastal lowland rice fields. Feeding habits and nature of damage are similar, if not identical, to those of *Leptocorisa* species.

2.3.11. Oxya *sp. and* Conocephalus *sp., grasshoppers*

Several species of short-horned grasshoppers such as *Oxya* sp. (Orthoptera: Acrididae) feed on rice leaves from transplanting until grain formation, but are not usually numerous enough to inflict serious losses.

Long-horned grasshoppers, mainly *Conocephalus* sp. (Orthoptera: Tettigoniidae) are harmful to maturing rice. Adults and larvae nibble on grains in the milky and early dough stages. The resulting dried and white endosperm showing on the outside of the husk resembles damage inflicted by small seed-eating birds. They become numerous when the main harvest period is over and sometimes totally destroy, together with rats and birds, fields that mature later than the surrounding fields.

2.4. THE INSECT PEST SITUATION BEFORE 1942 AND FROM 1942 UNTIL APPROXIMATELY 1968

Limited quantitative data are available on rice insects of South Sulawesi prior to 1968. Scientists from Bogor hardly ever visited the area, and few publications deal directly with the insect problems on this island. Since 1918, the director of the then *Instituut voor Plantenziekten* (Institute for Plant Diseases) at Bogor had included Sulawesi in the '*Mededelingen van het Instituut voor Plantenziekten*' (Reports from the Institute for Plant Diseases), an annual compilation of information pertaining to pests and diseases as supplied by agricultural research stations, agricultural counsels, teachers, farmers and others. These records do not give much more information than that stem borers and rice seedbugs were almost annual problems in many districts of South Sulawesi.

Yield losses caused by stem borers ran as high as 60 to 70 per cent in 1930 in a district which is now called Maros. In 1926, 25 to 40 per cent of the crop was lost in Bonthain; in 1936 borer losses amounted to 20 per cent in Maros, 30 per cent Pankajene and 15 to 20 per cent in Gowa. The rice seedbug inflicted crop losses of 30 per cent in Soppeng in 1931 and 20 to 50 per cent in Toraja in 1936.

Other pests, less important but frequently recorded, are 'omo putih' and armyworms. Omo putih appears to be the caseworm *Nymphula stagnalis* in some years and the leaf folder *Cnaphalocrosis medinalis* in other years. In fact, until 1974 the local agricultural extension service did not discriminate between the damage inflicted by these two species.

Though information from 1918 to 1942 is limited and not very detailed, it nevertheless indicates that during this period:

- apparently no major changes occurred in the pest spectrum.
- leafhoppers and planthoppers were never a problem.

The Agricultural Research Station Makassar was founded in 1946 and plans to look into the various problems more thoroughly were drawn up. An attempt to survey the prevailing insect pests of agricultural crops was of first priority. The director of the station reported only limited progress up to 1950 (ANONYMOUS, 1950) and no more information could be found apart from the rather neglected insect reference collection at Maros.

The period from 1942 to 1968 was probably the most tumultuous of the island's history and includes war and several dissention movements. During this period insecticides, fertilizers and improved rice varieties have reached South Sulawesi, quantities are unknown since reliable information is lacking. It seems unlikely that they had any great impact or affected the pest picture of rice at all.

Towards the end of the sixties, the situation became more stable and agricultural research in Indonesia, including South Sulawesi, appeared on the international scene again after a virtual absence of 25 years.

Indonesia had to catch up with the mainstream of modern rice research and rice growing. And it has done so remarkably well.

In a way, it had to start from scratch because, as pointed out by EVELEENS (1976), previous findings such as those pertaining to planting times, irrigation system and mechanical control of pests have little bearing on current research activities. Only on the biology, ecology and phenology of rice pests is relevant information available from before 1968, and more specifically from before 1942. These aspects have received little attention so far.

2.5. THE INSECT PEST PICTURE SINCE 1968 AND SHIFTS IN RECENT YEARS

The pest-wise rather stable situation in South Sulawesi has changed since about 1968. Irrigation projects have been initiated and renewed, high-yielding semi-dwarf rice varieties have rapidly spread through the province (Table 2) and fertilizers and insecticides are being used. Figures on pest and disease incidence and on agricultural inputs and outputs are being published.

Table 36 provides information on the total use of insecticides in South Sulawesi from 1968 to 1976 and Table 5 on the consumption of urea and triple superphosphate.

A quick glance through relevant literature shows that it is not a question of *whether* but *to what extent* these changes affect the insect and disease complex. Most rice pests (for instance stem borers and planthoppers) appear to thrive on high nitrogen applications (MOCHIDA and DYCK, 1976). Planthoppers

TABLE 5. Consumption of urea and triple superphosphate (TSP) from 1967/68 to 1975/76 in metric tons.

Season	Urea	TSP
1967/68	0	0
1968	0	0
1968/69	0	0
1969	250	100
1969/70	4,070	1,414
1970	727	358
1970/71	3,519	753
1971	2,088	1,025
1971/72	1,156	333
1972	1,280	302
1972/73	8,881	3,405
1973	1,756	751
1973/74	5,990	1,246
1974	4,095	1,035
1974/75	4,689	1,302
1975	3,550	2,164
1975/76	5,498	2,173

Source: South Sulawesi Extension Service

TABLE 6. Area in hectares infested by various insect pests in South Sulawesi from 1968 to 1976.

year	stem borer	caseworm leaf folder	leaf folder	army-worm	brown planth.	seed-bug	grass-hoppers
1968	45,103	11,298		2,489	0	16,561	0
1969	53,785	14,048		1,546	0	21,470	0
1970	50,103	30,076		6,628	0	9,220	0
1971	50,192	21,408		13,575	0	13,784	0
1972	22,282	3,075		3,230	0	3,439	0
1973	38,397	27,653		2,156	23	27,756	1,139
1974	9,269	9,203	6,525	2,129	150	7,019	0
1974/75	2,130	0	2,423	858	155	539	0
1975	3,678	0	5,534	997	0	7,928	0
1975/76	12,999	0	2,668	1,065	2,743	807	0
1976					0		

Source: South Sulawesi Extension Service.

clearly prefer the dense foliage of heavy tillering semi-dwarf varieties to tall, local varieties (ANONYMOUS, 1973a and 1974).

The use of insecticides upsets the balance of the ecosystem and so does a second rice crop of an irrigation scheme.

The area infested by various insect pests, as supplied by the South Sulawesi extension service, is given in Table 6. These areas comprise heavy, medium and light infestations. The data are thus of limited value, but nevertheless give some information. In 1974, the Agricultural Extension Service began to monitor and compute data on insect incidence, yields, etc. in growing seasons rather than in calendar years, which is indeed more informative (see Tables 6 and 7). Table 7 presents figures on heavy infestations as obtained from the extension service. 'Heavily' is referred to as '75–100 per cent of the crop did not bear seed'. This definition is questionable. It is very unlikely that stem borer infestations have caused such heavy damage year after year. In the case of the leaf folder, caseworm and armyworms, these near-total losses can only occur in the very early plant stages and usually the farmers should have been able to replant their fields.

TABLE 7. Rice area in South Sulawesi *heavily* infested by insect pests (Hectares).

Year	stem borers	caseworm/ leaffolder	leaf folder	army-worm	brown planthop-per	seedbug
1963	4,874	220		965	0	1,139
1964	2,105	90		2,041	0	6,686
1965	1,671	9		1	0	679
1966	6,661	45		24	0	1,924
1967	10,924	0		889	0	4,619
1968	13,588	3,605		47	0	1,527
1969	6,563	4,168		830	0	1,227
1970	9,987	9,263		1,379	0	1,980
1971	12,134	3,275		2,741	0	2,095
1972	3,199	594		932	0	186
1973	6,115	3,122		103	0	5,013
1974	923	1,603	949	168	0	523
1974/75	1	0	3	3	80	70
1975	309	0	123	3	5	476
1975/76	3,169	0	200	60	193	7
1976					0	

Source: South Sulawesi Extension Service

Table 8 presents stem borer infestations in three locations in South Sulawesi gathered from control plots of insecticide experiments from 1967 to 1977. It stands to reason that classifying the years has also not been free from arbitrary decisions. There were no data at all for some years or so conflicting that they were omitted.

Despite the relative value, the data of Tables 6, 7 and 8 indicate that it is

TABLE 8. Stem borer infestations expressed as dead heart (DH) and white head (WH) at three locations in South Sulawesi, compiled from control plots of insecticide experiments. WS = wet season; DS = dry season.
Infestation levels: low = less than 5%, moderate = 5 to 9%, high = 10 to 20%, very high = more than 20%.

	Maros		Lanrang		Panggentungan	
	DH	WH	DH	WH	DH	WH
1967 WS					high	high
DS	high	high	high	high		
1968 WS	low	high	high	high	low	moderate
DS			high	low		
1969 WS	very high	high	high	low	high	
DS			moderate	low		
1970 WS			moderate	moderate		
DS	moderate	very high	low	low		
1971 WS			moderate	moderate		
DS			moderate	moderate		
1972 WS			moderate	high	high	moderate
DS						
1973 WS	very high	very high	high	moderate		
DS	high	high	very high	moderate	high	moderate
1974 WS	high	high	high	low		
DS			moderate	moderate	low	
1975 WS	moderate	low	low	low	high	high
DS	low	low	high	low		
1976 WS	moderate	moderate	low	moderate	high	low
DS	low	high	low	low		
1977 WS	high	high			high	moderate
DS			low	low		

TABLE 9. Infestations of *Leptocorisa oratorius* in South Sulawesi using the KOH test (see Chapter 3.2.7.).

Location	Time	hectares	no. of samples	infestation (%)	
				average	range
Maros	DS 1974	2,426	10	17.9	14-25
Maros	WS 1974/75	17,820	30	7.6	2-14
Camba	WS 1974/75	3,817	15	9.6	6-15
Luwu	WS 1974/75	40,000	13	7.3	3-10
Toraja	WS 1974/75	17,800	14	5.7	2-11
Maros	DS 1975	3,041	59	20.8	5-85
Maros	WS 1975/76	17,800	115	5.6	0-22
Takalar	WS 1975/76	15,863	16	10.2	2-20
Gowa	WS 1975/76	29,132	24	9.7	1-20
Sidrap	WS 1975/76	34,500	20	3.2	1- 6
Maros	DS 1976	2,992	43	3.2	1- 9
Gowa	WS 1976/77	30,125	25	5.5	1-35
Maros	WS 1976/77	17,800	37	4.7	0-23

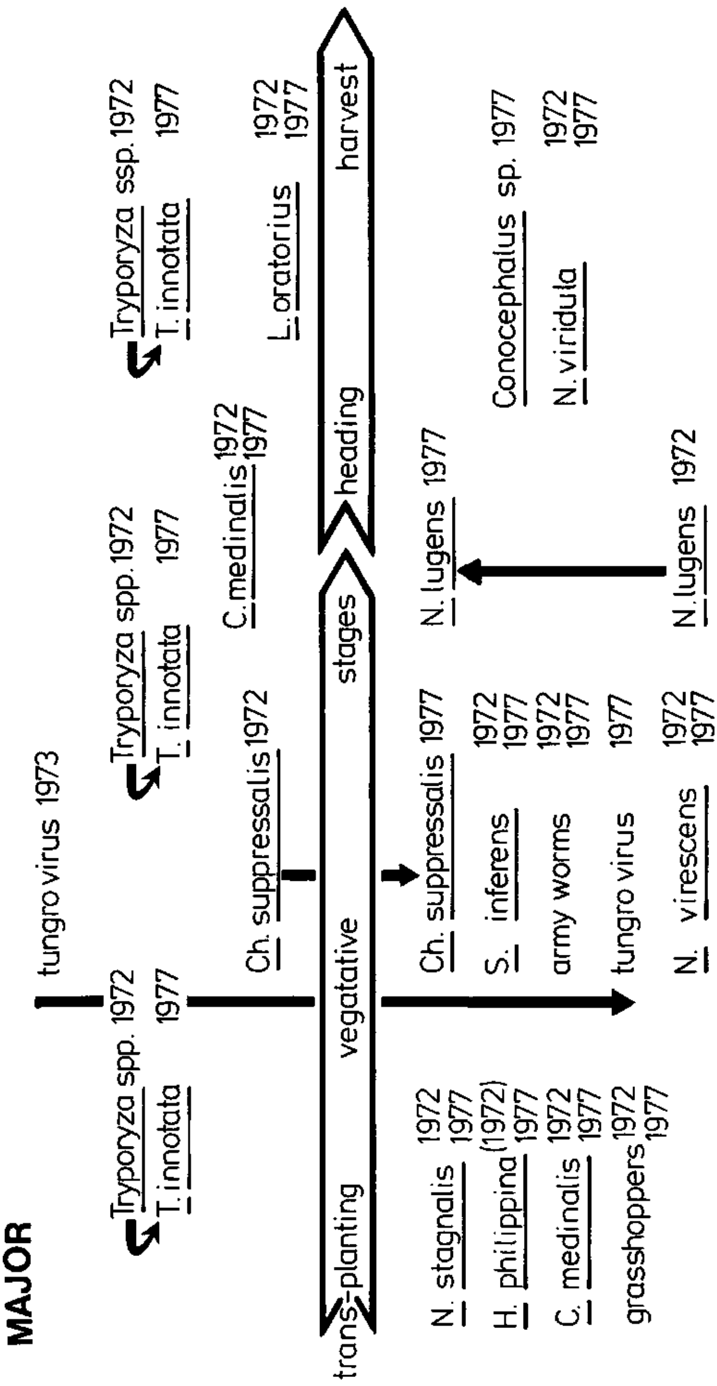


Fig. 6. Schematic picture of insect pests and the tungro virus of rice in South Sulawesi and their relative importance in 1972, 1973 and 1977.

more than probable that stem borers have for many years been the most important yield-loss inflicting insects in South Sulawesi.

Other significant pests acknowledged in the literature are the rice seedbug and, to a lesser extent, caseworm, leaf folder and armyworms. Table 9 gives the infestations of the rice seedbug for several seasons.

A schematic picture of insect pests of rice and their relative importance for South Sulawesi in 1972 and 1977 is shown in Figure 6.

Important for 1972 are:

- *Hydrellia* sp. is placed between brackets, since no mention was made of it before 1972.
- *Tryporyza* spp. were thought to be a mixture of *innotata* and *incertulas*. Although no information was available on relative abundance, *incertulas* was thought to be present in appreciable numbers.
- rightly or wrongly, *Chilo suppressalis* was rated rather important.
- the absence of tungro virus.

Important for 1977 are:

- the lowered status of *Chilo suppressalis*
- *Tryporyza incertulas* does not reach pest status. Only two reports (van HALL, 1919, and SHAGIR SAMA, 1976, personal communication) mention the presence of considerable numbers of *T. incertulas*, both from Palopo.
- the tungro virus was not mentioned in 1972, but was considered a major pest in 1973 and 1974 and insignificant in 1977.

So far a few distinct changes in the pest complex have taken place since 'modern' agriculture began:

– Armyworms. At present, these insects are obviously less of a problem than they were in the past, yet without any apparent cause.

– Brown planthopper. Recent *Nilaparvata lugens* infestations may be associated with changes in agricultural practices such as the growing of semi-dwarf, heavy tillering rice varieties with the increased use of fertilizer and insecticides. The causes commonly referred to are summarized by MOCHIDA and DYCK (1976) and they point out that the evidence is rather circumstantial.

– Tungro virus disease. From the literature, it seems unlikely that a tungro outbreak of the recent proportions has ever happened before in South Sulawesi. Therefore the outbreak of 1972 to 1974, is probably associated with changes in agricultural practices.

More information on the tungro disease can be found in Chapter 9.

Localized spots of hopperburn caused by the brown planthopper have been recorded in South Sulawesi since 1974 (Tables 6 and 7; SHAGIR SAMA and van HALTEREN, 1975). There does not seem to be any uniformity as far as the use of rice variety, fertilizer, insecticide and locality are concerned. In fact hopperburn has been observed in local varieties without any application of fertilizer or insecticide. For example, there was a most peculair outbreak reported from Mamasa, West Toraja (J. de VRIES, 1977, personal communication). The district is mountainous, and agriculturally one of the least advanced areas in

South Sulawesi, at an altitude of 1100m. A local tall variety with a growth duration of about seven months, received approximately 5 kg N per hectare and was treated with diazinon at a rate of about 0.5 l/ha at 2 weeks and 2.5 months after transplanting to control stem borers. About 0.5 ha was completely hopperburned shortly after flowering.

In contrast, hopperburn has still not occurred in the well-fertilized and heavy-tillering semi-dwarf varieties of the Institute's fields at Maros.

3. MATERIAL AND METHODS; RICE VARIETIES, INSECTICIDES, RATING SCALES.

To enable research workers to compare their data, it is important that they 'speak the same language'. Research methods have already been standardized to a certain extent. This process is still going on under the guidance of IRRI and with the cooperation of the scientists of the national programmes. Rice varieties are more difficult to standardize since growing conditions and agricultural practices in the various countries are rather varied. This chapter describes material and methods adopted by the Agricultural Research Institute at Maros.

3.1. MATERIAL

3.1.1. *Rice varieties*

For a correct distribution of labour and water supply, varieties with a short and varieties with a longer growth duration are grown simultaneously in any area.

For the experiments at Maros, only varieties of the improved semi-dwarf plant types were used. These types are more promising and are gradually replacing the tall rice varieties almost everywhere in South-East Asia. The following rice varieties have been used extensively in the research programmes at Maros.

Pelita I/1 and Pelita I/2. These semi-dwarf varieties are crosses of the IRRI variety IR 5 and the Indonesian tall variety Syntha. Both Pelitas have been widely distributed, and no more pure stands of Pelita I/1 and Pelita I/2 can be found. What is now called Pelita, has a growth duration of about 140 days. It is considered as the ideal plant type for Indonesia. The rather tall and sturdy stems do not easily lodge. The rice has excellent cooking and eating qualities. Pelita is susceptible to any insect and to the leafhopper-transmitted tungro virus. Because of these qualities and its high-yielding capacity it is ideal for insecticide experiments and demonstrations. Differences between treated and control plots show up very well.

Variety C4-63. This Philippine variety, common in South Sulawesi, has a lower potential yield and a shorter growth duration than Pelita. It has an intermediate resistance to tungro but does not show resistance against insects.

Variety IR 26. This IRRI variety is resistant to tungro and very high-yielding. It has approximately the same duration as C4-63 (125 days).

Variety IR 30. This variety matures in 110 days but tillering is poor and yields are low.

Line SPR 6726-76-2-3. It is a line from Thailand with relatively good yields, good plant type and a growth duration of about 125 days. It is rather resistant to tungro but susceptible to any insect.

3.1.2. *Insecticides and spraying equipment*

The insecticides tested were usually obtained from the various chemical companies in Jakarta as ordinary commercial samples.

Normal spraying was done with commercially available knapsack sprayers. Battery-operated ultra low volume sprayers were donated by chemical companies in Singapore.

3.2. EVALUATION OF INSECT INFESTATIONS; RATING SCALES

In March 1975, rice scientists around the world received a draft copy of a standard system for screening techniques as developed by IRRI, together with a request for comments, to be given preferably at the Annual Conference in the Philippines in April 1975. This resulted in the manual 'Standard evaluation system for rice (1975)'. During the annual conference in 1976, many workers complained that they found it very hard to apply the system.

It proved difficult to arrive at an accurate and not too complicated system that serves the needs of scientists working on such varied subjects as insecticides, phenology, ecology and varietal resistance. This chapter describes the systems used at Maros.

The practice of making observations at pre-set times, for instance the counting of dead hearts at 4 and 7 weeks after transplanting or white head at 10 days before harvest ('wat' and 'dbh' respectively), has been abandoned at Maros, but not yet in other places. It is far better to limit observations to those infestations that are worthwhile recording. Observations should be started in the control plots. If infestations are below a certain rating (see following pages) or percentage the observations should be discontinued.

An infestation percentage is much more illustrative than an average of ratings. In some of the LPPM publications (van HALTEREN *et al.*, 1974; SHAGIR SAMA *et al.*, 1974) ratings were therefore converted into percentages, using the following formula:

Infestation $I = [\Sigma(n \times v)]. Z^{-1}.N^{-1}. 100\%$, in which
n = number of hills per rating, v = rating, N = number of hills examined, Z = highest possible score.
No other institution converts ratings into percentages, and in 1974 this method was abandoned in favour of mean ratings.

3.2.1. *Hydrellia philippina*

The degree of infestation is evaluated according to a rating scale applied at 3 to 4 weeks after transplanting. Many varieties are too prolific to evaluate at 5 or 6 weeks after transplanting. As a rule, one or two rows per plot are examined which corresponds with 16 and 32 hills. In the following, the Maros rating criteria are listed together with the rating scale used at IRRI.

Rating scale used at IRRI

1. Less than one per cent; feeding lesions small, pinhead in size.
3. 1 to 5 per cent; feeding lesions about one centimeter long.
5. 5 to 25 per cent; feeding lesions about one centimeter long.
7. 25 to 50 per cent; feeding lesions occupying up to one half of the total leaf area but with no leaf breaking.
9. 50 to 100 per cent; feeding lesions severe, causing leaf curling and breaking in all leaves.

Rating scale used at Maros

0. No leaf affected.
1. Only one leaf of the hill with feeding lesions.
3. Two to five leaves with feeding lesions, but not yet one third of all leaves.
5. About one third of the leaves affected.
7. About 50 per cent of the leaves show feeding lesions; some leaves may be broken; plant somewhat stunted.
9. Over 50 per cent of the leaves with feeding lesions; many leaves broken and the plant is clearly stunted.

The lesionsize criterion of the IRRI scale is not accepted at Maros. Feeding lesions vary a great deal in length, width and colour. Narrow lesions can be accompanied by a complete leaf perforation, whereas wider lesions may only show unimportant, slight discolouration. Moreover, even if a large percentage of the leaves is affected, never is half the leaf area of a single leaf affected, let alone, half of the plant's total leaf area (IRRI ratings 7 and 9).

3.2.2. *Nymphula stagnalis*

Since infestations by the caseworm are usually low, there is little need to assess them. The following rating scale is only used for the evaluation of insecticides, but can also be used in future varietal screening or in economic threshold studies.

0. None of the leaves of a hill show any symptoms.
1. Only one leaf of a hill shows feeding damage; one leaf tip may be missing.
3. Two or three leaves show distinct symptoms; one or two leaf tips may be missing.
5. Several leaves show symptoms and the field has a whitish appearance; about 25 per cent of the leaves are affected.
7. About 50 per cent of the leaves are affected, many of them seriously.
9. Almost every leaf is seriously damaged.

3.2.3. *Stem borers*

Stem borer resistance (ANONYMOUS, 1976) and effectiveness of insecticidal applications are evaluated by establishing dead heart and white head percentages. The number of hills examined per plot is normally between 20 and 50. This number depends on plot size or length of rows. It is convenient to run through the full length of a replicate with two people while a third notes the counts.

In the majority of the experiments of the current report, the total number of tillers and the number of dead hearts of each hill were counted. The infestation percentage was then calculated.

In some of the later experiments, notably the varietal screening, and in probably all of the future LPPM experiments, the formula developed by ONATE (1965) is followed: $x = P.\bar{x}_{nz}.100$, where P is the ratio between the number of affected hills and the number of selected hills per plot, $\bar{x}_{nz}$ is the ratio between the number of dead heart and the number of tillers in the affected hills, and x is the percentage of dead heart. White head can be read instead of dead heart.

Onate's formula has the advantage that it is time-saving when infestations are light, since the number of tillers remain uncounted in unaffected hills, assuming that the number of tillers in stem borer-affected hills is the same as the number of tillers in unaffected hills.

A serious disadvantage of applying the system is the risk of going too quickly through hills that look unaffected. Consequently, infestation levels might be recorded even lower than they really are. GOMEZ and BERNARDO (1974) when applying Onate's formula did indeed find an underestimation of 4.8 per cent compared to complete tiller count.

Another, third method, to assess stem borer infestation is by visually assessing dead heart and white head percentages. More often than not, dead heart and white head are unevenly distributed within a plot and when re-evaluating earlier countings visually, discrepancies can be noticed. The frequency of incorrect results can be reduced by increasing the number of samples but this requires considerably more work. Estimating dead heart and white head percentages should, however, only be done by experienced personnel.

3.2.4. *Nilaparvata lugens*

Although only forming a minor problem so far, the brown planthopper could become a serious pest in South Sulawesi in the near future. This prospect has prompted the LPPM to start an orientating research into the phenology of the planthopper. Maros was selected by the government to take part in the International Brown Planthopper Nursery, to screen rice varieties for brown planthopper resistance (see Chapter 7). To monitor field populations for phenological studies, the following procedure is followed. Four rice hills are vigorously shaken and the number of hoppers floating on the water surface between the four hills is counted or estimated. Ten such places are observed at random within a plot. This method is faster and more convenient than net sweepings and suction pump, especially in a wet crop. The following rating scale is applicable for any plant stage (number of planthoppers floating on the water surface between four hills): 0 = 0; 1 = 1 to 10; 3 = 10 to 25; 5 = 25 to 100; 7 = 100 to 1000; 9 = over 1000. A similar procedure can be followed if effects of insecticides need to be rated.

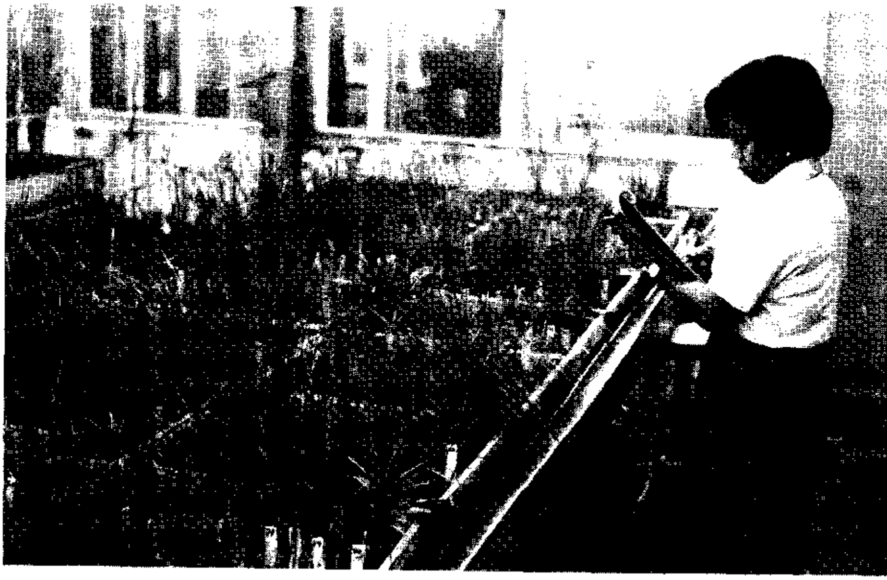


Photo 1. Evaluating for brown planthopper resistance (see text page 37). Maros, greenhouse, 1976.

Screening for varietal resistance is done in a greenhouse (Photo 1). The aim is to reject as many susceptible lines as early as possible. The procedure adopted by all participants of the International Brown Planthopper Nursery is as follows: one batch consists of 16 wooden boxes (10 × 40 × 50 cm) containing 22 entries each, with 20 to 30 seedlings per entry. There are no replications. Planthoppers are released when the seedlings are 10 days old. This results in an infestation level of approximately 1 or 2 planthoppers per seedling. The first reading is done when 50 per cent of the susceptible control seedlings (Taichung native 1) are dead. The second and third readings are done when the TN 1 seedlings show 90 and 100 per cent mortality, respectively. Generally, this means readings at 7, 10 and 12 days after releasing the planthoppers.
The rating scale used reads as follows:

0 – no visible symptoms
1 – some partial wilting of oldest leaf
3 – first and second leaf partially wilting
5 – pronounced wilting and some stunting
7 – wilting and severe stunting
9 – plants dead

This scale differs from the one published by IRRI (ANONYMOUS, 1975) in that 'yellowing' was replaced by 'wilting'. In Maros, as in India and Sri Lanka (M. B. KALODE and Y. ELIKAWELA, respectively; personal communication, 1977) seedlings do not turn yellow but wilt before dying. Initial fears that the seedling reaction may not necessarily reflect the reaction of a mature plant, the plant stage normally attacked by *N. lugens*, proved to be wrong (ANONYMOUS, 1968; M. B. KALODE, personal communication, India, 1977). Field observations show that varieties resistant in the seedling stage also exhibit a resistant reaction under heavy field pressure. For practical reasons it is impossible to test mature plants on a scale comparable to the seedling test.

3.2.5. *Nephotettix spp.*

So far, there has been only one record of direct sucking damage caused to rice by a green leafhopper (RAO *et al.*, 1976) in South Sulawesi. To establish field population densities, the same method and rating scale are used as for the brown planthopper.

3.2.6. *Cnaphalocrosis medinalis*

Only very few research and extension workers in South and South-East Asia consider the rice leaf folder as a major pest, and the need to evaluate an infestation is not felt. If required, a rating scale as for the caseworm (see 3.2.2) can be used in the earlier plant stages. In the later plant stages the infestation is readily evaluated using the following scale:

0 – no leaf folder damage in any upper leaf
1 – only a few upper leaves affected, less than one per square metre
3 – one to three leaves per square metre affected
5 – several leaves, about 5 to 10, per square metre affected
7 – many leaves affected; field has a whitish to brownish appearance
9 – almost every upper leaf of field damaged; field has brownish appearence.

If none of the control plots are given the rating 3, no further evaluation is carried out.

3.2.7. *Leptocorisa oratorius*

To establish the level of rice seedbug infestation two methods, largely complementary, can be followed:

1. determination of bug density in the field
2. determination of percentage of damaged grains as a result of a field infestation.

1. The number of larvae and adult bugs per square metre can be found or assessed. If only a few rows are grown, numbers per plant or per row can be recorded. The observation has to be done early in the morning and quietly so as not to disturb the bugs.

2. The seedbug infestation can be determined after harvest. From the outside of the husk it is difficult to see whether grains have been affected during the pre-harvest period. The grains can be opened by hand and inspected for seedbug damage (see Chapter 4.6), but this procedure is very laborious. Therefore, the 'KOH-technique', based on the findings of WILBUR *et al.*, (1970) is applied at Maros. Wilbur *et al.*, working with the seedbug *Oebalus poecilus*, ascertained

that damage symptoms of the kernels show up very clearly after grains are submerged in a 0.03 to 1.5 N solution of NaOH at 54°C for one minute. RAI (1974) studying the same bug, kept the grains for 10 minutes at 70°C. In Maros the NaOH was substituted by KOH because no NaOH was available at the time of the first experiments. It was found that boiling the samples for 5 to 10 minutes in a 5 or 10 percent solution of KOH was as good as the treatments described by Wilbur and Rai.

To check the value of the KOH-method, it was compared to opening the grains by hand. Opening by hand gives the most exact information. In an experiment at Maros, 24 field samples of ten panicles each, taken from different places, were analyzed. From each sample, approximately 100 grains were opened by hand and the yield loss calculated by weighing the infested and non-infested grains. The infestation is thus directly converted into percentage yield loss. A second group of grains from the same sample was boiled for 10 minutes in a 5 per cent KOH solution. Figure 7 shows the results of the comparison between the infestation percentages as found by the KOH treatments and the percentage yield loss as found by opening grains by hand. In the straight

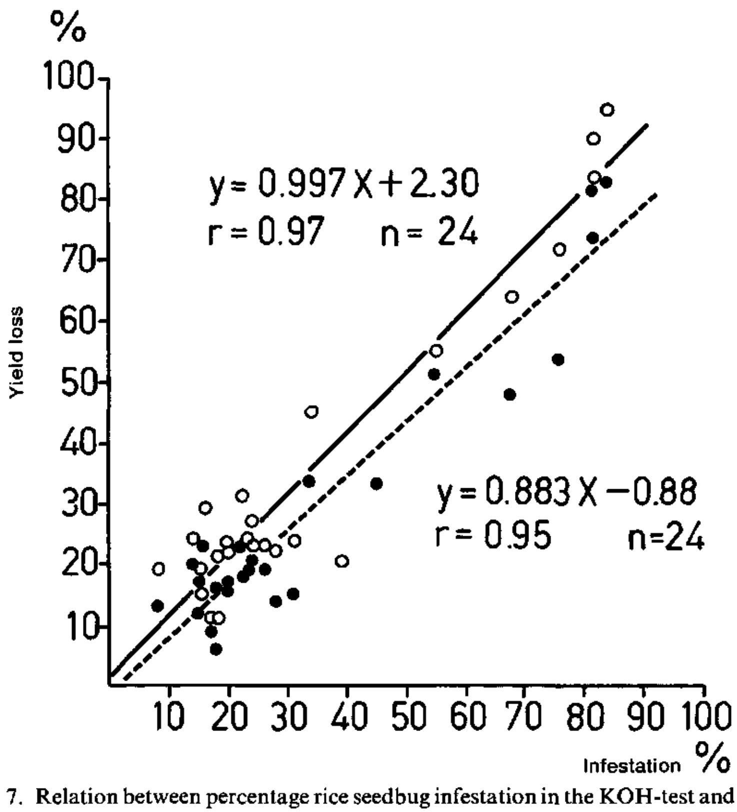


Fig. 7. Relation between percentage rice seedbug infestation in the KOH-test and the corresponding yield loss inflicted. For straight line and broken line see text.

line, all blackish, brownish and lighter parts caused by seedbugs were removed before weighing because these parts would be discarded in a thorough rice cleaning process. In the broken line these affected parts were included. The correlation coefficients between the KOH-method and opening by hand were $r = 0.95$ and $r = 0.97$, respectively, with their corresponding regression lines of $y = 0.883x - 0.88$ and $y = 0.997x + 2.30$. These regression lines show that each unit per cent kernel infestation in the KOH-test virtually represents one per cent yield loss.

It is sometimes difficult to discriminate between seedbug-infested grains and grains affected by fungi or bacteria. To ascertain that the KOH-method is not significantly biassed, 17 grain samples from plants grown in cages and kept free from seedbugs were analyzed. The results showed $6 \times 0, 6 \times 1, 2 \times 2, 2 \times 3$ and 1 x 4 per cent 'infestation' in the KOH-test. The average of 1.2 percent, which in fact was caused by fungi and bacteria, is considered to be sufficiently low.

Hence, by using the KOH-method the seedbug infestation may be overestimated by one or two per cent. However, kernels completely emptied during or shortly after flowering are not recorded as seedbug damage in the KOH-test. This, at least partially, levels out any overestimation.

Assessment of infestation percentages by applying the KOH-technique has proved to be fast and convenient, especially if larger areas are to be surveyed.

To assess the relation between population density and loss of yield (see 4.6), daily observations were made in the field and in the greenhouse. Bug density was expressed in 'bug-days per square metre'. So, for instance, 200 bug-days are the equivalent of 20 bugs sucking for 10 days, 40 for 5 days or 200 for one day.

Since it is impossible to discriminate between damage inflicted by adults and that inflicted by larvae, data on losses or damage always refer to the combined effect of the bug stages.

In the surveys, samples were taken from farmers' fields and from farmers returning from the field with their harvests.

3.3. Experimental designs and statistical methods

There are advantages in combining the study of several factors in a split-plot design or other factorial experiment, but this does not apply if external factors spoil the experiments too often. The standard field experiment at Maros is a randomized block design with only one variable and three or four replicates. Plot sizes vary from 1 x 1 m. to 10 x 10m., but are normally 4 x 4 m. Apart from the yield, as many observations are done as is practicable, depending upon the aim of the experiment. In insecticide experiments for instance, the incidence of every insect pest is, in principle, evaluated; this being the reason why the evaluation systems were developed.

Ideally, every observation should be analyzed statistically as is sometimes done at IRRI, but this involves a lot of work and is often not worth the effort.

Moreover, tables with a lot of statistical information become too large and are often confusing. In Maros, only the yields are statistically analyzed, usually using the method of Least Significant Differences (LSD). In some of the yield loss studies, the Signed Rank Test from Wilcoxon was used for paired samples (SNEDECOR and COCHRAN, 1967).

A regression line was computed only if the corresponding correlation coefficient was significant at a 5 or 10 per cent level.

Yields per plot were converted into kilograms per hectare. Conversion is allowed if the plot size is at least five square metres (IRRI, K. GOMEZ, 1974, personal communication). In the tables, values or means followed by the same letter are not significantly different at a 5 per cent level.

3.4. CONDITIONS AT THE SITES OF EXPERIMENTS

Virtually all experiments presented were conducted at the experimental sites of the LPPM: Maros, Lanrang and Panggentungan. Here, general agricultural practices are similar to those of the farmers of the surrounding areas. Varieties, land preparation, planting distance and weeding are the same, and the same difficulties are encountered with water supply and rat and bird damage. Only the levels and timing of nitrogen and phosphorus applications are slightly more optimal at the Institute's fields.

4. POTENTIAL YIELDS AND LOSSES INFLICTED BY THE PROBLEM INSECTS

Viewing the crop-loss assessment work and crop-loss data on insect pests of the more important crops as summarized by the FAO (ANONYMOUS, 1971a), it is astonishing to note that relevant information on rice, the world's most important food plant, remains limited. Quite a lot of information on rice yields and losses originates from Japan but this country is atypical for the other rice-growing areas of Asia.

In this chapter, the yield losses are analyzed so as to show the damage caused by each individual pest species involved. It is possible that the effect of two or more insects interact, but this interaction is likely to be small. SMITH (1967) has summarized the various methods in use in crop-loss studies.

The term economic threshold, has been defined by STERN *et al* (1959), but as pointed out by CHIANG (1973) and de LUCA (1975) the term is conventionally equated to that level which will cause crop damage of the same value as the cost of the control.

Attempts to establish thresholds or injury levels do not make sense if the development of the population cannot be forecast with reasonable accuracy. The damage already inflicted by a certain population is of less relevance than the damage to be expected. The costs of control measures must be compared with the damage that is still pending. The damage that has already been inflicted before any action must nevertheless be taken into account (see also HEADLY, 1972), together with the fact that control measures vary a great deal in their effectiveness and are rarely one hundred per cent satisfactory.

Even the best farmer notices the results of an increase in insect population densities when substantial damage has already been inflicted. From then on his daily dilemma, realizing the costs of the control measures, is whether he has to act or not.

FARRINGTON (1977) rightly remarks that the costs of control are higher for the peasant farmer than for a modern farmer. Also, plots which have a low potential yield will suffer a higher proportionate loss but a lower absolute loss than fields with a high potential yield for a given infestation.

Another important aspect is the much greater variation in yield in tropical areas compared to temperate areas, often more than 50 per cent. These fluctuations make the net economic benefits obtainable from pest control so variable that thresholds should be adapted to suit the circumstances of individual farmers. For the peasant farmer it is crucial that he does not end up with sub-optimal economic returns, let alone a net loss.

4.1. Potential yields in South Sulawesi

Of interest here is the yield potential of common, improved rice varieties grown under South Sulawesi conditions, when protected from insects. That is, land preparation, water supply, weed control, and nitrogen application as practiced by, or within the reach of, most farmers.

This yield potential is approximately Smith's (1967) economic crop potential and what Chiarappa *et al* (1975) call 'attainable yields'.

The method of applying a systemic insecticide to the root-zone of rice plants turned out to be an important improvement in insect control (see Chapter 6), and clearly shows the effect of insects on the potential yield of rice. Crop-loss

Table 10. Yield losses as shown by root-zone insecticide experiments conducted in South Sulawesi from 1973 to 1977.

rice variety	considerable tungro (T) infestation	yield tons/ha			yield loss	
		highest	control	lowest	compared to control	perc.
MAROS						
Pelita		6.313	1.425	1.425	4.888	77
C4-63		5.155	3.275	3.275	1.880	36
C4-63		4.125	1.725	1.725	2.400	58
C4-63		6.445	3.526	3.526	2.919	45
C4-63		6.642	3.842	3.842	2.800	42
IR34		5.551	3.864	3.864	1.687	30
Pelita		7.918	6.259	6.259	1.659	21
SPR		4.538	2.327	2.327	2.211	49
IR26		6.577	4.751	4.751	1.826	28
Pelita		7.835	5.706	5.366	2.129	27
Pelita		6.755	4.696	4.696	2.059	30
LANRANG						
Pelita	T	5.938	2.594	2.594	3,344	56
Pelita		6.5	4.8	4.8	1.7	26
Pelita		5.9	3.2	3.2	2.7	46
Pelita	T	4.7	2.9	2.9	1.8	26
Pelita	T	5.6	3.4	3.4	2.2	39
Pelita	T	5.9	3.3	3.3	2.6	44
Pelita	T	4.478	1.961	1.961	2.517	56
C4-63		2.961	2.185	2.185	0.776	26
IR34		3.737	3.516	3.034	0,221	6
Pelita	T	4.477	2.035	2.035	2.442	55
Pelita	T	6.4	3.3	3.0	3.1	48
Pelita		4.898	2.367	2.367	2.531	52
PANGGENTUNGAN						
IR20		3.6	2.0	2.0	1.6	44
IR20		4.2	2.3	2.3	1.9	45
Pelita	T	4.309	2.149	2.149	2.160	50
IR26		5.084	4.215	4.125	0.869	17

assessment data not based on root-zone applications of insecticides, must be looked at critically, since it is likely that the yield losses have been underestimated. For instance, prior to the introduction of the root-zone applications, a yield increase of 157 per cent resulting from 5 granular applications of carbofuran would have been applauded as a great achievement. In the same experiment (Table 28), one root-zone application, however, yielded 5,663 kg.

To establish the potential yield of some rice varieties in the absence of insects and the yield losses inflicted by insects, the highest yield, the yield of the control plot and the lowest yield of all the LPPM's insecticide trials over the years are listed (Table 10). Only insecticide experiments with at least one root-zone application among the treatments were selected. In Table 11, the yield of non-treated

TABLE 11. Yields and yield losses of a twice-weekly planting experiment[1]. Maros, 1975-1977.

rice variety	yield in t/ha		yield loss	
	carbofuran mudball 1.0 kg a.i./ha	control	kg/ha	perc.
Pelita	7,256	5,456	1,800	24.8
Pelita	7,085	4,433	2,652	37.4
Pelita	5,630	2,534	3,096	55.0
Pelita	5,347	3,674	1,673	31.3
IR26	6,640	5,830	810	12.2
IR26	4,254	3,640	614	14.4
IR26	3,651	2,940	711	19.5
IR26	6,120	4,534	1,586	25.9
SPR6726	5,657	4,451	1,206	21.3
SPR6726	6,769	4,935	1,834	27.1
SPR6726	6,481	5,259	1,222	18.9
SPR6726	5,096	3,570	1,526	29.9
SPR6726	4,305	3,578	727	16.9
SPR6726	6,840	6,712	128	1.9
SPR6726	6,652	5,774	878	13.2
SPR6726	6,720	6,400	320	4.8

[1] Plots affected by rats, birds and tungro were excluded from the analysis.

plots of a twice-weekly planting experiment are compared with the yields of plots that received a root-zone application. The tables show that the yield potential of two common rice varieties, Pelita and C4-63, under the conditions and practices prevailing at Maros, are close to 8 and 7 tons paddy per hectare, respectively. The yield potential of Pelita in Lanrang is 6.5 tons per hectare and that of SPR in Maros close to 7 tons per hectare (Table 11).

The yields of the non-treated plots come close to what is generally harvested by farmers of the neighbouring fields. From Tables 10 and 11 it can be concluded that in South Sulawesi, insects either alone or in combination with the tungro virus reduce the potential yield of varieties such as Pelita, C4-63, IR5, IR20, IR26, SPR and B462c by about 1 to 3 tons of dry paddy per hectare or

30 to 40 per cent.

This loss level agrees with the mean percentage of 34.4 as calculated by CRAMER (1967a) for Asian countries in general.

4.2. LOSSES CAUSED BY INSECTS IN THE EARLY PLANT STAGES

The main insect species able to attack the rice plant immediately after transplanting are *Hydrellia philippina*, *Nymphula stagnalis*, *Cnaphalocrosis medinalis*, *Spodoptera* spp., stem borers and grasshoppers. Under normal field conditions, it is impossible to study the effect of one of these species in the absence of the others. Quite often the damage seems to be inconspicuous. Several experiments were needed to assess the damage done by the insect conglomerate in the period from transplanting to 4 weeks after.

During 1975 and 1976 yields were compared from plots treated with the insecticide carbofuran to the root-zone giving full insect control (Chapter 5), with plots that did not receive any insecticide up to 4 weeks after transplanting, but were kept free from insects from then on to harvest. These trials were conducted five times with 3, 9, 3, 7 and 4 replicates, respectively (Table 12). Rating scales for infestation levels were applied. Although differences in yield between the plots in which insects were fully controlled up to harvest and plots in which no control took place during the first four weeks proved to be insignificant at a 5 per cent level; in four out of five cases yields were lower when there was no control during the first four weeks.

TABLE 12. Differences in yield between plots kept free of insects from transplanting to harvest, compared to fields with no insect control during the first four weeks after transplanting but then with full control ([1,2]).

full control from 3 dat or wat till harvest	variety and season	Hydrellia rating	Cnaph. rating	Nymph. rating	dead heart percent.	yield kg/ha
3 dat[3]	Pelita	0.0	0.0	0.0	0	4,705 a[4]
4 wat[3]	DS 1975	0.3	0.0	0.0	3	4,737 a
3 dat	Pelita	0.0	0.0	0.0	0	7,199 a
4 wat	WS 1976	2.2	0.0	0.0	3	6,690 a
3 dat	IR 34	0.0	0.0	0.0	0	6,519 a
4 wat	WS 1976	0.5	0.2	0.2	4	6,270 a
3 dat	IR 30	0.2	0.1	0.0	0	3,810 a
4 wat	WS 1976	1.4	1.2	0.0	0	3,549 a
3 dat	B462c	0.0	0.0	0.0	0	3,780 a
4 wat	DS 1976	3.1	0.1	0.1	4	3,340 a

[1] ratings at 4 weeks after transplanting
[2] averages of five trials with 3, 9, 3, 7 and 4 replicates respectively
[3] dat and wat stand for days and weeks after transplanting
[4] yields followed by a common letter are not significantly different at 5% level.

All five experiments showed that at four weeks the plots without insecticides were clearly less healthy compared to those that did receive insecticide.

It is estimated, that despite the insignificant differences, roughly 5 to 10 per cent of the yield potential is lost through the combined effects of 'normal', 'insignificant' infestations of *Hydrellia*, *Cnaphalocrosis*, *Nymphula*, stemborers and grasshoppers up to four weeks after transplanting.

It is not possible to select a density threshold at which control measures must be initiated to prevent damage by these combined insects. The only possible solution appears to be one or more prophylactic insecticide treatments.

4.3. Yield losses caused by the whorl maggot, *Hydrellia philippina*

Although *H. philippina* was not considered to be a serious pest in South Sulawesi, reports from the Philippines (V. A. Dyck, 1975, IRRI, personal communication; Anonymous, 1975) incited an investigation of this potential problem. To establish the effect of a whorl maggot infestation on yield, 12 small-scale field experiments were conducted. Infestations were evaluted according to the rating scale described in Chapter 3. The infestation of 25 to 100 hills of rice varieties with distinctly different agronomic characteristics was evaluated, scoring the infestation at two weeks and four weeks after transplanting. At seven weeks after transplanting, the number of tillers per hill were counted and one week before harvest the number of panicles per hill. The grain weight per hill was also determined. There was no significant correlation between these parameters and the infestation rates at two weeks, four weeks and two and four weeks combined, not even at the rating five. In fact in quite a few instances the correlation coefficient was even positive, indicating higher yields at higher infestations. It may be possible, that low infestation rates increase the number of tillers, but more experiments are needed to check this assumption.

To exclude some unwanted effects associated with field experiments, whorl maggot-infested plant hills (ratings 3 and 5), and non-infested hills were removed from the field and planted in concrete basins of a screened insectary. Growing conditions here were almost ideal, and the plants had ample opportunity to recover. Varieties used were: Pelita, IR26, IR30, B462c and SPR. It was concluded that the infestation ratings 3 and 5 had not affected the time of flowering, number of panicles or yield per hill.

The effect of man-made infestations by introducing young *Hydrellia* flies into cages containing 2-week old seedlings varied from no visible damage to quickly dying plants (Schuiling, 1977).

Results of the various experiments discussed here led to the tentative economic threshold of 100 per cent plant infestation of rating 5.

4.4. Yield losses caused by stem borers

Since stem borers are widely recognized as being of paramount importance, it seems natural to assume that assessing the yield losses inflicted would be relatively easy. This assumption is wrong.

The use of dead heart and white head figures as a basis when working on stem borers is accepted by almost all research workers. Consequently yield losses are related to percentage dead heart and percentage white head. The relationship usually hypothesized is linear and has been published by KHOSROWSHASHI and DEZFULIAN (1976) who found that every one per cent increase in dead heart represented 1.26 per cent yield loss in *Chilo suppressalis* studies. ISRAEL and ABRAHAM (1964) developed a linear but multiple regression equation and found among other things that for every one per cent increase in white heads there was a loss of 1.1 per cent. GOMEZ and BERNARDO (1974), found that the relationship between yield and percentage of incidence was exponential rather than linear.

Besides the analyses of natural field infestations, the effect of stem borers on yield is studied in simulation experiments under greenhouse conditions. Growing points of tillers are severed with a thin needle to provoke dead heart and white head symptoms (THAN *et al*, 1976; DYCK, 1976, personal communication). In these studies, the reduction in yield is positively related to different intensities of simulated dead hearts and the relationship is often linear.

The relationship between field infestations and yield losses was investigated under South Sulawesi conditions.

4.4.1. *Yield losses associated with dead hearts*

To correlate dead heart percentages to yield losses and dead heart percentages to number of panicles, field plots of 25 to 100 hills of the varieties Pelita, IR26, SPR 6726 an B462c were selected at planting time and each hill was examined for dead heart every two weeks. Towards and during flowering the plots were treated with two or three applications of granular carbofuran (1.0 kg a.i./ha) to prevent the formation of white heads. The great majority of the data obtained did not show a significant correlation between the dead heart percentage and the grain yield on hill basis, One typical analysis is presented in Figure 8.

Apart from this poor correlation, there was no difference in effect on yield and number of panicles by dead hearts in plants at 3 to 4 weeks after transplanting and plants at 6 to 8 weeks after transplanting. With some reservations, it can be stated that the trials indicate that each unit per cent dead heart results in a yield loss of about 0.5 per cent, possibly relatively independent of the age of the plant.

It is concluded from the above, that the world-wide accepted method of counting dead hearts poorly reflects the yield losses inflicted, at least when working with *Tryporyza innotata*. It might be possible to give fairly accurate figures on one variety in one location under certain conditions, but this is probably not worth the effort.

These incomprehensible results call for a discussion. Since the yield per hill can be easily and correctly calculated, the discrepancy must be attributed

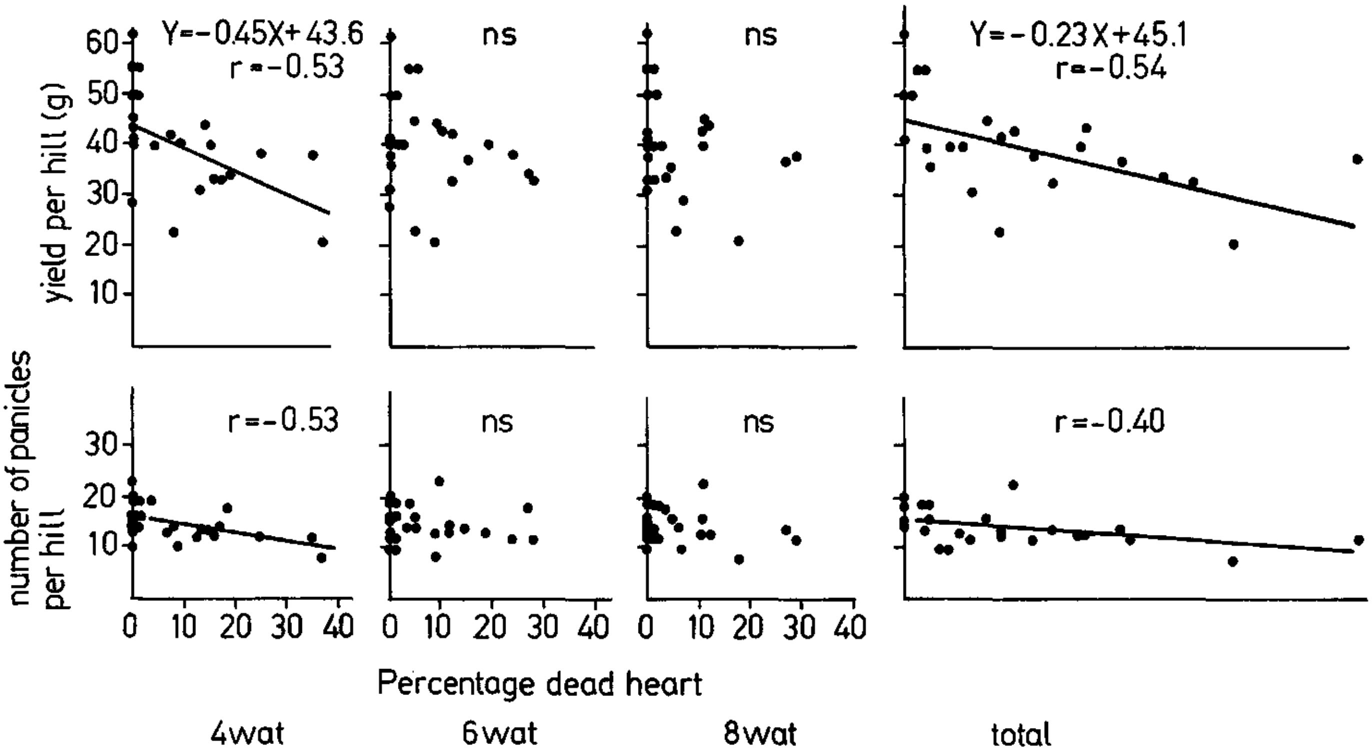


FIG. 8. Correlations between dead heart percentage per hill and yield per hill (upper part), and between dead heart percentage per hill and the number of panicles per hill (lower part).
Maros, October 1976. Rice variety Pelita.

to the inefficiency of the evaluation method applied.
The following imperfections must be taken into consideration:

1. Many young stem borer larvae feed in the leaf sheath. The affected leaf may discolour and be mistaken for dead heart, especially in the first few weeks after transplanting.
2. Larvae may severe the youngest leaf from its base without killing the growing point. This will be mistaken for dead heart. Such a dead heart is of course far less damaging than dead heart in which the growing point is killed.
3. Larvae may feed on and damage a tiller but not seriously enough to make it form a dead heart.
4. It is difficult to decide whether an old rotting tiller with a dead heart should still be included in the new count.
5. Many of the new tillers formed as compensation for dead heart tillers mature late or will only bear a small panicle or no panicle at all. Apart from this, it is hard to decide which panicle to include when counting and weighing the yield. This does not only apply to infested hills but to borer-free hills as well.
6. Borer-free hills together with badly infested hills will grow much better thus reducing the yield loss per unit area, but increasing the differences among hills. Consequently, the possibility of compensation becomes even more questionable.

4.4.2. *Yield losses associated with white head*

A considerable number of trials were conducted to assess the relation between the occurrence of white heads and yield losses. In each of 15 rice fields a small section with non-affected hills and hills showing serious white head symptoms was selected just prior to harvest time. After harvest of every hill, the percentage white head was established and plotted against the yield of that hill. The correlation coefficient between the two parameters and the linear regression equation were then calculated. Table 13 summarizes the results. Percentage yield loss per unit per cent white head ranged, with one exception, from 0.85 tot 2.08 (average 1.19).

The effect of white head type of injury was also studied by provoking this injury artificially. Emerging panicles were severed from their bases by gently pulling a panicle upwards and leaving it *in situ*. Correlation coefficients and regression equations show that out of six experiments the mean percentage yield loss per one per cent artificial white head was 0.99. From three rice fields, yield loss results relating to natural white head and artificial white head are simultaneously available: 1.19 per cent and 1.15 per cent; 1.16 per cent and 1.00 per cent; 1.13 per cent and 0.77 per cent, respectively (Table 13).

An economic threshold can be calculated for every area in South Sulawesi, computing 1.2 per cent yield loss for every unit per cent white head infestation. Of course, it is impossible tot initiate control measures based on infestation percentage as presented by white head.

TABLE 13. Regression equations and correlation coefficients of the relation between white head percentage (x) and yield (y, grain weight in grams per panicle). South Sulawesi.

date	variety	regression equation	corr. coeff.	n	perc. yield loss per 1% white head
natural white head					
27/10 1975	SPR	$y = -0.047x + 2.8$	-0.53	11	1.68
22/4 1976	Pelita[1]	$y = -0.047x + 3.9$	-0.73	16	1.19
21/4	SPR	$y = -0.030x + 3.2$	-0.66	24	0.94
22/4	SPR[2]	$y = -0.037x + 3.2$	-0.87	26	1.16
23/4	IR30	$y = -0.007x + 2.5$	-0.45	17	0.29
27/4	IR34	$y = -0.031x + 2.2$	-0.51	31	1.41
26/8	Pelita	$y = -0.029x + 3.1$	-0.62	20	0.93
26/8	IR20	$y = -0.022x + 2.0$	-0.78	20	1.10
14/9	IR20	$y = -0.031x + 1.5$	-0.59	25	2.08
14/9	IR34	$y = -0.028x + 1.4$	-0.66	19	1.97
19/10	IR30	$y = -0.024x + 2.3$	-0.65	13	1.05
19/10	SPR[3]	$y = -0.026x + 2.3$	-0.82	20	1.13
23/10	B462c	$y = -0.028x + 2.4$	-0.55	21	1.17
26/10	Pelita	$y = -0.023x + 2.7$	-0.70	25	0.85
28/10	IR30	$y = -0.015x + 1.6$	-0.71	22	0.94
simulated white head					
20/4 1976	SPR	$y = -0.025x + 3.0$	-0.49	34	0.83
22/4	Pelita[1]	$y = -0.047x + 4.1$	-0.78	23	1.15
22/4	SPR[2]	$y = -0.033x + 3.3$	-0.82	30	1.00
23/4	IR30	$y = -0.022x + 1.5$	-0.58	24	1.47
23/4	TKM6	$y = -0.013x + 1.8$	-0.42	30	0.73
9/10	SPR[3]	$y = -0.022x + 2.9$	-0.43	18	0.77

[1], [2] and [3] are natural and simulated white head from the same field. n is the number of hills per experiment.

4.5. YIELD LOSSES CAUSED BY *CNAPHALOCROSIS MEDINALIS*

The leaf folder, *Cnaphalocrosis medinalis*, is often most prolific towards plant maturation. In this plant stage, yield losses caused by the leaf folder were assessed by weighing panicles, the flag leaf of which showed the following injury categories (damaged leaf area): 0 per cent, 10 to 50 per cent, 50 to 100 per cent. Table 14 summarizes the results of a number of field experiments. Although yields and yield losses among the respective infestation levels did not significantly differ statistically, the figures are consistent enough to presume that a flag leaf injury of 50 to 100 per cent, results in a yield loss of 5 to 10 per cent. It must be realized that only the flag leaf was taken into consideration; the infestation as presented in Table 14 gives no information on infestation of the older leaves (see also Chapter 4.7).

The economic threshold is thought to be close to rating 7 of the scale presented in Chapter 3.2.6.

TABLE 14. Yield losses resulting from flag leaf infestations by the rice leaf folder during plant maturation. Maros, 1976.

date in 1976	rice variety	size of sample (panicles)	mean grain weight (g) and yield loss at 3 injury categories (percentage damaged leaf area)				
			0%	10–50%	(loss%)	50–100%	(loss%)
3/4	SPR	1 × 25	3.41	3.19	(6.5)	3.22	(5.6)
1/5	IR30	4 × 10	2.38	2.47	(– 3.8)	2.11	(11.3)
25/10	Pelita	4 × 10	2.67	2.51	(6.0)	2.41	(9.7)
28/10	IR30	4 × 10	2.33	2.21	(5.2)	1.95	(16.3)
30/10	Pelita	4 × 10	2.66	2.61	(1.9)	2.47	(7.1)
17/11	IR29	4 × 10	1.74	1.50	(13.8)	1.54	(11.5)

4.6. YIELD LOSSES CAUSED BY *LEPTOCORISA ORATORIUS*

The rice seedbug has long been recognized as one of the most important pests of rice in Indonesia and elsewhere in South-East Asia (KALSHOVEN, 1950; GRIST, 1953). Many farmers in South Sulawesi consider the seedbug as the most damaging insect pest and yield losses as high as 50 and 100 per cent are mentioned. Primitive control measures such as bug netting or chasing the bugs away by moving long ropes through the field are still applied.

A large scale survey on seedbug infestation in the Maros district during the dry season of 1975, demonstrated a wide range of infestation percentages, varying from 5 to 85 per cent with an average of 21 per cent. Infestation detection was based on the KOH-method described in Chapter 3.

The relation between seedbug density per square metre in seedbug-days (Chapter 3), and the percentage kernel infestation follows the regression equation: $y = 11.34 \log x - 7.34$ ($r = 0.676$ and $n = 36$) (see Figure 9).

The economic threshold can be derived from this equation, and depends per definition on the cost of control and the price of the harvested product in the region concerned. If, for instance, a 5 per cent yield loss forms the economic threshold, the farmer can tolerate only 15 bug days per square metre, or one seedbug per square metre over a 15 day period. This is much lower than generally accepted by farmers and extension workers.

DYCK (1973) calculated two seedbugs per square metre to form the tentative economic threshold at Los Banos, the Philippines, on less detailed investigations.

Figure 9 also shows that even extremely high bug densities rarely cause losses of 50 per cent or more. This is due to the fact that one square metre bears as many as 30,000 to 40,000 grains and that the vulnerable period is rather short. Moreover, there are indications that high densities have a negative effect on the feeding activities of the individual bug. In this case, the difficulty is not setting a proper economic threshold, nor the inefficiency of insecticides, but rather the chance that a rapid re-infestation of a treated field occurs due to the high mobility of the adult seedbugs.

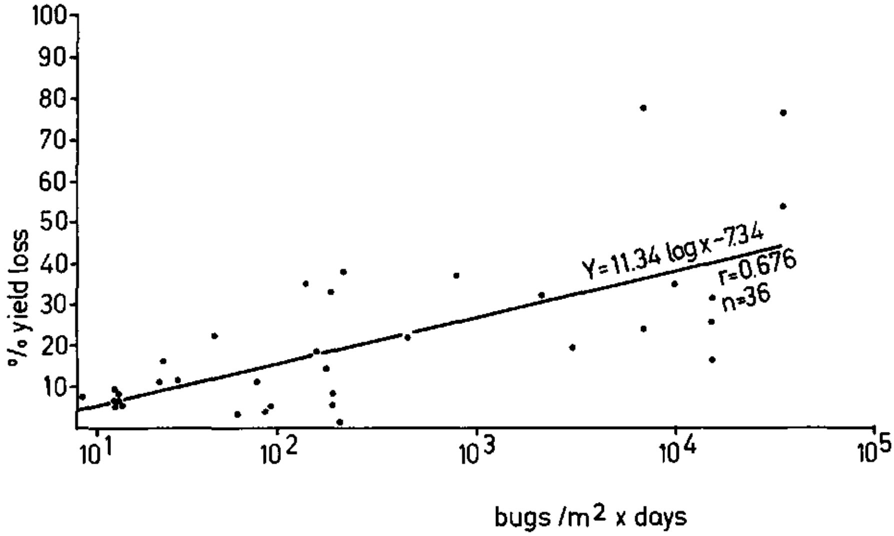


Fig. 9. Correlation coefficient and the regression line of the relation between the seedbug population per square metre in seedbug-days and the yield loss in percentages.

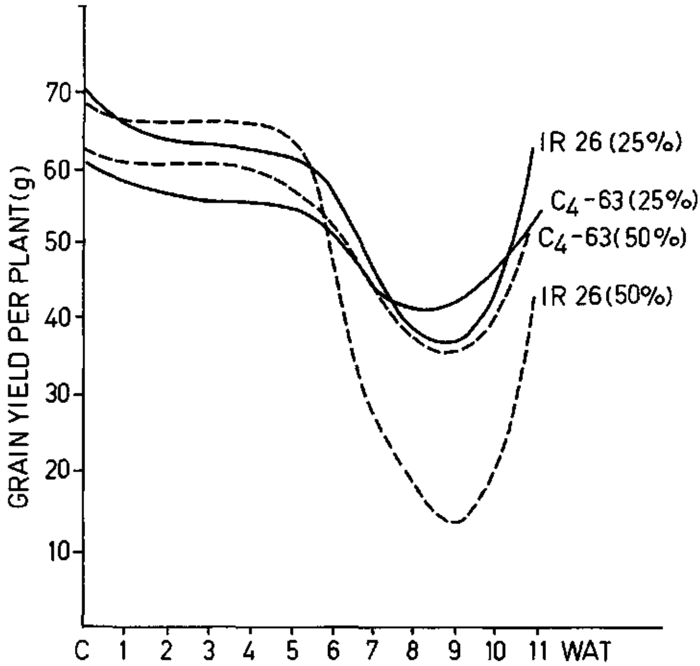


Fig. 10. Average grain yield per plant after defoliation of the top quarter (25%) and the top half (50%) of the leaf blades. One single defoliation at a certain week after transplanting. Maros, 1974.

4.7. ARTIFICIAL INJURY, THE EFFECT OF DEFOLIATION

In order to obtain additional information on yield loss, damage caused by leaffeeding insects was simulated by cutting entire leaves, entire leaf blades or parts of leaf blades with scissors. Although artificial defoliation does not fully represent the damage inflicted by insects, it may complement the earlier results on insect damage such as those caused by *Nymphula stagnalis*, *Cnaphalocrosis medinalis* and *Spodoptera* spp.

Figure 10 represents the results of a field experiment with 10 hills per treatment and 3 replications. It shows the effect of one single defoliation of the top quarter (25%) or top half (50%) of all leaf blades at one of the 11-week intervals after transplanting. The effect of such a defoliation within the first 5 weeks does not appear to have a great impact. The most vulnerable period is about 8 and 9 weeks after transplanting. This period coincides with early panicle formation. Towards ripening the effect diminishes. It seems logical to assume that the defoliation effect on varieties with a high grain foliage ratio, such as IR30 and IR26, is more pronounced than on varieties where this ratio is less critical, such as in local varieties.

The effect of one single defoliation of the entire foliage down to the base of the plant and a single defoliation of the top half (50%) of the entire foliage was investigated both in a greenhouse and under field conditions. The greenhouse experiments consisted of 18 plants per treatment and 5 replications (variety IR30). In the field experiments 30 hills per treatment and 5 replications were used. To eliminate insect damage a carbofuran rootzone application was made followed by carbofuran broadcast treatments from flowering to harvest. In both experiments the plants were defoliated at two weeks after transplanting. Results (Table 15) indicate that plants do not completely recover from a foliage reduction of 50 per cent and over, even at a very early growth stage.

Apart from experiments on the effect of a single defoliation, trials with multiple defoliation were also performed. When multiple defoliation is applied in such a way that every formed leaf, after having fully extended is cut either for 25% (top quarter), 50% (top half) or 75%, three weeks after transplanting until flag leaf emergence, the results were as presented in Table 16. There were eight plants per defoliation level without replication and without statistical analysis. Panicle weight was recorded and not grain weight per panicle.

TABLE 15. Yields of rice plants (g) after removing the entire foliage down to ground level (100%) and the top half of the foliage (50%) two weeks after transplanting. Maros, 1977.

	variety	control	total foliage reduced by	
			50%	100%
greenhouse	IR30	513 a[1]	415 b	377 b
field	Pelita	1,906 c	1,738 d	1,621 d

[1] yields followed by the same letter do not significantly differ at 5 per cent level.

TABLE 16. Effect of multiple defoliation of Pelita leaf blades from three weeks after transplanting until flag leaf emergence. Makassar, 1973, greenhouse.

observation per plant (mean)	control	defoliation level		
		25%	50%	75%
panicle weight (g)	3.5	3.1	2.8	2.0
total weight of panicles (g)	28.7	24.9	22.8	16.1
number of grains	1,108	950	787	715
100–grain weight (g)	2.94	2.79	2.76	2.65
length of stem (cm)	77	70	62	55

As mentioned in Chapter 4.5 the rice crop in South Sulawesi is often attacked by *Cnaphalocrosis medinalis* towards blooming and during the ripening stages. To simulate this damage, attention was paid to defoliation of the flag leaf and to defoliation of the last but one leaf. A single defoliation of 50 per cent (top half) or 100 per cent (entire leaf blade) was applied on the varieties Pelita and IR30 in a greenhouse. The treatments consisted of 8 plants per replicate and three replications. Removing the last but one leaf after emergence of the flag leaf did not affect the yield nor did the cutting of the flag leaf after panicle emergence (Table 17).

It was not possible to reveal the effect of removing a flag leaf on the panicle concerned. This was due to the large differences within a hill among panicles emerging early and those emerging later.

TABLE 17. Mean yield (g) per plant after cutting the top half (50%) and the entire leaf blade (100%) of IR30 and Pelita. Maros, 1976, greenhouse.

treatment	IR30		Pelita	
	50%	100%	50%	100%
no defoliation (control)	38.3	35.6	38.7	43.8
all flag leaves defoliated after emergence	27.2*	24.8*	40.7	41.4
last but one leaf defoliated after emergence of flag leaf	34.8	31.4	41.5	42.4
last but one leaf + flag leaf defoliated after emergence of flag leaf	22.2*	18.0*	38.4	27.3*
flag leaf defoliated after emergence of panicle	39.0	33.4	47.5	42.0

*yield followed by an asterix significantly differ from the control in the same column at 5% level.

4.8 Yield reduction due to the tungro virus

The dramatic impact of the tungro virus outbreak from 1972 to 1974 and the subsequent research are dealt with in Chapter 8. Only a few data on the effect of the virus infection on yield are presented here.

Yield losses caused by tungro infestation depend very much on the time of infection but other variables such as the recovering ability of the variety, the quantity of inoculum and the virulence of the strain are also important. Samples consisting of 30 healthy and 30 virus-infected plants were obtained from three different sources. The difference in yield between the diseased and healthy hills may represent the magnitude of losses in yield when the crop is totally infested with tungro, in these cases almost 50 per cent (Table 18). From the same samples, the weight of 100 filled grains of healthy hills were compared with the weight of the same from diseased hills. The results show that only a minor percentage of the yield loss can be attributed to a smaller size of fully developed grains of infested plants (Tables 19).

In two insecticide experiments, infestations by stem borers and other insects were so low and so uniform that the tungro infestation percentages were plotted against the yield. The results were shown in Figures 11 and 12. There was a highly significant linear correlation between tungro percentage and yield. Each one per cent increase in tungro infestation reduced yields by 0.54 per cent in Pelita and 0.82 per cent in C4-63.

TABLE 18. Average grain weight of 10 hill samples of tungro-infested and non-infested plants. Three replications. Lanrang, D. S. 1973.

rice variety	average grain weight (g) of 10 hills		yield reduction (percent)
	non-infested	tungro-infested	
Pelita	452	268	41
IR5	528	324	39
IR5	572	289	49

TABLE 19. Average weight of 100-grain samples of tungro-infested and non-infested plants. Three replications. Lanrang, D. S. 1973.

variety	average weight of 100 grains (g) from		grain weight reduction (%)
	non-infested plants	tungro-infested plants	
Pelita	2,944	2,551	10.4
IR5	2,967	2,781	6.3
IR5	3,205	3,075	4.0

Fig. 11. Relation between the tungro infestation percentage and yield (tons/ha.). Panggentungan, DS 1973

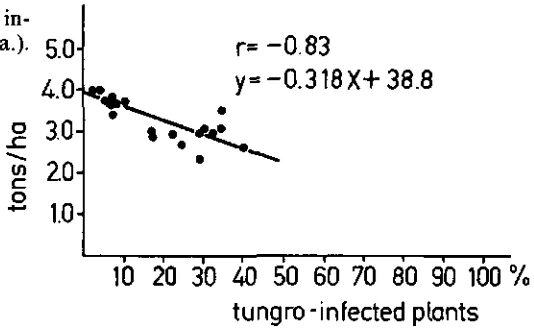
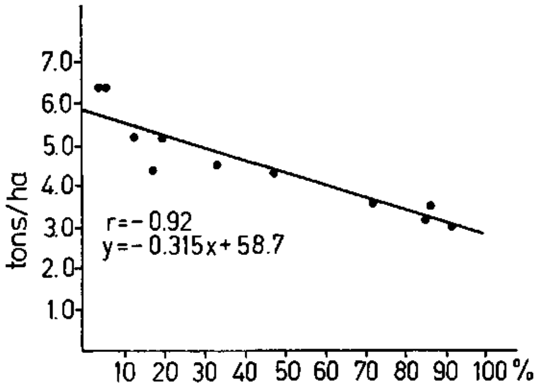


Fig. 12. Relation between the tungro infestation percentage and yield (tons/ha). Lanrang, WS 1974.



5. INSECT POPULATION FLUCTUATIONS

In South Sulawesi data on insect population fluctuations were lacking until 1974. In that year a start was made to monitor these fluctuations as a first step to a future insect-outbreak forecasting system. A twice-weekly planting experiment was started in order to continual monitor insect population densities at Maros throughout the year. These registrations were done by direct counting of insect numbers per hill and insect numbers caught in the light trap close to the experiment or by an indirect method using damage symptoms. These damage symptoms were scored according to the rating scales of Chapter 3.

The twice-weekly planting programme (Figure 13) comprised of three replications per planting (I, II, III), and each replicate consisted of 3 plots of 3 × 3 m. One of these three plots (black square) received a root-zone application of carbofuran, the other two plots (C_1 and C_2) are control plots. The hills of the C_2 plots could be removed and used for laboratory analysis, the C_2 plots were left intact and used for the field observations. The light trap was operated two nights per week.

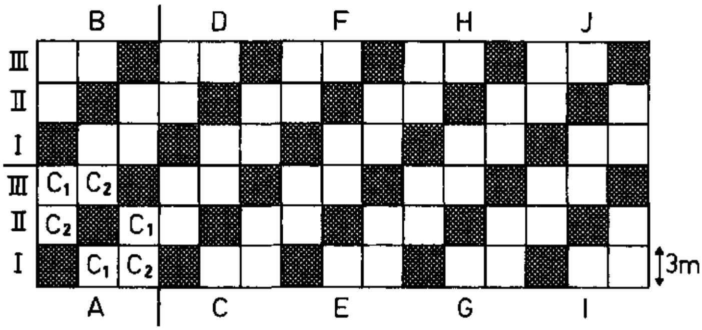


Fig. 13. Set-up of twice-weekly planting experiment. Black plots are treated with carbofuran Plot size is 3 × 3 m. Maros, 1975 – present time.

The rating scales covering the damage inflicted by the various insect species run from 0 to 9 as described in Chapter 3. The ratings denote the average infestations of three rows per plot which corresponds with 3 × 12 hills. Missing data are caused by rat infestations, birds, drought, etc. often during out of season periods. The thicker sections of the X-axes of Figures 14 to 23 indicate the main planting periods of the Maros district in the year concerned. It is not to be expected that the few square metres involved in this experiment will interact with the insect populations of the entire area.

5.1. *HYDRELLIA PHILIPPINA*

Population fluctuations of the whorl maggot are shown in Figure 14. The damage inflicted by the larvae was rated three weeks after transplanting. *H.*

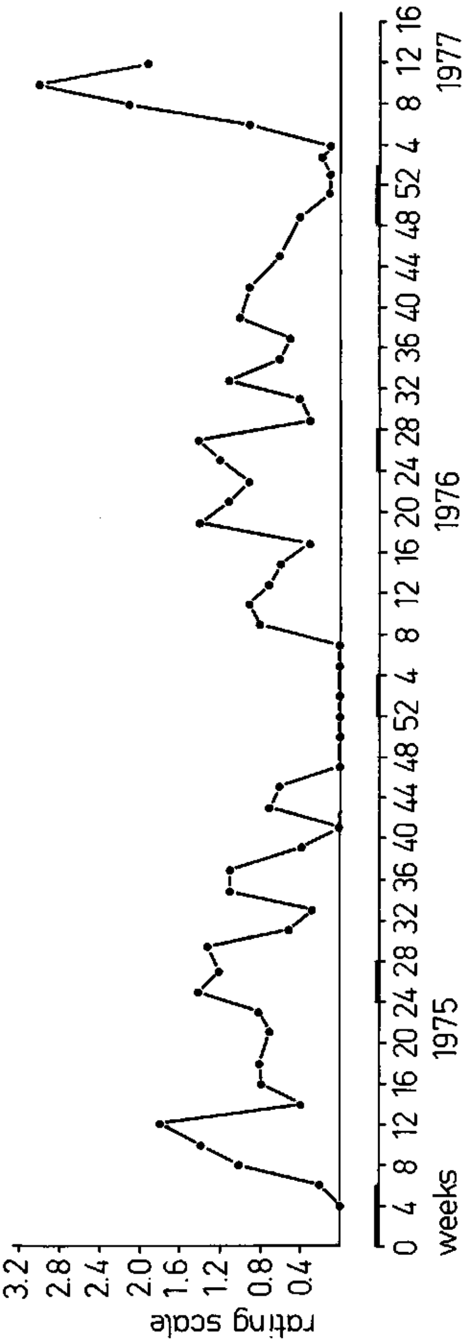


Fig. 14. *Hydrellia philippina* damage ratings in hills 3 weeks after transplanting. Rating scale 0 to 9. Maros.

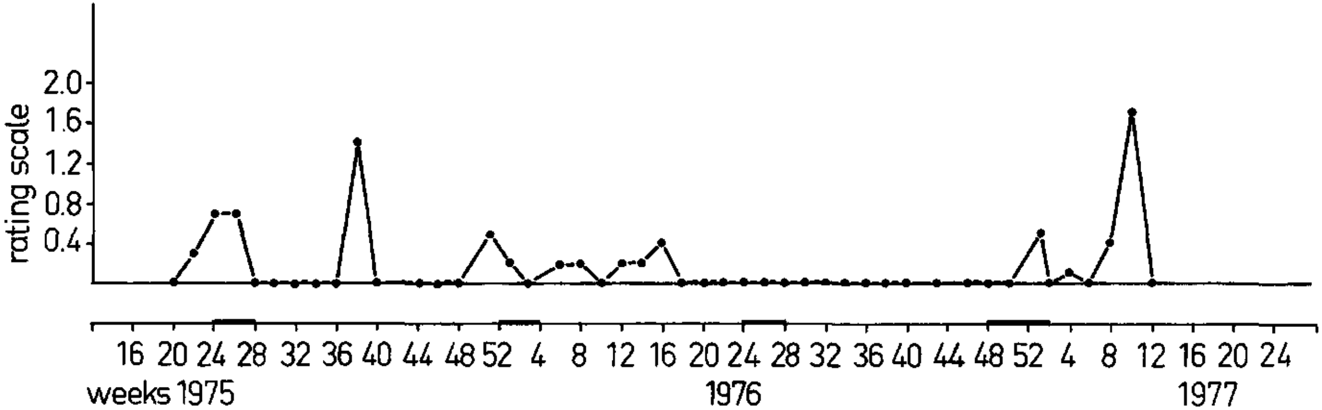


Fig. 15. *Nymphula stagnalis* damage ratings at 5 weeks after transplanting. Rating scale 0 to 9. Maros.

philippina occurs fairly evenly throughout the year except during the period of heavy rainfall in the wet season (December to February). It is possible that the rains interfere with the flying activity or that the eggs or larvae are washed into the paddy water. The flies are not caught in the light trap.

5.2. *NYMPHULA STAGNALIS*

Caseworm levels were recorded at five weeks after transplanting using a rating scale for plant damage symtoms. Infestation was low at Maros during 1975 and 1976 (Figure 15).

5.3. *CNAPHALOCROSIS MEDINALIS*

The occurrence of *C. medinalis* was registered directly applying a light trap, and indirectly using the damage symptoms as a criterium, both on hills five weeks after transplanting and on flag leaves. Results are summarized in Figures 16 and 17. Figure 16 shows that a peak in infestation of the flag leaves did not coincide with a peak in the younger hills. The figure supports the general observation that older plants are more seriously attacked than younger plants. It is doubtful whether it is worth monitoring infestation rates of five-week old plants, except in those cases where rats and bacterial leaf blight do so much damage that the leaf folder infestation is hard to score in later stages.

When comparing Figures 16 and 17, it can be seen that a peak in the light trap catches in March 1975 was followed by an increase in infestation in the five-week old hills in April. Also, the peak light trap catches in the wet season of 1976 (March) coincided with and were followed by a rise in infestation of the maturing hills. However, the outbreak during the dry season of 1975 was neither followed nor preceded by substantial light trap catches. More data are needed to verify the significance of light trap catches as an indication of field infestations.

5.4. *NOCTUIDAE*

It proved virtually impossible to distinguish *Spodoptera mauritia* moths from other *Spodoptera* moths in light trap catches. Also, since the number of moths of the pink stem borer, *Sesamia inferens*, caught by the light trap were very low – only 0.096 per cent of the total number of stem borer moths in 1975 – it was decided, at the end of 1975, to lump all *Noctuidae* when sorting out light trap catches.

The peak in Figure 18 at about week 18 in 1976 could well have been made up of non-rice feeding *Spodoptera* moths, since it did not coincide with an armyworm or pink borer outbreak on rice.

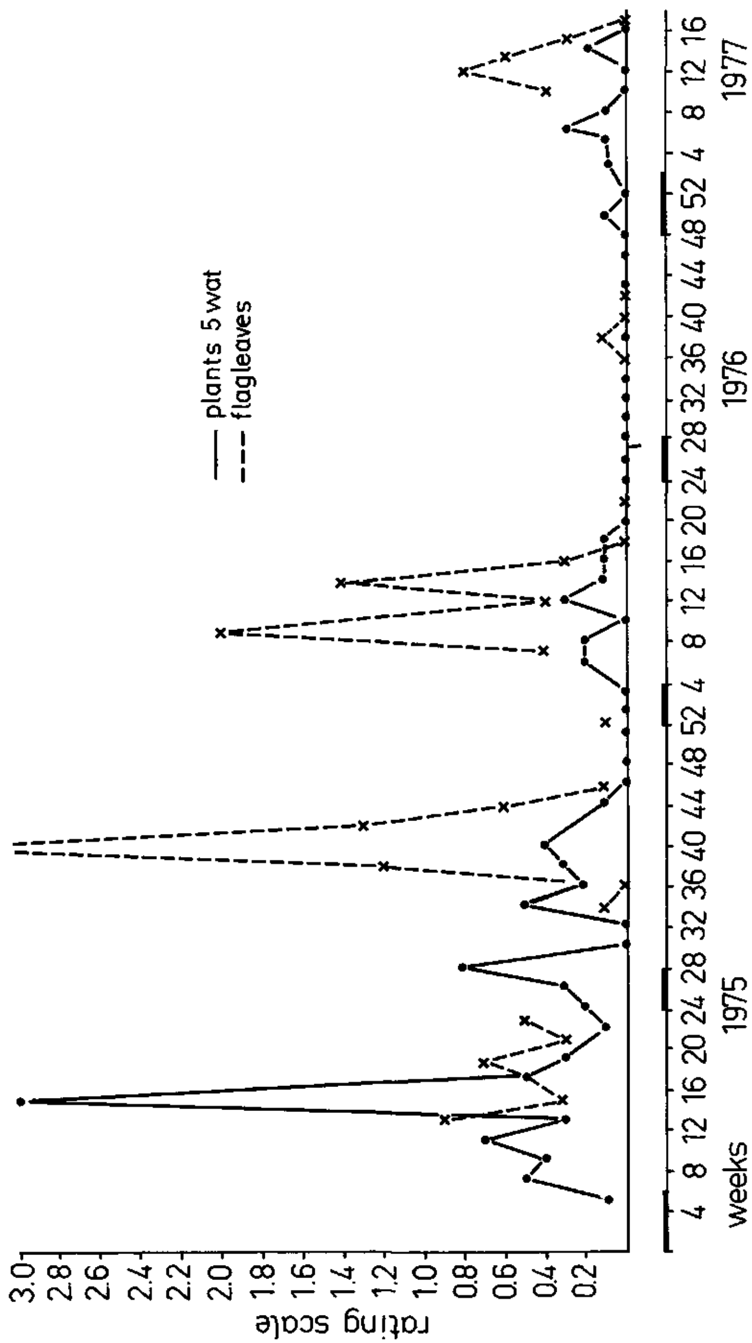


Fig. 16. *Cnaphalocrosis medinalis* damage ratings. Rating scale 0 to 9. Maros.

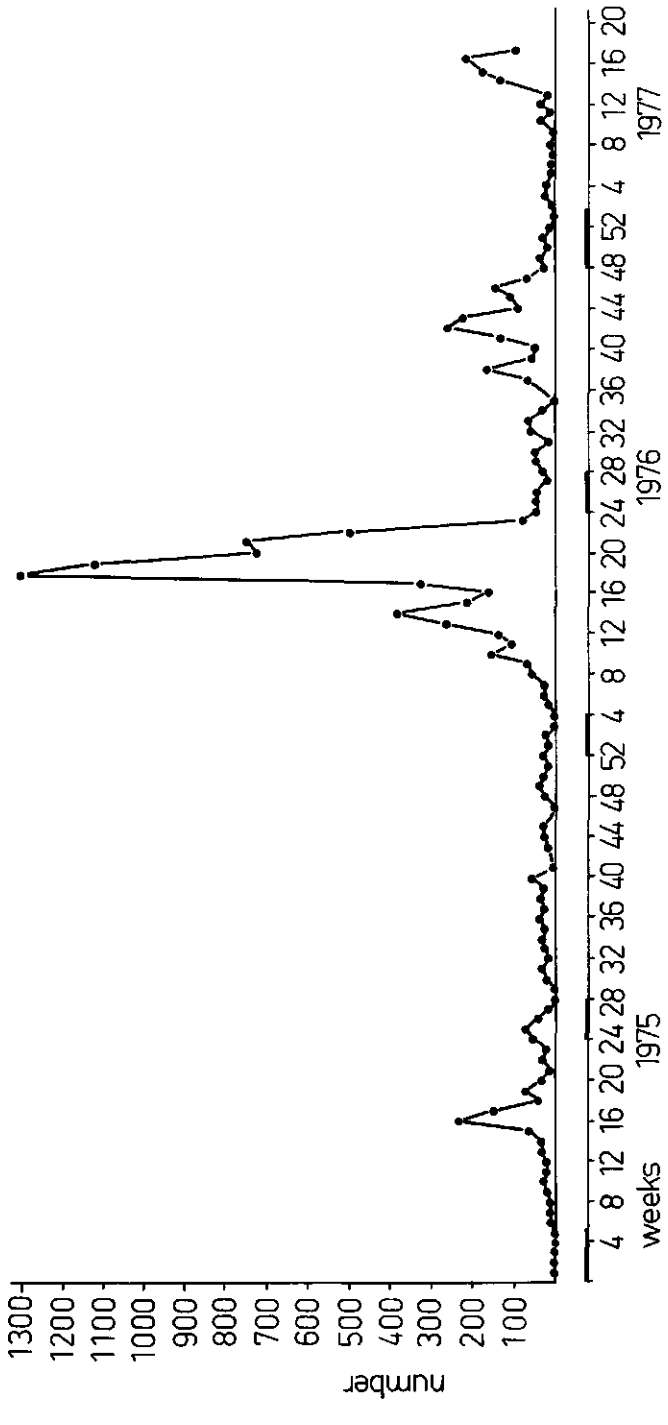


Fig. 17. **Light trap catches of** *Cnaphalocrosis medinalis*, twice weekly. Maros.

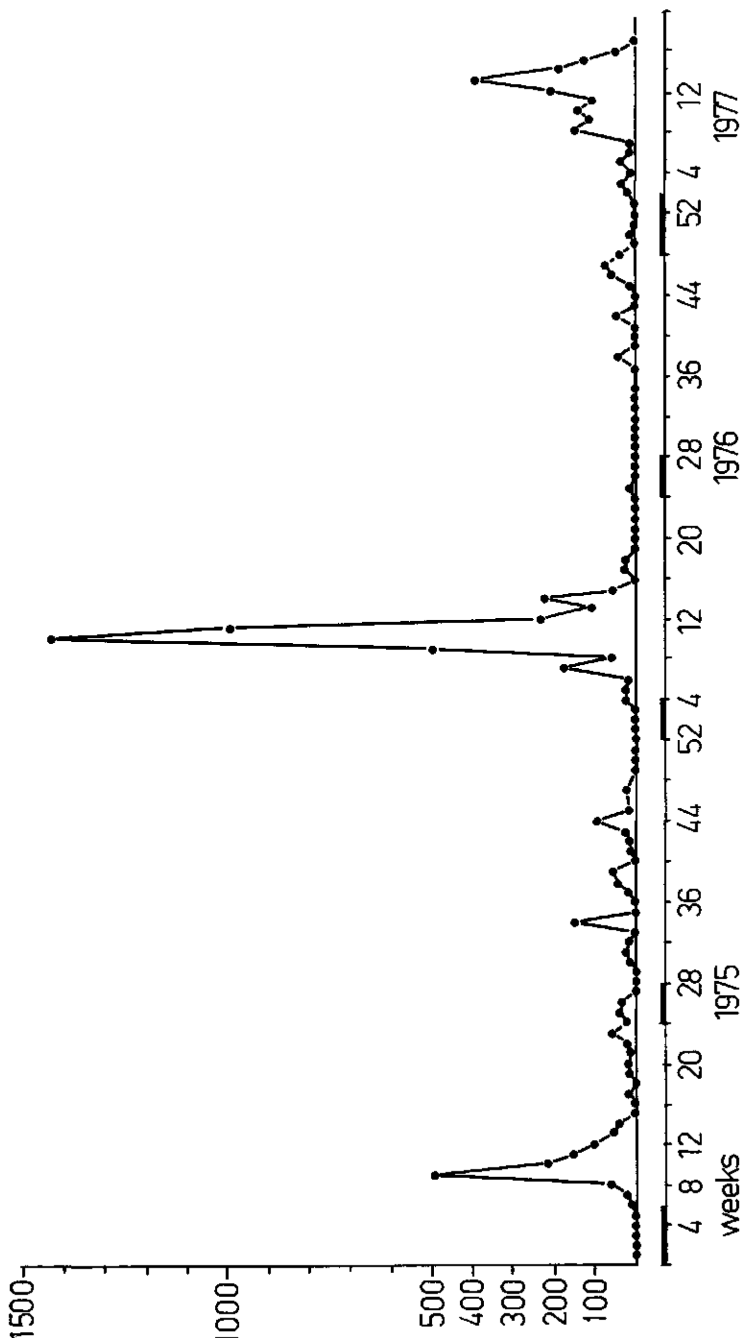


Fig. 18. Light trap totals of noctuid moths, twice weekly. Maros.

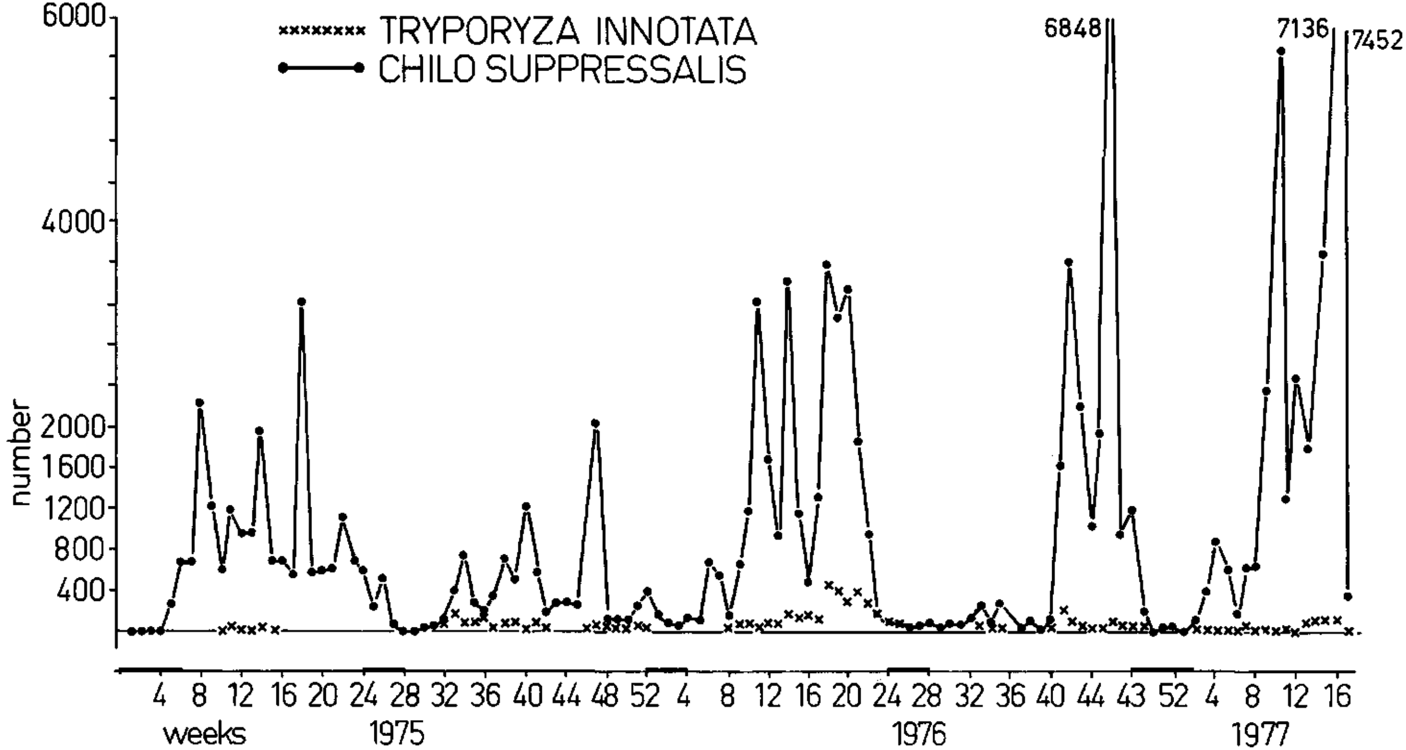


Fig. 19. Light trap catches of *Tryporyza innotata* and *Chilo suppressalis*. Twice weekly. Maros.

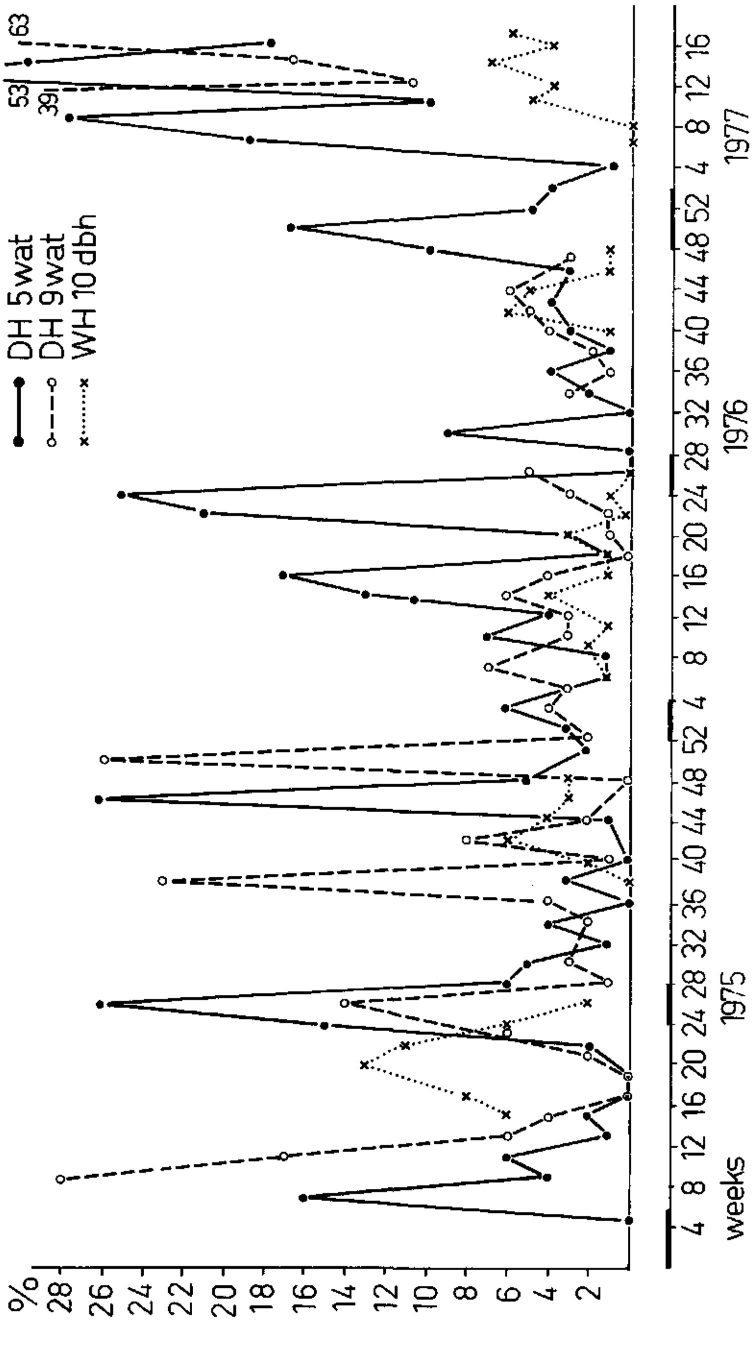


Fig. 20. Dead heart and white head percentages. Maros.

T. innotata, *Ch. suppressalis* and *S. inferens* levels were recorded by operating a light trap, by opening rice tillers and by monitoring dead heart and white head percentages.

T. innotata moths are easily recognized in the light trap catches. *Ch. suppressalis* moth counts are probably slightly too high since several moths, including other *Chilo* species, look quite similar. For traps of *S. inferens* the reader is referred to Chapter 5.4.

Figure 19 and Table 20 show the results of two light trap catches per week at Maros.

TABLE 20. Light trap catches of rice stemborers in Maros, trap operated two nights per week

	Total	*T. innotata*	*Ch. suppressalis*	*S. inferens*
1975	31,120	95.9%	4.0%	0.1%
1976	52,844	93.4%	6.6%	?
1977 1/1–1/5	36,492	97.7%	2.3%	?

The data on dead heart and white head are presented in Figure 20. There are some very distinct discrepancies among the three observations. It is hard to account for 13 per cent white head at a time when dead heart is very low (week 20, 1975) or for 3 per cent and 23 per cent dead heart in hills of 5 weeks and 9 weeks old, respectively (week 38, 1975). Also, the peaks at weeks 16, 24 and 50 in 1976 need clarification.

To reveal the relative percentages of stem borer larvae, 36 randomly choosen five-week old hills were dissected every two weeks. Borer numbers were low. Only 33 and 181 larvae and pupae were found in 1975 and 1976, respectively (Table 21). This practice was discontinued because of practical difficulties. Instead, six five-week old hills with dead heart symptoms were selected and dissected on a monthly basis and this methos proved to be more satisfactory. The initial results are summarized in Table 22.

The LPPM made a five-day intensive study on the occurrence of stem borers in lowland rice in the main areas of South Sulawesi (11 locations, from April 5th to 9th, 1977). This was done under the guidance of a visiting Japanese

TABLE 21. Number of larvae and pupae of stemborers found after dissecting 36 randomly selected hills every two weeks. Maros.

	T. innotata		*C. suppressalis*		*S. inferens*	
	number	perc.	number	perc.	number	perc.
1975	32	97	1	3	0	0
1976	156	86	3	2	22	12
1977 1/1–1/4	117	100	0	0	0	0

TABLE 22. Number of larvae and pupae of stem borers found after dissecting six five-week old hills with dead heart symptoms. Maros.

	T. innotata		*Ch. suppressalis*		*S. inferens*	
	number	perc.	number	perc.	number	perc.
1976, 24/8–31/12	89	79	19	17	4	4
1977, 1/1– 1/5	53	100	0	0	0	0

scientist Dr. I. Hattori. In all, 2,200 stems were opened by hand yielding 1,358 larvae and 45 pupae. Of these, 1,319 or 94.0 per cent were *Tryporyza* sp. and the remainder *Ch. suppressalis*, *Ch. polychrysus*, *Ch. auricilia* and *S. inferens*.

All the results indicate that *Tryporyza innotata* accounts for more than 90 per cent of the stem borer population and is responsible for the damage inflicted in South Sulawesi throughout the year. *Chilo suppressalis* and *Sesamia inferens*, the next two in importance, together make up for less than 10 per cent.

5.6. *NEPHOTETTIX VIRESCENS*

Population fluctuations of the green leafhopper, *N. virescens*, at Maros were registered by recording the number of leafhoppers caught in the light trap (Figure 21). To see whether light trap catches reliably reflect leafhopper field densities, a start was made to monitor density fluctuations by a scoring method (Chapter 3). There is a promising similarity between the two methods as shown by Figures 21 and 22.

Each increase in tungro incidence is preceded by an increase in the number of *N. virescens*. This correlation can be seen in Figure 21 where tungro virus percentages are recorded 6 weeks after transplanting.

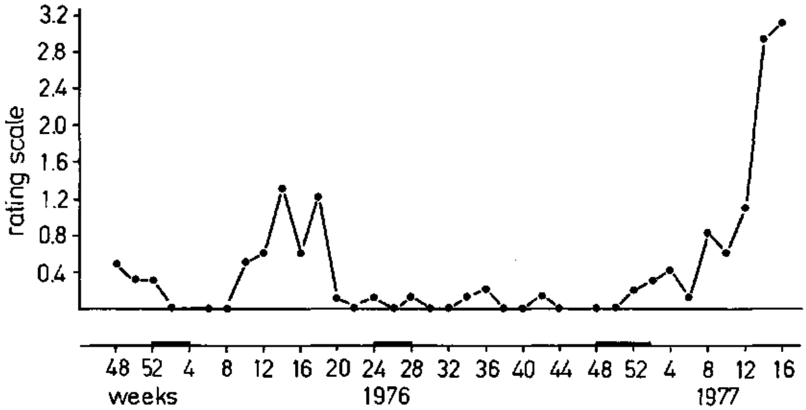


Fig. 22. Population fluctuations of *Nephotettix virescens*, based on a rating scale. Rating 0, 1, 3 and 5 correspond with 0, 1 to 10, 10 to 25 and 25 to 100 leafhoppers per 4 hills.

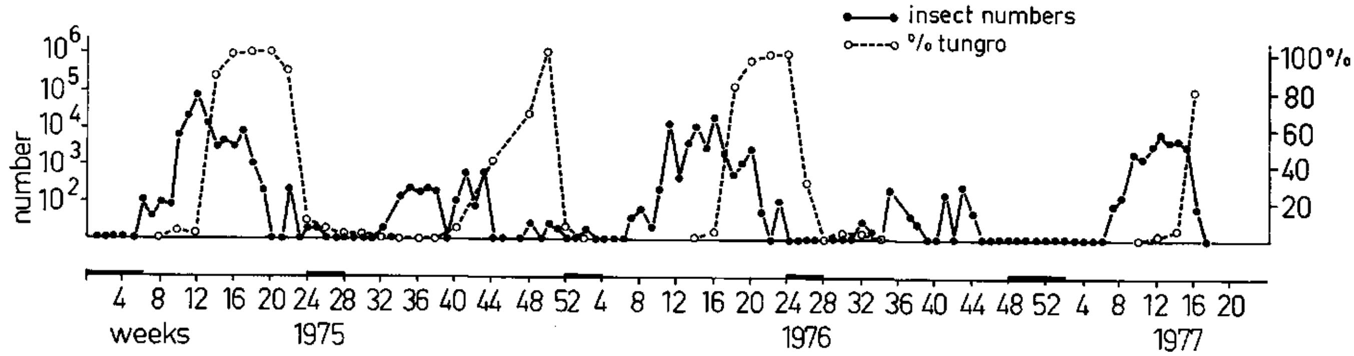


Fig. 21. Light trap catches of *Nephotettix virescens* (twice weekly) and tungro infestation percentages in Maros.

5.7. *LEPTOCORISA ORATORIUS*

The rice seedbug, *L. oratorius*, is not caught by the light trap. Assessment of grain infestation percentage by applying the KOH technique (Chapter 3) forms a convenient method of monitoring population fluctuations. Results are presented in Figure 23. Rats and birds were responsible for the gaps in the observations.

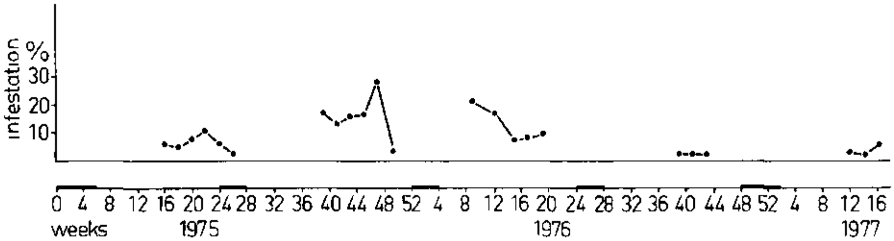


Fig. 23. *Leptocorisa oratorius* infestation percentage of grains harvested every two weeks from the staggered planting experiment at Maros. By KOH technique.

5.8. PROSPECTS OF AN INSECT-OUTBREAK FORECASTING SYSTEM

The information gathered so far shows that a comparison of the various methods leaves a lot to be desired. There is still a great deal to be sorted out and at this stage it is of no use to relate the entomological information to meteorological data.

With the information available so far it is quite impossible to set up a forecasting system and this situation will prevail for many years to come.

6. THE EFFECT OF INSECTICIDES ON THE VARIOUS RICE INSECTS AND THE PRACTICAL IMPLICATIONS OF THEIR USE

In the period 1968 to 1977, an impressive number of insecticide experiments were conducted in South Sulawesi with chemicals that were then becoming available. Only the more relevant data are reported in this chapter.

Until 1973, most of the attention was focussed on the conventional application of spray liquids and granular insecticides, which are the application of water-based spray liquids using a knapsack sprayer and the broadcasting a granular insecticide into the paddy water by hand. In the latter case, the rice plant takes up the dissolved active material and insects feeding on the plant are killed.

Application of ultra low volume (ULV) sprayings using battery-operated equipment in 1976 and 1977 proved unsuccessful at Maros. There is often not enough wind to use the sprayers effectively. Crop penetration was poor and insecticides often caused serious phytotoxic symptoms, even the ones based on vegetable oils.

A similar approach to control rice insects was followed at Bogor, Java, the results of which have been summarized by PANUDJU *et al.* (1974), PANUDJU and LEEUWANGH (1974) and SOEKARNA *et al.* (1974).

The use of certain systemic insecticides by means of the root-zone application technique as developed at IRRI, was thought to have great potential and the extraordinary results obtained at Maros since 1973 justify a more detailed account.

6.1. CONVENTIONAL APPLICATION OF INSECTICIDES

In table 23, insecticides that control the most relevant insect pests most efficiently and those that are virtually non-effective are listed arbitrarily. Much attention was given to spray liquids. Some of the granular formulations proved to be very good, especially in controlling stem borers. Tables 24, 25 and 26 summarize the more important insecticides tested.

Because of the overwhelming importance of stem borers in the insect pest complex everywhere in Indonesia, and the difficulties in finding good curative insecticide treatment, a great deal of effort has been put into trials to find a prophylactic set of insecticide applications based on the number of weeks after transplanting. PANUDJU and LEEUWANGH (1974) summarized the trials of the Central Research Institute at Bogor. Similar information concerning South Sulawesi can be found in SHAGIR SAMA *et al.* (1974), ANONYMOUS (1971) and ANONYMOUS (1973). Applications of foliar sprays at 5, 7 and 9 weeks after transplanting, or the use of granules at 5 and 9 weeks after transplanting are

TABLE 23. Effectiveness of the more intensively tested insecticides against the major rice pests of South Sulawesi.

	good control		not effective	
insect	granules	spray	granules	spray
whorl maggot (*Hydrellia philippina*)	carbofuran chlordimeform[2]	diazinon monocrotophos	BPMC	
case worm (*Nymphula stagnalis*	carbofuran chlordimeform[2]	CYP monocrotophos		
stem borers (*Tryporyza innotata, Chilo suppressalis*)	carbofuran chlordimeform[2] mephosfolan diazinon cartap lindane[1]	endrin[1]		carbaryl
brown plant-hopper (*Nilaparvata lugens*)	carbofuran BPMC	diazinon parathion	chlordimeform[2] lindane[1]	endrin[1] endosulfan
army worms (*Spodoptera* spp.)		endosulfan CYP monocrotophos	lindane	
leaf folder (*Cnaphalocrosis medinalis*	diazinon carbofuran BPMC	CYP diazinon carbaryl monocrotophos		
seedbug (*Leptocorisa oratorius*		CYP pyridaphention carbaryl endosulfan fenitrothion	any granular application	MBCP
prevention of tungro virus (control of *Nephotettix* vectors)	carbofuran chlordimeform[2] BPMC mephosfolan	monocrotophos CYP fenitrothion	Dyfonate	

[1] No more allowed by government regulation
[2] Withdrawn from the market because of possible side-effects

frequently recommended by these and other authors.

However, these experiments based on time of application have lost most of their significance with the increased importance of other problems, notably brown planthopper, gall midge, grassy stunt virus and tungro virus. Also, some granular systemic insecticides are so good and quick-acting that the need for killing the borer larvae before they enter or re-enter a tiller has diminished.

TABLE 24. Comparative effects of several insecticides applied conventionally to Pelita at 5, 7, 9 and 11 weeks after transplanting. Maros, WS 1972/73. 3G = 3 per cent granular product, 50 SP = 50 per cent soluable powder, 50 EC = 50 per cent emulsifiable concentrate, 100 SC = 100 per cent soluable concentrate.

insecticide	dosage kg a.i./ha	percent stemborer infestation: dead hearts 45 dat	dead hearts 70 dat	white heads 100 dat	rice leaf folder 70 dat	grain yield kg/ha
chlordimeform 3G	0.75	3	0	1	0	6,904
cartap 10G	1.25	13	0	0	3	6,856
chlordimeform 50 SP	0.50	11	0	0	3	6,405
carbofuran 3G	0.50	4	0	0	0	6,148
cartap 50SP	0.50	9	2	8	3	5,617
S.6626 5G	1.25	2	1	2	1	5,504
chlorfenvinphos 10G	1.25	6	0	2	1	5,263
lindane + carbaryl 5G	1.25	2	0	4	0	5,193
isoxathion 50EC	0.50	5	1	11	0	5,503
lindane 6G	1.25	7	1	6	5	4,828
diazinon 10G	1.25	4	2	7	5	4,619
endrin 19EC	0.30	16	3	10	0	4,571
chlorpyrifos 40EC	0.50	6	1	10	0	4,474
endosulfan 35EC	0.50	12	3	15	5	4,474
phosphamidon 100SC	0.80	18	3	9	0	3,975
CYP 25EC	0.50	18	17	26	1	3,724
azinphosethyl 40EC	0.50	18	13	13	0	3,734
Salithion 10G	1.25	17	3	6	5	3,653
diazinon 60EC	0.90	20	27	16	3	3,460
control		33	42	35	7	2,253

6.2. ROOT-ZONE APPLICATION TECHNIQUE

Some systemic insecticides are taken up by the roots when applied into the root-zone of rice plants, and transported to almost any plant part. BPMC, carbofuran, cartap, chlordimeform and mephosfolan for instance proved to be extremely effective in controlling insects and even at low dosages have a long-lasting effect.

The method of applying insecticides, with medicinal gelatine capsules, to the root-zone of rice plants, was developed at IRRI from rice seedling root-soak treatments (ANONYMOUS, 1972). The Maros Research Station began research activities along this new line of insect control in 1973 because the concept had some definite advantages over conventional applications:

- Losses due to rainfall, overflowing water, volatilization, light and heat are minized, because the insecticide is situated in the reduced layers of the submerged soil.
- Harmfull effects on natural enemies of rice pests and other non-target or-

Table 25. Comparative effectiveness of insecticides, applied conventionally, at three stations in South Sulawesi, 1972 and 1973.

insecticide	dosage kg a.i./ha	percentage stemborer infestation (dat)									
		Langrang WS '72			Pangg. DS '72			Maros WS 72/73			Average
		45	70	100	45	70	100	45	75	100	
chlordimeform 3G	0.75	6	0	1	1	2	2	3	0	1	2
carbofuran 3G	0.50	4	1	2	3	4	1	4	0	0	2
S.6626 5G	1.25	7	0	4	5	3	4	2	1	2	3
chlorfenvinphos 10G	1.25	8	0	4	4	3	1	6	0	2	3
chlordimeform 50 SP	0.50	5	1	2	3	1	1	11	0	0	3
lindane + carbaryl 4-4G	1.25	5	1	2	4	2	1	2	0	4	3
lindane 6G	1.25	6	1	5	3	3	1	7	1	6	3
isoxathion 50EC	0.50	7	0	5	5	5	1	5	1	11	3
diazinon 10G	1.25	6	0	6	4	3	2	4	2	7	4
chlorpyrifos 40EC	0.50	7	0	4	2	1	3	6	1	10	4
Salithion 10G	1.25	7	0	5	6	3	2	17	3	6	5
phosphamidon 100 SC	0.80	5	0	4	4	5	2	18	3	9	6
endosulfan 35EC	0.50	8	0	6	9	4	2	12	3	15	7
endrin 19EC	0.30	9	0	4	9	10	2	16	3	10	7
azinphosethyl 40EC	0.50	6	0	5	5	5	2	18	13	13	7
CYP 25EC	0.50	7	0	4	5	6	2	18	17	26	10
diazinon 60EC	0.90	6	0	8	7	4	5	20	27	16	10
control	0.00	13	1	14	15	17	6	33	42	35	19

TABLE 26. Comparative effectiveness of insecticides on the yield of rice grown in three substations in 1972 and 1973.

insecticide	dosage kg a.i./ ha	grain yield (kg/ha) Lanrang '72 WS	Panggen-tungan '72 DS	Maros '72/73 WS
carbofuran 3G	0.50	3,957	5,123	6,148
chlordimeform 50SP	0.50	4,505	4,140	6,405
chlordimeform 3G	0.75	4,070	3,789	6,904
lindane + carbaryl 4-4G	1.25	4,308	4,772	5,198
S 6626 5G	1.25	4,238	4,491	5,504
chlorfenvinphos 10G	1.25	3,985	4,351	5,263
isoxathion 50EC	0.50	3,705	4,281	5,053
endrin 19EC	0.30	4,112	4,000	4,571
phosphamidon 100SC	0.80	4,056	4,140	4,474
diazinon 10G	1.25	3,649	4,351	4,619
chlorpyrifos 40EC	0.50	3,803	4,281	4,474
endosulfan 35EC	0.50	3,845	4,211	4,474
lindane 6G	1.25	3,859	3,789	4,828
CYP 25EC	0.50	4,028	4,491	3,734
azinphosethyl 40EC	0.50	3,564	4,140	3,653
diazinon 60EC	0.90	3,607	3,789	3,460
Salithion 10G	1.25	3,452	2,930	3,476
control	0.00	2,807	3,368	2,253
LSD 5%		585	627	902

ganisms are probably negligible.

Initial trials of the LPPM were duplications of the IRRI experiments with capsules and insecticides obtained from the Philippines. Since gelatine capsules are too expensive for the ordinary farmer in South Sulawesi, the LPPM tried to develop a method of applying insecticides to the root-zone of rice plants that could be adopted by a peasant farmer.

These experiments were started by applying mixtures of granular insecticides and moist clay as a carrier. The required quantity of an insecticide for a field was thoroughly mixed with clay in a container, in the ratio of one to two or one to four, depending on the moistness of the clay, and made into mud balls with diameters approximately 10 to 15 cm.

In some experiments, small pills with diameters of 0.5 to 1.5 cm were rolled out of the big ball and allowed to harden before application, but none of these experiments are included in the current chapter. The method of making these small pills proved too time-consuming and was abandoned in favour of the method in which small lumps were plucked from the big mud ball in the field and pushed into the soil.

This method became known as the mud ball technique, and currently applies

TABLE 27. Infestation percentages and yield after applying insecticides in gelatine capsules three days after transplanting, compared with a conventional spraying of Surecide 25 EC at 3, 17, 31, 45 and 59 dat. Lanrang, DS 1973, variety Pelita.

insecticide	kg a.i./ha	*Hydrellia* 20 dat	stem borer: dead heart 30 dat	stem borer: dead heart 50 dat	stem borer: white head 70 dat	tungro 20 dat	tungro 60 dat	yield kg/ha
BPMC	2.0	2.3	0.7	9.7	0.9	0.3	1.7	5,188
carbofuran	2.0	0.1	0.1	0.1	0.2	0.3	0.0	5,938
cartap	2.0	3.6	0.0	1.0	0.2	1.8	0.0	5,500
chlordimeform	2.0	2.0	0.2	1.0	1.0	1.5	3.1	4,031
mephosfolan	2.0	0.0	0.1	0.5	1.0	0.0	0.5	4,281
diazinon	2.0	1.9	6.1	31.9	2.2	1.3	13.9	2,813
CYP (Surecide) spray 5 × 2 ltr/ha		4.0	7.1	32.9	1.2	4.3	13.7	3,718
control		4.2	11.1	54.2	8.8	5.5	37.0	2,594
						LSD 5%		955

TABLE 28. Effect of various dosages of carbofuran and chlordimeform applied to the root-zone of rice-plants in gelatine capsules at 3 dat, compared with granular broadcast applications of both insecticides and with Surecide sprays, all at 3, 17, 31, 45 and 59 dat. Variety Pelita. Maros, WS 1973/74.

insecticides	kg a.i./ha	*Hydrellia* 20 dat	dead heart 35 dat	dead heart 50 dat	*Cnaphalocrosis* 55 dat	*Cnaphalocrosis* flag leaf	white head 10 dbh	yield kg/ha
capsules:								
carbofuran	2.0	0.1	0.0	0.0	0.1	0.0	0.39	6,313 a
carbofuran	1.0	0.1	0.0	0.0	0.0	0.2	1.09	6,063 a
carbofuran	0.5	0.1	0.8	0.4	0.1	1.3	1.7	5,663 a
chlordimeform	2.0	2.2	2.5	1.8	2.1	1.8	4.7	4,475 b
chlordimeform	1.0	2.8	4.2	3.6	2.9	1.8	5.9	3,725 c
chlordimeform	0.5	2.6	8.4	7.7	3.1	2.1	6.8	3,313 cd
broadcast:								
carbofuran	5 × 0.5	3.0	5.8	6.9	3.9	1.6	6.2	3,663 c
chlordimeform	5 × 0.75	3.3	8.3	11.7	2.0	1.9	11.2	2,475 e
spray:								
CYP (Surecide) 25EC	5 × 2 ltr/ha	3.2	12.7	16.3	3.7	2.8	9.1	2,750 de
control		3.7	23.2	27.2	4.5	3.1	24.0	1 425 f

yields followed by the same letter do not significantly differ at 5% level to any method in which a pesticide or fertilizer is applied to the soil with clay or mud as a carrier. If 90 kg N/ha is to be applied, the mud balls have diameters of 5 to 7 cm. If 0.5 kg carbofuran is to be applied per hectare the lumps may be as small as 0.5 to 1.0 cubic cm.

Table 27 gives the results of one of the earlier experiments where gelatine capsules with insecticide were applied three days after transplanting. BPMC, carbofuran and cartap controlled insect pests until harvest and produced high yields. Chlordimeform and mephosfolan gave good control but had lower yields, possibly because of phytotoxic effects on earlier plant stages. Diazinon failed to give satisfactory control.

To investigate the correct dosage per hectare, several dosages and treatments of carbofuran and chlordimeform were tested and compared with granular broadcast application of the same insecticides and conventional foliar applications of Surecide (Table 28). The results show that when applied in capsules, carbofuran at 0.5 kg and 1.0 kg a.i/ha are about as good as at 2.0 kg a.i./ha even under unusually high insect infestations. Carbofuran is superior to chlordiform. The limited effect of carbofuran and chlordimeform granules when broadcast was caused by torrential rainfall which caused the plots to frequently overflow. It shows the advantage of the root-zone application over broadcasting.

Table 29 presents the results of a number of insecticides applied as mud ball lumps tested in 6 dosages. Although there is considerable overlap, the higher dosage range (1 and 2 kg a.i./ha) gives the best results.

Experiments were also conducted to find out whether the application of one mud lump per hill was any better than one lump between two hills or one in the middle of four hills. Table 30 presents the results of one of these trials. In general, one application per hill is better than one mud lump between two hills or one lump in the centre of four hills. Differences are, however, small and often, as in Table 30, not significant.

Because of obvious disadvantages of the mud ball technique in preparation and application, the search continued for easier ways of applying insecticides into the root-zone The LPPM used an ordinary knapsack sprayer with spray-nozzle to inject a carbofuran 75 SP solution into the root-zone. Table 31 gives the results of one of the experiments. Technically, the method left a lot to be desired, but it worked. IRRI's follow-up, the liquid applicator (HEINRICHS, 1976) proved to be much better in that it had a better discharge with less clogging and was included in some of the later experiments (Table 32). In the IRRI liquid applicator, the insecticide solution (or suspension etc.) runs by gravity from a tank through a plastic pipe into some sort of sledge which is pushed by hand over a newly transplanted field. From underneath the sledge, two rims with a small pipe each allow the liquid to enter the soil. A disadvantage of the liquid applicator for South Sulawesi is that the fields have to be smoother and better prepared than is usually the case, in order to allow smooth sliding of the applicator.

TABLE 29. Effect of various dosages of insecticides applied in mud lumps to the root-zone of rice plants one week after transplanting. Variety Pelita. Lanrang, DS 1974/1975.

insecticides	kg a.i./ ha	leaf[1] damage	stem borer dead heart (%)		tungro (%)		yield
			45 dat	66 dat	45 dat	66 dat	tons/ha
carbaryl + chlor-	2.00	0.6	3.4	5.3	2.3	2.0	4.8
dimeform (5-3G)	1.00	0.6	3.9	8.5	3.2	1.7	5.1
	0.50	1.1	4.0	7.4	6.0	30.3	3.9
	0.33	0.8	3.3	10.3	2.5	3.3	4.6
	0.25	0.8	5.1	8.6	6.2	24.3	3.8
	0.00	0.9	6.9	11.1	13.0	71.7	3.0
mephosfolan	2.00	0.2	1.8	4.8	4.7	10.0	4.4
	1.00	0.3	2.8	4.7	9.9	46.0	4.0
	0.50	0.3	3.7	5.4	3.6	41.7	3.6
	0.33	0.1	3.6	5.3	2.3	15.0	3.9
	0.25	0.3	4.5	9.7	10.6	49.0	4.0
	0.00	1.2	6.0	10.3	11.3	78.3	2.6
cartap	2.00	0.4	0.3	1.4	1.8	4.0	4.6
	1.00	0.6	0.4	3.3	3.4	5.3	3.8
	0.50	0.7	1.9	3.8	8.0	30.0	3.1
	0.33	0.5	3.9	8.0	5.1	35.2	3.9
	0.25	0.9	4.0	12.0	5.9	36.2	3.6
	0.00	1.5	11.3	14.8	23.0	96.0	2.6
carbofuran	2.00	0.0	0.3	3.5	1.7	0.0	5.9
	1.00	0.0	3.3	6.4	5.4	1.3	5.4
	0.50	0.3	6.6	5.6	2.8	0.2	4.3
	0.33	0.3	7.7	8.0	8.1	5.3	4.3
	0.25	0.3	5.2	8.0	6.6	6.0	4.4
	0.00	1.0	12.1	13.3	8.5	58.3	3.3

[1] damage caused by *Hydrellia*, *Nymphula* and *Cnaphalocrosis* totalled, using a rating scale from 0 to 9.

TABLE 30. Effect of applying carbofuran in mud lumps at various densities to the root-zone of rice plants one week after transplanting. Variety Pelita. Lanrang, DS 1974/75.

insecticide carbofuran	kg a.i./ ha	leaf[1] damage	dead heart (%)		tungro (%)		yield
		45 dat	45 dat	66 dat	45 dat	66 dat	t/ha
1 mud lump/1 hill	0.5	0.4	4.4	5.1	3.2	3.3	4.7 a
1 mud lump/2 hills	0.5	1.2	3.1	6.0	4.0	5.7	4.5 a
1 mud lump/4 hills	0.5	1.6	4.5	7.8	3.8	7.7	4.2 a
control		2.4	10.9	11.6	7.1	57.0	2.9 b

[1]damage caused by *Hydrellia*, *Nymphula* and *Cnaphalocrosis* totalled, using a rating scale from 0 to 9.

TABLE 31. Effect of a root-zone application by injecting a solution of carbofuran 75SP and of an application of carbofuran 3G containing mud lumps (one lump per hill), each at one week after transplanting. Panggentungan, wet season, 1974/75. Variety IR20.

application	stem borer dead heart (%)		leaf folder % infested hills	plant hopper rating	stem b. white head %	yield t/ha
	5 wat	52 dat	52 dat	53 dat	10 dbh	
injection of 0.5 kg a.i./ha carbofuran between the roots with knapsack sprayer	0.5	2.8	3	0.9	9.8	4.2 a
application of mud lumps containing carbofuran at 0.5 kg a.i./ha	0.1	0.6	0	0.2	6.0	4.1 a
control	4.0	18.7	47	1.8	11.6	2.3 b

yields followed by the same letter do not significantly differ at 5% level

All experiments on root-zone application clearly show that one application shortly after transplanting gives protection until harvest. Consequently, there was not much need to investigate later applications. Even so, it is quite possible, that an application at three days or one week after transplanting could be too much of a burden during a time that many farmers have not yet finished their planting activities. Field trials showed that a root-zone application up to three weeks still proved to be satisfactory, provided no insect or virus infestation occurred before the application. Five weeks after transplanting is too late to apply an insecticide to the root-zone. Apparently, for unknown reasons, roots no longer take up the insecticide and no more protection is obtained by such a late application (see also Table 33).

The method developed by IRRI in which a granular broadcast was incorporated in the soil by puddling before transplanting, appeared to be inferior to a root-zone application using mud balls in several experiments. Fields should be properly drained to prevent the formation of pools, because it is difficult to incorporate insecticide dissolved in those pools. These field conditions are not normally fulfilled in South Sulawesi and the method is therefore not recommended.

The dipping of seedlings in a 1,000 ppm carbofuran solution before transplanting (ANONYMOUS, 1972), gives protection of about two weeks which could be useful in areas where early infestations are expected and when there is no time for the immediate application of insecticide to the root-zone after transplanting.

A selection was made from the various possibilities discussed in this chapter

TABLE 32. The effect of the IRRI liquid applicator on insect infestation, tungro incidence and yield of two rice varieties with carbofuran 75SP and BPMC 50EC, compared to mud lumps containing the same insecticides and the controls. Panggentungan, DS 1976

Insecticide, time of application and dosage in kg a.i./ha	dead heart[1] 35 dat		*Cnaphalocrosis*[2] 65 dat		tungro[1] 35 dat		tungro[1] 65 dat		yield kg/ha	
	Pelita	IR26	Pelita	IR26	Pelita	IR26	Pelita	IR26	Pelita	IR26
carbofuran 1 wat 0.5	2.4	0.1	3.0	0.3	1.3	0.3	25	3	3,414	5,084
carbofuran 4 wat 0.5	1.3	0.3	1.3	0.7	3.0	0.7	16	2	3,217	4,919
carbofuran 7 wat 0.5	2.6	4.1	3.0	3.0	3.0	0.3	56	9	2,453	4,527
carbofuran 1 wat 1.0	3.1	0.0	2.3	0.3	2.3	0.3	23	2	3,418	4,618
carbofuran 4 wat 1.0	2.2	0.7	0.3	0.3	3.0	0.0	13	2	3,239	4,718
carbofuran 7 wat 1.0	3.7	1.5	3.0	3.7	4.7	0.3	58	28	2,555	4,357
carbofuran mud lumps 1 wat 1.0	0.9	0.6	1.0	0.7	0.0	0.0	8	2	4,309	4,825
control	3.4	3.8	3.0	5.0	4.3	0.7	86	30	2,149	4,215
BPMC 1 wat 0.5	3.3	0.3	3.0	1.3	1.3	1.0	25	7	3,703	4,895
BPMC 4 wat 0.5	3.7	1.6	1.3	3.7	3.7	0.7	30	11	2,813	4,455
BPMC 7 wat 0.5	3.4	1.9	3.0	3.0	3.7	1.0	59	10	2,297	2,957
BPMC 1 wat 1.0	3.1	0.5	2.3	1.3	0.7	0.7	17	6	4,130	4,535
BPMC 4 wat 1.0	3.7	1.3	2.3	3.0	3.7	0.7	30	16	2,928	4,707
BPMC 7 wat 1.0	3.7	2.5	3.7	5.0	3.0	1.0	57	9	2,654	4,160
BPMC mud lumps 1 wat 1.0	1.7	1.2	2.3	2.7	0.0	0.7	17	5	4,209	4,727
control	6.2	3.0	4.3	4.3	3.0	1.0	86	29	1,325	2,093

[1] percentages
[2] mean rating (scale 0 to 9)

TABLE 33. A comparison of some of the most promising root-zone application methods with carbofuran. Variety Pelita. Lanrang, WS 1976.

Method, time and dosage	Percentage infestation			
	dead heart 5 wat	white head 10 dbh	tungro 9 wat	yield kg/ha
Mud balls 3 dat; 2.0 kg a.i./ha, 1 lump/4 hills	1.0	0.2	2	4,477
Broadcast application 3, 6, 9 wat; 1.0 kg a.i./ha/appl.	1.6	0.0	3	4,404
Mud balls 3 wat; 1.0 kg a.i./ha, 1 lump/4 hills	7.0	0.4	6	4,367
Mud balls 3 dat; 0.5 kg a.i./ha; 1 lump/hill	0.4	0.6	3	4,330
Seedling dip 24 hrs; mud balls 3 dat; 0.5 kg a.i./ha,	9.8	0.6	6	4,182
Incorporated 1 dbt; 1.0 kg a.i./ha	3.9	1.2	5	4,034
Broadcast 1 wat; 0.15 kg a.i/ha. Mud balls 5 wat; 1.0 kg/ha, 1 lump/ hills	8.2	2.7	13	3,479
monocrotophos spray 3, 6, 9 wat; 1 ltr 24% a.i./ha/appl.	6.9	5.2	7	2,849
Mud balls 5 wat; 1.0 kg a.i./ha, 1 lump/4 hills	9.3	0.5	49	2,553
Control	9.9	2.0	70	2,035

to control insects. Table 33 presents the results of one out of two identical experiments, with simular results.

Treatments 1, 2, 3, 4 and 5 are very good and very reliable, invariably giving high yields with carbofuran and also with BPMC, cartap, mephosfolan and others. Treatment 6 could be good but is of questionable value in South Sulawesi as already explained. The other treatments are of limited value, because spraying has serious limitations and a root-zone application at five weeks after transplanting is too late to be effective.

Which of the five treatments or similar treatment should be chosen depends largely on the financial means of the farmer and the economics of the area concerned. It is quite possible that in one area a high dosage applied as mud lumps in the centre of four hills should be recommended because of a relative scarcity of labour, whereas in another area with plenty of labour but high prices of insecticides, a low dosage applied to each hill is more profitable.

Some information is available on the economics of insecticide application. The recommended method of plucking small lumps from a previously prepared large moist mud ball containing carbofuran, requires 40 to 60 man-hours per hectare if each hill is treated. If only one lump is applied in the centre of four hills, the work requires approximately 30 man-hours per hectare. This is less than the labour needed for transplanting and about as much as for five spraying operations, which is about Rp 5,000 per hectare. Broadcasting a granular insecticide is considerably less work. However, if 0.5 kg a.i./ha root-zone application is considered to be equally effective as three broadcast applications of 1.0 kg a.i., the saving by applying the insecticide in mud lumps is 2.5 kg a.i./ha. This means that over 80 kg Furadan 3G or Rp 14,000 per hectare at the subsidized price of Rp 175 per kg is being saved by this method. If the Furadan were not subsidized, the savings would be Rp 40,000.

The price of five sprayings with one litre Surecide or diazinon will be 5 x Rp 900 = Rp 4,500 with a government subsidy, and Rp 22,500 with no subsidy, not taking into account the maintenance costs of the troublesome knapsack sprayers. And there is no doubt that one application of 0.5 kg a.i. carbofuran to the root-zone is by far superior to five sprayings of one litre Surecide or diazinon.

It is important to note that less effective spray liquids are more heavily subsidized than carbofuran.

Some economic information is presented in Table 34.

The root-zone application method is an ideal control technique for the smallholder. He normally has time to spare for the extra manual input needed.

TABLE 34. Estimated net profits of some insecticide treatments

	carbofuran a.i./ha				
	0.5 kg root-zone application	5 × 1.0 kg granular broadc.	3 × 0.5 kg granular broadc.	Surecide/ diazinon 5 × 2 l/ha sprayings	Surecide/ diazinon 3 × 1 l/ha sprayings
yield increase:					
kg/ha	2,500	2,500	2,000	1,500	500
Rp.	125,000	125,000	100,000	75,000	25,000
costs subsidized (Rp):					
insecticide	2,975	28,875	8,925	9,000	2,700
application[1]	7,500	1,000	600	5,000	3,000
sprayer				1,000	600
	10,475	29,875	9,525	15,000	6,300
costs unsubsidized (Rp):					
insecticide	10,200	99,000	30,000	35,000	10,500
application[1]	7,500	1,000	600	5,000	3,000
sprayer				1,000	600
	17,700	100,000	30,600	41,000	14,100
net profits (Rp):					
subsidized	114,525	95,125	90,475	60,000	18,700
not subsidized	107,300	25,000	69,400	34,000	10,900

approximate price dry paddy in 1976 and 1977 is Rp 50/kg
US$ 1.00 = Rp 410
1. one mud lump applied per hill

His monetary input will be low and his net profit high.

The method is equally attractive for the Indonesian government, because of the subsidies. Withdrawing of the subsidy would have hardly any effect on the economics of the root-zone application, but granular broadcast applications, especially the higher dosages, would become, prohibitively expensive (Table 34).

6.3. The actual use and consumption of insecticides

Virtually the total quantity of insecticides used for rice crop protection in South Sulawesi is applied within the government controlled BIMAS and INMAS programmes at subsidized prices as shown by Table 35. These programmes are part of the activities of the Agricultural Extension Service.

Table 35. Total insecticide use in kgs[1] in South Sulawesi

	1968	1969	1970	1971	1972	1973	1974
Bimas/Inmas	29,918	51,357	76,900	26,940	66,102	90,837	276,044[2]
Cash payments	5,144	2,852	3,690	11,436	1,776	1,939	-
Demonstrations and applications	1,359	373	6,870	2,305	1,592	12,518	-

[1] The South Sulawesi Extension Service calculates 1 kg for every litre independent of specific gravity.
[2] From this, 141,038 is Furadan 3G.
Source: South Sulawesi Extension Service, 1976.

For farmers not included in these programmes, insecticides are prohibitively expensive (Table 36). Generally, these farmers belong to the less advanced category.

In South Sulawesi, insecticides are not sold by local shops and even authorized dealers in Makassar have hardly if any stock at all. The government is practically the sole distributor of insecticides.

Table 37 records the total lowland rice area and the portion of that area covered by the BIMAS and INMAS programmes. It shows that only one in every 3 to 4 hectares receives insecticide.

In the late sixties and early seventies, the irregular supply and insufficient local distribution of insecticides prevented much progress. The situation has markedly improved but there is still a lot to be desired. It is not uncommon for instance, that the bulk of insecticides for a particular season arrives at the harbour when the growing season is already well on its way. Even for the BIMAS and INMAS programmes no more than 3 litres per hectare are available (1976 to 1977). This quantity is not sufficent for a normal season, let alone for an outbreak season. There are discrepancies between what is available, what should be used and the actual demand.

TABLE 36. Some insecticides with their subsidized and unsubsidized prices in Rupiah per kg or litre. 1 US$ = Rp 410

insecticide	BIMAS/INMAS price	unsubsidized price
Surecide 25EC	900	3,000 - 4,000
Diazinon 60EC	900	4,000 - 5,000
Sevin 85SP	1,230	4,000 - 6,000
Padan 50SP	1,230	4,000 - 6,000
Furadan 3G	175	500 - 750

Source: South Sulawesi Extension Service, 1976.

TABLE 37. Area planted with lowland rice from 1970 to 1976 and the share of the BIMAS and INMAS programmes

year	total lowland rice area	BIMAS/INMAS programmes	percentage BIMAS/INMAS
1970	523,000	79,894	15
1971	561,000	79,630	14
1972	412,000	129,296	31
1973	597,000	182,702	31
1974	529,000	114,380	22
1975	540,000	118,261	22
1976	546,000	157,922	29

Source: South Sulawesi Extension Service, 1977.

For years, the assortment of insecticides has been too small, either only diazinon was available or only Surecide. In recent years, the government has varied the assortment to enable farmers to control the full spectrum of insects.

As far as equipment is concerned, there have not always been enough sprayers, spray nozzles and other spare parts. It is not uncommon to see a farmer use a sprayer without an orifice and hit the leaf tips to disperse the full discharge into somewhat finer droplets. They also tend to use too low concentrations and dosages per hectare and as a result of the poor control of insects they then become reluctant to invest in insecticides again.

7. INSECT RESISTANCE IN RICE AND ITS INCORPORATION INTO HIGH-YIELDING VARIETIES

The incorporation of genes for insect resistance into rice varieties has only recently been given any real attention. The first major undertaking was started by Pathak and co-workers in the mid-sixties and was aimed at finding resistance against the striped rice borer, *Chilo suppressalis* (PATHAK *et al.*, 1971). The real breakthrough came with the discovery and incorporation of a brown planthopper resistant gene in some high yielding IRRI varieties in the early seventies, notably in IR26.
Since then several other rice pests have received attention from IRRI and from the national programmes, usually through the cooperative International Rice Testing Programme (IRTP), initiated in 1974.

The IRTP is a combination of some sections of national rice improvement programmes and IRRI's Genetic Evaluation and Utilization (GEU) Programme (ANONYMOUS, 1975; ANONYMOUS, 1976). The objective of the IRTP is to formalize a network of rice scientists covering various disciplines. Nurseries are developed and maintained to test breeding material and varieties from IRRI's GEU programme and from national programmes. The IRTP also organizes regional monitoring tours for scientists to acquaint them with symptoms and conditions abroad and to stimulate the use of internationally accepted techniques.

The IRTP nurseries dealing with insects are: Brown planthopper nursery (IRBPHN), Gall midge nursery (IRGMN), Stemborer nursery (IRSBN) and Tungro virus nursery (IRTN).

Of course, not all genetic evaluation research in rice is formalized in IRTP and GEU-type programmes. Many local crossing and testing activities are being conducted independently of international and national programmes. This is particularly the case for activities on more fundamental problems related to resistance and its subdivision into non-preference, antibiosis and tolerance as developed by PAINTER (1951, 1958). Research along this line is done at IRRI (PATHAK *et al*, 1971; SAXENA, 1976; PABLO, 1976), at Bogor (van VREDEN and SUARTINI, 1976; ARIFIN and van VREDEN, 1977), in India (KULSHRESTHA, 1976) and recently in Maros (1977).

The previously mentioned success of IR26 in the Philippines led to widespread planting of this variety in Indonesia. Resistance to the brown planthopper, *Nilaparvata lugens*, and high-yielding capacity materialized but the acceptance of the variety was met with great reluctance because of its cooking and eating qualities. Moreover, under certain growth conditions the panicles do not fully exsert and some of the grains are discoloured.

The concepts of vertical and horizontal resistance have only recently become subjects for discussion.

TABLE 38. Insects and viruses that are, or may become, of some significance in South Sulawesi with their respective centres of GEU-type activities.

Tryporyza incertulas	IRRI (Philippines), Bogor (Indonesia)
Tryporyza innotata	Maros (Indonesia)
Chilo suppressalis	IRRI (Philippines: Bogor (Indonesia)
Nilaparvata lugens	IRPT in India, Bangladesh, Thailand, Philippines, Indonesia, Sri Lanka
Sogatella furcifera	IRRI (Philippines); Maros (Indonesia); India
Nephotettix virescens	IRRI (Philippines); India
Orseolia oryzae	IRTP in India, Thailand, Indonesia, Sri Lanka
Cnaphalocrosis medinalis	IRRI (Philippines); Maros (Indonesia), Sri Lanka
Hydrellia philippina	IRRI (Philippines)
Spodoptera mauritia	Bogor (Indonesia)
Leptocorisa oratorius	Maros (Indonesia)
Rice Tungro virus	Maros (Indonesia); India; IRRI (Philippines); Bangladesh; Thailand
Grassy stunt virus	IRRI; Sukamandi and Bogor (Indonesia)

7.1. THE SEARCH FOR RESISTANCE AGAINST INSECTS AND VIRUSES IN SOUTH SULAWESI

Table 38 presents a list of insect pests and virus diseases that are already a problem or may become one in South Sulawesi, together with the countries and research centres where these pests and diseases are studied.

7.1.1. *Stem borers*

Even with prolonged and intensive research, IRRI reports only limited success in its attempts to develop a variety with acceptable resistance to *Chilo suppressalis* (ANONYMOUS, 1975). Reports from Java are not very encouraging either (G. van Vreden, Indonesia, 1973, personal communication).

The simultaneous presence of some four stem borer species complicates the screening for varietal resistance. Resistance to one species does not necessarily mean resistance to another species. Evaluation using dead heart and white head percentages does not give information on the individual borer species.

SOEJITNO *et al* (1974) state that varieties that are resistant (or less susceptible) to one borer species are quite often susceptible to other species. DAS (1976), however, has shown that rice varieties exhibit a general similarity in their degree of resistance or susceptibility to the four borer species tested. According to him, the consistancy of the resistance of several varieties to the four stem borers suggests the presence of a complex of factors which is responsible for such a broadbased, though low level of resistance.

Another complication in screening for stem borer resistance, is that no correlation appears to exist between the reaction in dead heart and white head stages (PATHAK *et al*, 1971). In other words, a variety may show resistance to stem borer attack in the vegetative stages but may be susceptible when blooming, or vice versa. This was also found to be the case in South Sulawesi. Even the internationally accepted resistant check variety TKM 6 usually has low dead heart percentages but shows a suspectible reaction when evaluated for white head. There is a need for a better standard variety than TKM 6.

Much remains to be done to reveal the nature of resistance to stem borers. Meanwhile the screening of as many varieties as possible should continue and crosses be made to increase the present low level of resistance.

In South Sulawesi, *Tryporyza innotata* is the predominant stem borer which often accounts for as much as 90 to 100 per cent of the total stem borer population at almost any time of the year. This situation facilitates the evaluation of resistance and the study of related subjects.

From 1973 to 1977, some 1,000 varieties and lines were evaluated for stem borer resistance through dead heart and white head counts. The following varieties and lines consistently show low stem borer infestation percentages (Tables 39).

TABLE 39. Varieties and lines with consistently low stem borer infestations (mainly *T. innotata*). Maros and Lanrang, South Sulawesi, 1973 to 1977.

Ase sawe saleku (local variety)	IR 2153-26-2-4
Ntinuwu (local variety)	IR 2071-573-3-3
W. 1263 (from India)	IR 2071-621-2-3
Oryza officinalis	IR 2755-E2-11-1-1
B 2360-2-9-3 (line from Bogor)	IR 2755-E4-5-12-2
B 2360-18-3 (line from Bogor)	IR 2760-E1-33-1-2
B 2388-7-4 (line from Bogor)	IR 2762-E6-6-7-2

Ase sawe saleku and Ntinuwu are local varieties with possibly new genes for the international germ plasm bank. They were proposed for the IRSBN in 1977 for testing abroad. In the same year, crossing started with Pelita and other high-yielding varieties at Maros and Bogor.

Crosses between the two local varieties themselves were also done to investigate whether the level of resistance could be further increased. The line IR 2755-E2-11-1-1 holds special promise. It already has an excellent plant type and also shows resistance against brown planthopper, green leafhopper, tungro virus and grassy stunt virus.

With the dominant position of *T. innotata* it would be neither feasible nor sensible to study varietal resistance against the other stem borers in South Sulawesi.

7.1.2. *Nilaparvata lugens*

Devastations repeatedly caused by the brown planthopper, *N. lugens*, in the Philippines, India, Indonesia and other countries since the end of the sixties have triggered an extensive research programme for the search of resistant rice varieties, the identification of the genes involved and the incorporation of these genes into high-yielding varieties (PATHAK *et al*, 1969; ATHWAL *et al*, 1971; PATHAK, 1971).

The factors governing susceptibility and resistance of certain rice varieties were studied (SOGAWA and PATHAK, 1970) and are still being investigated (SAXENA, 1976) at IRRI.

IR26 was the first improved variety resistant to the brown planthopper. Within a few seasons, however, it was realized that the brown planthopper problem was not solved that simply. IR26 and related lines proved to be susceptible in India and Sri Lanka and subsequently several planthopper biotypes and corresponding resistant genes were discovered. As early as 1976, the original planthopper of many places (biotype 1) became replaced by planthoppers of biotype 2 in several locations in the Philippines (FEUER, 1976), and reports came in of resistance breakdowns of IR26 and hitherto resistant varieties IR30 and IR34 in Java and Sumatra (MOCHIDA *et al*, 1977).

In South Sulawesi, *Nilaparvata lugens* outbreaks occurred on too small a scale for a breakdown of resistance.

MOCHIDA and DYCK (1976) summarized the situation up to 1976, and the position up to 1977 was reviewed during the Brown Planthopper Symposium at IRRI) April, 1977.

The Maros Research Institute for Agriculture joined the IRTP in 1975 with the First International Rice Brown Planthopper Nursery and started screening activities in cooperation with CRIA (Bogor and Sukamandi) and IRRI. The objectives of these activities were:

Photo 2. The reaction of some well-known rice varieties to a moderate infestation of the brown planthopper of South Sulawesi. Maros, greenhouse, 1976.

TABLE 40. Reaction of entries of the First International Rice Brown Planthopper Nursery. Maros, greenhouse, 1975.

entry	*origin*	*resistant gene*	*reaction*[2]	
(Semi-) dwarf varieties:				
Chianung-sen-yu 11	Taiwan		R	R
C62-1-373	Taiwan	bph 2	R	R
CR 94-13	India			R
Hamsa	India	Bph 1		R
IR26	Philippines	Bph 1	R	R
IR 1154-243-1	Philippines	bph 2		R
IR 1364-37-3-1-1-1	Philippines			R
IR 1480-125-2-3-10	Philippines			R
IR 1514A-E597	Philippines	Bph 1		R
IR1539-823-4-1	Philippines	Bph 1		R
IR1628-632-1	Philippines	bph 2	R	R
IR1632-93-2-2	Philippines	Bph 1		R
IR2035-255-2-3-1	Philippines			S
Jayanti (IET 1039)	India			S
RP 9-6	India	Bph 1	R	R
TN_1	Taiwan			S
Triveni	India			R
Pelita 1/1	Indonesia		S	S
Tall varieties:				
Andaragahawewa	Sri Lanka	Bph 1	R	R
ARC 6650	India		R	R
ASD 7 (Karsamba red)	India	bph 2	R	R
Babawee	Sri Lanka	bph 4		R
Co 9(PI 193176)	India		R	R
Dalwa Sannam (MTU 15)	India	Bph 1	R	R
Gangala	Sri Lanka		R	R
H5	Sri Lanka	bph 2	R	R
H 105	Sri Lanka	bph 2		R
Jyoti (Ptb 39)	India			R
Kencana	Indonesia			S
Dikwee 328	Sri Lanka	bph 2		R
Mudgo	India	Bph 1		R
Murungakayan 3	Sri Lanka	bph 2	R	R
Murungakayan 101b	Sri Lanka	bph 2	R	R
Murungakayan 303b	Sri Lanka	bph 2	R	R
Mthumanikam	Sri Lanka	bph 2	R	R
Palasithari 601	Sri Lanka	bph 2	R	R
Ptb 19 (Athileraya)	India		R	R
Ptb 21 (Tekkan)	India	Bph 1	R	R
Rathu Heenati[2]	Sri Lanka	Bph 3		S
Red rice	Iran			S
Thella Gerikasanavari[2]	India	Bph 1	S	MS

[1] R = resistant, MS = moderately susceptible, S = susceptible.
[2] probably wrong seed.

1. to assist other institutions in testing their varieties and lines,
2. to check exotic varieties and new lines for possible future use in South Sulawesi,
3. to find resistant local material and
4. to establish the presence of planthopper biotypes.

Until the middle of 1977, some 4,000 varieties and lines were evaluated including F2 and F3 material. Details of the screening process are described in Chapter 3.2.4. Table 40 gives the reaction of two testings of the first IRBPH nursery. Bph 1 and Bph 3 (with capital B's) are dominant resistance genes, and bph 2 and bph 4 are recessive genes. The second IRBPHN was evaluated in early 1977. Apparently, biotype 1 is the predominant brown planthopper in South Sulawesi (Photo 2). The unexpected susceptible reaction of Rathu Heenati and Thella Geriksanavari was due to wrong seed (H. E. KAUFFMAN, IRRI, 1975, personal communication). From 488 local varieties from Sulawesi, 36 showed a resistant reaction. Of these, Kulibungga, Nggulahi, Pulut Rada, Ase Garis and the wild rice *Oryza officinalis*, were rated as highly resistant and sent for further evaluation to other institutions abroad, including the third IRBPH nursery. The LPPM has embarked on a modest programme to identify the genes involved and to incorporate these genes, if different from those already known, into high yielding varieties. Table 41 presents the reaction of some well-known varieties.

TABLE 41. Some widely grown or well-known varieties with their reaction to brown planthopper. Maros, greenhouse, 1975 to 1977.

resistant	susceptible
IR 26	SPR 6726-76-2-3
IR 28	IR 5
IR 29	IR 8
IR 30	IR 20
IR 32	Pelita
IR 34	C4-63
IR 36	B 462c
Mudgo	Remaja
	Sigadis
	Pulut bolong
	Lotong

7.1.3. *Leptocorisa oratorius*

So far, no systematic genetic evaluation work has ever been conducted on the rice seedbug, *Leptocorisa oratorius*. It has been reported that bearded varieties are more severely attacked by rice seedbugs than non-bearded (van der GOOT, 1949), but the opposite has also been reported (UICHANCO, 1921).

Table 42 compares the seedbug infestation of bearded and non-bearded varieties as obtained from the surveys in the Maros district. The tendency is that bearded varieties are not attacked quite as much. Chances that resistant

TABLE 42. Comparison of rice seedbug infestations of bearded and non-bearded rice varieties harvested simultaneously from the same location. Maros regency, 1974 to 1976.

	non-bearded		bearded	
	percentage infestation	number of samples	percentage infestation	number of samples
Maros WS 1974/75	7.1	(19)	8.7	(11)
Camba WS 1974/75	10.1	(5)	9.1	(5)
Maros DS 1975	16.5	(4)	14.5	(2)
Maros WS 1975/76	8.4	(47)	3.2	(31)
Maros WS 1975/76	7.0	(12)	2.7	(17)
Maros WS 1975/76	11.2	(5)	4.0	(8)
Maros DS 1976	6.3	(11)	3.6	(7)

material will be found are slim. Nevertheless, it was felt that in an area like South Sulawesi, where the rice seedbug causes severe damage almost every dry season, it would be worthwile evaluating the available local germ plasm together with some of the widely grown improved varieties. Preliminary experiments started during the dry season of 1976 in Maros will be continued.

7.1.4. *Other insect pests and viruses*

With the exception of *Sogatella furcifera* and *Cnaphalocrosis medinalis* no research on resistance has been done so far in South Sulawesi concerning the insects that have not been discussed in the previous sections.

Resistance to the green leafhopper, *N. virescens*, was found at IRRI, while looking into tungro virus problems. The resistance to tungro and green leafhopper is governed by different genes and it was thought that green leafhopper resistance is useful in keeping the incidence of the tungro disease more easily within acceptable limitts. The resistance to the green leafhopper is monogenetic (ATHWAL *et al*, 1970 and 1971). So far, five genes have been identified and designated Glh 1, Glh 2, Glh 3, glh 4, and Glh 5 (ANONYMOUS, 1975). Apart from glh 4, they are all dominant genes. Almost all of IRRI's more recent lines are resistant to the green leafhopper and most Indonesian varieties are not. In 1977 the LPPM started to screen for resistance.

Regarding *S. furcifera*, the LPPM started in 1976 with a small-scale follow-up of IRRI's varietal screening work by Pablo (1976).

Preliminary investigations on varietal resistance against *Cn. medinalis* in 1975 failed. Experiments should be started again now that the economic importance of the insect has become more apparent (Chapter 4.5).

The rice gall midge *Orseolia oryzae* (Wood-Mason), formerly known as *Pachydiplosis oryzae*, has not yet occurred in South Sulawesi. Intensive research and breeding for resistance in South and SouthEast Asia include Bogor and Sukamandi. If South Sulawesi is confronted with an outbreak, a quick despatch of resistant material and expertise is envisaged.

For grassy stunt virus, not known to occur in South Sulawesi, the same applies as for the rice gall midge: sufficient knowledge and expertise is available from Java if needed.

The tungro virus is extensively dealt with in Chapter 8.

7.2. SOME REMARKS ON THE INTRODUCTION OF RESISTANT VARIETIES

The effect of the introduction of resistant rice varieties in Indonesia has been very distinct in the cases of the brown planthopper and tungro disease (ANONYMOUS, 1976b and Figure 24). The costs of the research activities are negligible compared to the savings. Nevertheless, the introduction of a resistant variety does not neccessarily mean the final answer to a pest problem. As mentioned earlier, new biotypes and strains may arise.

Tungro resistance appears to hold enough promise since several different sources are available, but grassy stunt gives rise to much concern since only one good source of resistance, *Oryza nivara*, is known and utilized. Resistance to the brown planthopper, *N. lugens*, is likely to break down wherever it is introduced as shown by reports from the Philippines (FEUER, 1976) and Indonesia (MOCHIDA, 1977).

Another question of considerable relevance is whether or not a new insect-resistant rice variety should be introduced in areas where the insect concerned is of little or no importance as in the cases of the green leafhopper, *N. virescens* and the brown planthopper, *N. lugens*, in South Sulawesi. Introduction of green leafhopper resistant rice varieties will upset the ecosystem of the green leafhopper but will also affect the brown planthopper and the white-backed planthopper.

It is also questionable whether varieties with resistant traits should be grown before these hoppers develop into an important pest. Again, their ecosystems might be disturbed and it also quite likely that the resistance breaks down before it can be used to curb a large-scale and devastating outbreak. This might seem academic at the present stage but it is felt that some voluntary restraints are advisable.

8. INCIDENCE AND CONTROL OF THE RICE TUNGRO VIRUS AND ITS VECTOR *NEPHOTETTIX VIRESCENS*, WITH REFERENCE TO ECOLOGICAL AND PHENOLOGICAL ASPECTS

The tungro virus, spread by the vector *Nephotettix virescens*, causes a disease of paramount importance in South Sulawesi and it has been subject to much research. It proved impracticable to incorporate these results into the various preceding chapters. Therefore, most aspects of the virus are dealt with here.

The tungro virus was identified as a virus in the Philippines by IRRI. Basic information on the virus characteristics can be found in OU (1972 and 1973) and LING (1972). The virus does not persist in its vector, the retention period is generally less than a week, there is no demonstrable latent period in the vector and infectivity is lost during moulting. The incubation period in the plant is 10 to 14 days.

The most striking feature of the symptoms is the bright discolouration of the rice leaves into shades of yellow and orange. Stunting is severe on susceptible varieties but less so or inconspicuous, on more resistant ones. The panicles may not fully exsert and remain partially enveloped by the flag leaf.

8.1. HISTORY OF THE TUNGRO VIRUS DISEASE AND THE 1972 TO 1975 OUTBREAK IN SOUTH SULAWESI

The history of tungro disease in rice in Indonesia probably goes as far back as 1859. Then, and later, the discolouration syndrome and stunting was often referred to as 'Omo mentek'. Its nature was obscure and often considered to be either a physiological disorder, nutrient deficiency, nematode problem, virus disease or a combination of these. It was Ou who, after studying the reports, came to the conclusion that 'mentek is also caused by a virus, possibly similar to penyakit merah or tungro' (OU, 1965). There was no serious outbreak of the disease in Sulawesi until 1972. Minor outbreaks were reported (TANTERA and OKA, 1972) in the same year from South Kalimantan and Sumatra.

In October 1972, several thousand hectares near Palu, Central Sulawesi, were infected by tungro. In November, symptoms were observed near Rappang in South Sulawesi. During the first week of December, reports of tungo infection were received from Sidrap and Pinrang. During the period January to March, 1973, tungro was reported to be widespread in the Palopo and Polmas areas as well as in some fields in mountainous Toraja and Enrekang. In mid-May the disease spread across the mountain range south of Pare-Pare and was subsequently observed in Barru, Maros, Gowa and the southern-most districts of Takalar and Bulukumba. Fortunately, the rice crops in these areas were approaching maturity and so the damage was not serious.

At the end of 1973, the beginning of a new rice-growing season in many regions of South Sulawesi, tungro virus infection was distinctly declining. Apparently because farmers had changed from Pelita and IR5 to more resistant varieties such as C4-63, IR5-198 and IR20, and with the additional effect of using insecticides, tungro was almost totally absent in early 1975.

Apart from the growing of a large percentage of tungro and *N. virescens* susceptible rice varieties (Pelita and IR5), the extremely long and severe dry season of 1972 and an increased use of nitrogen fertilizer could have contributed to the tungro outbreak in Sulawesi.

Since *N. virescens* is an efficient vector, a very low population density is enough to cause a spread of the disease as long as there are sufficient sources of infection and rice is grown continuously in the area.

On the other hand, since patchy, apparently spontaneous, initial outbreaks were scattered all over Sulawesi and often located kilometres apart, it might be more realistic to speak of many small tungro outbreaks that merged after some time, rather than of one outbreak that spread. It is difficult to know why no outbreak occurred in Java and Bali, where conditions were at least as favourable.

Figure 24 presents the tungro infestation of the two main rice-growing areas, Pinrang and Sidrap from 1972/73 to 1975 and the area grown with IR20 and

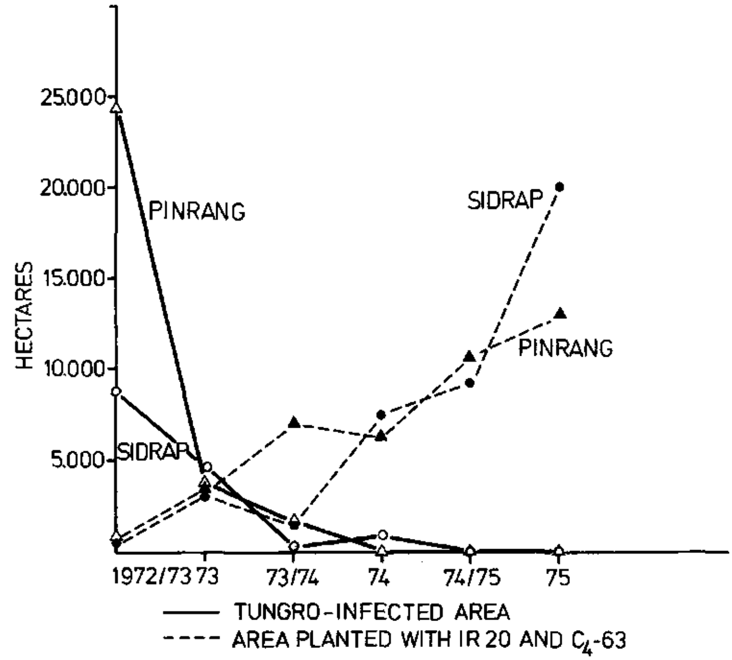


Fig. 24. Tungro infection and area grown with the moderately resistant rice varieties C4-63 and IR20 in two main rice-growing areas (Pinrang and Sidrap) from 1972 to 1975 (Source: South Sulawesi Extension Service).

C4-63. IR5-198 and local resistant varieties are not included because no data are available. The total lowland rice area of these regions is approximately 45,000 each. For almost any region in South Sulawesi, similar graphs can be drawn.

Nevertheless, in some areas the tungro incidence dropped too sharply to be caused by the growing of resistant varieties and insecticide use, and it is felt that the incidence could have, in part, tapered off naturally.

In the next sections, the research data along both lines of tungro virus control are summarized.

8.2. INSECTICIDES IN TUNGRO DISEASE CONTROL

The severe outbreak of 1972 to 1974 caught farmers, extension workers and research workers unprepared, and insecticide experiments and chemical control measures were conducted with insecticides available at that time. The effect of insecticides on the control of the green leafhoppers is expressed in virus incidence in percentages of infected hills and not by counting or assessing insect mortality.

Table 43 shows the results of an evaluation of insecticides for tungro virus

TABLE 43. Green leafhopper control in terms of tungro infection percentage. Insecticides were applied at 1, 5, 7 and 9 weeks after transplanting. Rice variety: C4-63. Reading at 80 dat. Volume of spray liquid 400 l/ha/application. Plot size: 3 × 10 m. Panggentungan, DS 1973.

insecticide	dosage in kg a.i./ ha per application	percentage tungro-infected hills, average of 3 replicates
CYP 25EC	0.5	5
diazinon 60EC	0.5	17
phosphamidon 100SC	0.5	29
monocrotophos 60EC	0.5	7
azinphosethyl 40EC	0.5	7
isoxathion 50EC	0.5	10
chlorpyrifos 30EC	0.5	25
MBCP 30EC	0.5	17
cartap 50SP	0.5	30
chlordimeform 50SP	0.5	34
carbofuran 3G	0.5	3
carbaryl + lindane 4-4G	1.25	3
S 6626 5G	1.25	7
chlorfenvinphos 10G	1.25	22
Salithion 10G	1.25	40
lindane 6G	1.25	29
diazinon 10G	1.25	5
chlordimeform 3G	0.75	32
control		42

control. Carbofuran 3G, carbaryl + lindane 4-4G, diazinon 10G and CYP 25EC, when applied at 1, 5, 7 and 9 weeks after transplanting gave a satisfactory control. In later experiments, chlordimeform and cartap also controlled the tungro very well.
One experiment with monocrotophos 60EC showed that it makes no difference whether, 50, 100, 150, 200, 300 or 400 litres of spray liquid are used for the control of the tungro virus.

Excellent control of the virus was obtained by applying systemic insecticides to the root-zone of rice plants as shown in Chapter 6. The effectiveness of carbofuran and BPMC when applied in mud balls to the root-zone is shown in Table 44. Both chemicals kept the percentage of tungro-infected plants low, even under heavy pressure. Aldicarb (and also fonofos and endosulfan, included in the same experiment), being a non-systemic insecticide hardly controlled the virus at all.

TABLE 44. Effect of some insecticides and methods of application on the incidence of tungro when applied at a rate of 0.5 kg a.i./ha per application. Lanrang, WS 1975.

insecticide	method of application	time of application in wat	percentage tungro-infected hills. mean of 3 replicates
carbofuran	root-zone	1	4
carbofuran	broadcast	5, 9	20
BPMC	root-zone	1	5
BPMC	broadcast	5, 9	47
BPMC	spraying	5, 7, 9	33
aldicarb	root-zone	5, 9	86
aldicarb	broadcast	5, 9	85
control			93

The effect of various rates of insecticides applied in mud balls on tungro infection is shown in Table 45. Dosages as low as 0.33 and 0.25 kg a.i. carbofuran per hectare distinctly reduce tungro incidence.

The various insecticide experiments show that the root-zone application of systemic insecticides is the best method for controlling *N. virescens* and consequently tungro virus incidence.

Economical and other aspects of the root-zone application method are dealt with in Chapter 6. Farmers must treat fields before they become infected. However, with their current income level they are not readily inclined to carry out a prophylactic treatment.

TABLE 45. Tungro infection percentage after the application of various dosages of insecticides in mudlumps to the root-zone at 1 wat. Reading at 66 dat. Rice variety: Pelita. Lanrang, DS 1974/75.

insecticide	dosage in kg a.i./ha					
	2.00	1.00	0.50	0.33	0.25	0.00
chlordimeform + lindane	2	2	30	3	24	72
mephosfolan	10	46	42	15	49	78
cartap	4	5	30	35	36	97
carbofuran	0	1	0	5	6	58

8.3. VARIETAL SCREENING FOR TUNGRO DISEASE RESISTANCE

The growing of tungro susceptible varieties was the main reason for the widespread occurrence of tungro in South Sulawesi in 1972 to 1974. Almost from the beginning of the outbreak, the LPPM recommended stopping the growing of Pelita and IR5. This recommendation was followed by the extension service in the BIMAS and INMAS programmes all over the province.

At the beginning of 1973 farmers changed from Pelita and IR5 to the already widely-grown C4-63, a moderately resistant variety from the University of the Philippines, to IR5-198, a line from IRRI that has never officially been released and to local varieties. IR20 and IR26 were grown more extensively when more seed became available. From 1973 onwards, there was an urgent demand from the farmers for tungro-resistant varieties.

From 1970 to 1972 severe tungro outbreaks caused near-famine in some areas of the Philippines, and IRRI had embarked on a research programme to produce high-yielding tungro disease resistant varieties. This programme, though well under way, suffered badly when the disease subsided in 1972, just at the time when it was attaining disastrous proportions in South Sulawesi. In a cooperative research venture of IRRI, CRIA and the LPPM, the Entomology section of the LPPM took up the field screening work of IRRI and became the world's main station for tungro varietal screening work.

The release of varieties such as IR28, IR30 and IR34 by IRRI was greatly influenced by their resistance against tungro as found by the LPPM. At that time, the risk of tungro sweeping over Java and other islands of the archipelago was thought to be great. This assumption was proved wrong in later years, but as a precaution all CRIA's promising lines were included in the screening activities at Maros.

Conditions for tungro screening were so favourable in South Sulawesi that it could be conducted in the field which greatly increased the capacity, and the results were also excellent. With an increase in staff and with more funds available the methods were subsequently standardized and further improvements made, such as the testing of field nurseries during tungro peak periods and the release of laboratory-reared viruliferous vectors.

The activities induced the creation of a separate Pathology Department at Maros and the assignment of DR. P. S. RAO, IRRI pathologist, as adviser to the Institute. By the time the screening for varietal resistance against tungro was handed over to the Pathology Department in 1975, some 8,000 lines and varieties had been evaluated. This number had approached 15000 by 1977 (P. S. RAO, Maros, personal communication).

At the LPPM, the following steps in varietal screening for tungro resistance are taken (HASANUDDIN *et al*, 1975; P. S. RAO, Maros, personal communication):

a. Planting in the field is deliberately delayed towards the end of the growing season so as to expose the screening material to a maximum number of vector insects. Each planting consists of up to 500 entries with an average of about 300.

b. A double-row entry, with 10 plants per row, is flanked by a double row of non-inoculated susceptible check plants (Taichung Native 1 = TN 1). After every 10 entries IR20 is planted as a resistant check.

c. TN 1 seedlings, raised in trays, are mass-inoculated. These seedlings are transplanted perpendicular to the entries in between two ranks of testing material. This procedure is not necessary if large amounts of inoculum exist near the screening trial.

d. A batch of 1,500 to 2,000 viruliferous *N. virescens* from the greenhouse is released in the field one week after transplanting in an area of 1,000 m^2, the size of the screening block.

e. Green leafhoppers are collected daily and released in the screening trial.

f. To attract more leafhoppers from outside, and to disperse those released, a light source (a petromax kept in a cage to avoid insect injury) is placed for 30 to 60 minutes every two to three days at different places in the screening trial.

The scoring for resistance is done at 3, 6 and 9 weeks after transplanting using the following two scales (adopted from IRRI's 'Standard evaluation system for rice'; slightly modified):

Percentage hills infected		Severity of infection	
0	no information available	0	no information available
1	about 1%	1	no visible symptoms of the disease on plants. The foliage colour, tillering, height and flowering not affected
2	about 5%		
3	about 10%		
4	about 20%	3	plants green, slightly stunted, plants show irregular flowering
5	about 30%		
6	about 40%	5	some leaves yellowish, plants slightly stunted, irregular flowering
7	about 60%		
8	about 80%	7	plants light yellow, stunted, negligible flowering
9	about 100%		
		9	plants orange yellow, severely stunted or even dying.

It is not necessary to tabulate the reaction of all lines and varieties tested. These results were sent to the cooperating parties. What must be presented here is a list of the resistant local varieties from Sulawesi, because of the evident interest for future breeding work. From the 556 local varieties of Sulawesi, 69 were resistant or moderately resistant (Table 46). *O. officinalis* is also resistant.

Table 47 lists several widely grown or well-known varieties with their reaction to tungro as found by the LPPM.

TABLE 46. Tungro-resistant local varieties of Sulawesi out of a total of 556 tested. Lanrang. DS, 1974/75.

Alus	Leter	Pulut adina
Anoika	Manado	Pulut bimba
Apollo	Monyapi merah	Pulut bonja koba
Ase anak wara	Mutiara	Pulut karu
Ase Bali I	Pae bokua	Pulut lamalo
Ase Bali II	Paedai nggulahi	Pulut lotong
Ase cella lise	Pae loiyo IV	Pulut makosey
Ase garis	Pae sagona	Pulut manietti
Ase rankang	Paggeakkang	Pulut ompong
Ase sawe dendang	Panci	Pulut tomene
Ase sawe kaluku	Parada	Pulut topong bango
Ase tallang	Pare bugi	Roya
Benjangguni	Pare datte	Salapaka
Banda	Pare jepang	Santubi
Bulu bawa	Pare karunrung	Seratus hari
Burita	Pare kasalle	Sinisir
China gan	Pare mandetti	Takalulu
Dua delapan	Pare mandi	Tasia
Kalurung	Pare minak	Tojuma
Kawalujan	Pare nangka	Tingga loko
Kenari	Pare riri pulut	Topembangu
Kurompo	Pululei	Ujung Pandang
		Unggul merah

TABLE 47. Some widely grown or well-known varieties with their reaction to the tungro virus disease. Lanrang, 1973 to 1977.

resistant	moderately resistant	moderately susceptible	susceptible
IR26	IR20	IR22	Pelita
IR28	C4-63	IR24	IR8
IR29	Sigadis	Lapang	IR5
IR30	SPR	Batara	Bakka
IR32			Dewih ratih
IR34			Syntha
TKM6			Remaja
Pankhari			Seratus malam
Bengawan			Dara

The varietal reaction may fluctuate and some symptoms may be expressed more distinctly than others. For instance, Pelita may give a pronounced orange discolouration with only limited stunting. The ability of this variety to recover is remarkable, and the discolouration may disappear leaving only some irregular flowering towards maturity. IR20, on the other hand, may not show any orange discolouration even under high pressure, but it shows stunting at only moderate pressure with poor panicle exsertion, discoloured grains and lower yields.

When testing material that has been brought in from other countries for tungro resistance, it is often not known whether short but green hills are stunted because of tungro (and thus susceptible) or rather short but healthy (and thus resistant). It is again proposed to apply carbofuran to the root-zone of one to five plants of each entry. These hills will not suffer from tungro and scoring will be facilitated. Only in cases where the population of the green leafhopper is maintained by artificial means and with considerable difficulty is the application of carbofuran not recommended.

With the introduction of tungro-resistant varieties which often have a lower yield potential than some improved susceptible varieties (IR20, IR28, IR30, IR34 and Pelita, IR5 respectively), the question naturally arises whether it would be advisable to apply insecticides on a tungro-susceptible variety with a high yield potential or to apply no insecticide on a resistant variety with a lower yield potential. This dilemma, which will be solved within a few years, is shown in Table 48.

TABLE 48. Tungro infection percentages and yield of a susceptible and a resistant rice variety after applying carbofuran at 0.5 kg a.i. per hectare per application. Lanrang, WS 1973.

treatment	percentage tungro infection at 9 wat		yield in kg/ha	
	Pelita	IR34	Pelita	IR34
root-zone application 3 dat	4.7	1.0	4,478	3,367
broadcast 3, 30, 60 dat	10.7	0.7	4,255	3,737
broadcast 30 and 60 dat	17.3	2.3	3,664	3,701
control	48.3	1.7	1,961	3,516

8.4. SOME ECOLOGICAL AND PHENOLOGICAL ASPECTS OF THE TUNGRO VIRUS – *NEPHOTETTIX VIRESCENS* RELATIONSHIP

8.4.1. *Transmission and related aspects*

Ou (1973) reported from the Philippines that the green leafhoppers *Nephotettix virescens* and *N. nigropictus* and the zig-zag leafhopper *Recilia dorsalis* are the vectors of the tungro virus. *N. virescens* is the predominant species in rice fields in South-East Asia and the most successful transmitter but, as in other vectors, its effectiveness depends on the percentage of active transmitters among a given population.

The success of transmittance by the LPPM was relatively low in the earlier experiments (1972), the maximum in seven experiments being only 31 per cent for *N. virescens* and practically nothing for *Recilia dorsalis*. This could have been brought about by the lack of experience of all persons concerned and because of inadequate facilities. In later years, when research conditions had greatly improved, the percentage of potentially active transmitters was found to be 75 per cent for *N. virescens* at Maros (P. S. RAO, 1976, personal communication).

A question that remained unsolved for several years was the observation that some systemic insecticides could effectively prevent an infection by tungro, given the non-persistent nature of the virus-vector relationship, even on small plots. Studying the matter in later years, has taught us that the green leafhoppers died before they were able to transmit an appreciable quantity of tungro inoculum. Data from two experiments may illustrate this.

– When ten tungro-infected green leafhoppers were caged on ten carbofuran-treated plants (root-zone application at 0.5 kg a.i./ha), all ten insects died within an hour, compared to only one out of the ten control insects. No virus symptoms developed on the carbofuran-treated plants.

– When three batches of 20 tungro-infected green leafhoppers were released in cages containing a mixture of treated plants and carbofuran-free plants, the majority of the leafhoppers died within half an hour. Only a few survived longer on the control plants and only some of the control plants developed tungro symptoms.

In addition, these cage experiments dismissed the persistent rumour that carbofuran exhibits a repellent action on the feeding behaviour of green leafhoppers when applied to the root-zone or when broadcast.

The fact that the green leafhoppers are killed before they can transmit enough

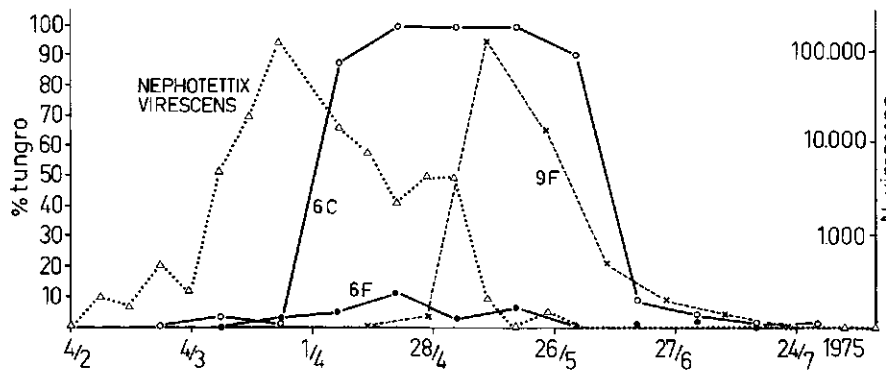


Fig. 25. Percentage of tungro infection of six-week old plants and nine-week old plants both treated with 1.0 kg a.i./ha carbofuran at 3 dat to the root-zone and the tungro percentage of six-week old non-treated plants (6F, 9F and 6C, respectively) from February to August 1975. Numbers of *N. virescents* caught by the light trap are also given. Rice variety: SPR. Maros.

virus particles to infect carbofuran-treated rice plants, is also shown by a field experiment. In Figure 25 the tungro infection percentage is given of six-week old plants and nine-week old plants both treated with 1.0 kg a.i./ha carbofuran to the root-zone, three days after transplanting and the tungro percentage of six-week old non-treated plants (6F, 9F and 6C, respectively) from early February to August 1975. There was a heavy incidence of tungro in the six-week old plants from early April to the end of May in uncontrolled plots, whereas carbofuran-treated plants of the same age remained virtually free from the virus. By the middle of May, the rice fields surrounding the experiment had been harvested, resulting in an extraordinarily high pressure on the experimental plots. This, in turn, resulted in an increase of tungro incidence in the nine-week old hills because the carbofuran left in the plants failed to kill the green leafhoppers rapidly enough.

Tungro symptoms will not be observed until three or more weeks after transplanting. Since the incubation time is 10 to 14 days, this means that infection takes place in the field and not in the seedbed.

To substantiate this claim, two identical experiments were conducted in which 100 seedlings and 100 transplanted plants were taken from the field at 1, 2 and 3 weeks after sowing and transplanting, respectively. They were then planted in cages kept free of *Nephotettix* spp. Three weeks later, the plants were checked for tungro symptoms. Results given in Table 49 show that an appreciable infection could occur directly after transplanting in the field but that infection in the seedbed was negligible.

It was noticed that direct-seeded rice was less affected by tungro than transplanted rice. This observation was confirmed by an experiment at Lanrang in 1974, where eight planting systems combined with carbofuran treatments were compared. The results clearly showed the lower tungro incidence when the fields were direct-seeded in rows 25 cm apart, compared to transplanting at 10 days or 3 weeks after sowing.

It is also in accordance with the observation that no infection occurs in the seedbed.

TABLE 49. Tungro infection in seedlings and transplanted plants removed from the field and transferred to leafhopper-free cages. Percentage infection determined three weeks after transfer. Average of four replicates of 25 plants each. Variety Pelita. Lanrang WS 1973.

plants transferred to cage at	percentage tungro infection	
	experiment A	experiment B
7 days after sowing	0	0
14 days after sowing	0	0
21 days after sowing	1	0
7 days after transplanting	46	38
14 days after transplanting	68	55
21 days after transplanting	81	76

Nephotettix spp. are positively phototactic. The lighter appearance of the water surface of a newly transplanted field due to light reflection as compared to the darker appearance of an older crop, may also contribute to an early infection by attracting the leafhoppers.

Since yellow is more attractive to leafhoppers, including *Nephotettix* spp., it might well be that newly transplanted seedlings, often yellowish in colour, attract the insects from adjacent grasses or rice. It could also mean, that yellow, tungro-infected plants attract a relatively high proportion of the insect population, thus increasing the percentage of viruliferous insects.

KONDAIAH and JOHN (1977) studied this subject in more detail, but in general more attention should be given to these aspects than they have so far received.

8.4.2. *Relative abundance of* Nephotettix *spp.*

The article written by Ghauri (1971) was used in identifying the *Nephotettix* species.

Net sweepings in the rice foliage at 16 locations in South Sulawesi from 1972 to 1974 yielded 1,156 adult green leafhoppers, 76 per cent of which were *N. virescens*, 24 per cent *N. nigropictus* and one or two specimens of their interspecific crosses.

From 1975 onwards, regular observations were made on the presence of the green leafhoppers by light trap and on their relative abundance. Again, only *N. virescens* and *N. nigropictus* were collected. Out of 141,341 green leafhoppers caught in 1975, 86.8 per cent consisted of *N. virescens*. In 1976 55,430 were trapped, 90.2 per cent of which were *N. virescens* (Table 50).

Table 50 shows that the percentage of *N. virescens* increases with the total number of green leafhoppers caught in the light trap. The increase coincides

TABLE 50. Relative abundance of green leafhoppers caught in the light trap at Maros.

4-week period	total number of green leafhoppers caught		ratio *virescens/nigropictus*	
	1975	1976	1975	1976
1 - 4	2	68	-	0.4
5 - 8	454	130	1.5	3.8
9 - 12	102,053	12,705	5.8	21.5
13 - 16	26,837	33,453	15.4	16.1
17 - 20	8,986	7,818	6.6	2.1
21 - 24	268	304	3.5	1.1
25 - 28	65	28	0.5	0.7
29 - 32	56	92	1.4	1.9
33 - 36	770	364	2.4	5.5
37 - 40	581	180	6.0	6.5
41 - 44	1,118	248	68.9	11.4
45 - 48	80	4	0.7	-
49 - 52	71	36	1.5	0.9

with the progress of the rice-growing season.

Cage experiments revealed that *N. virescens* is able to displace *N. nigropictus* completely after about 5 generations if reared on rice seedlings in cages.

Figure 21 represents the light trap catches of *N. virescens* for two nights a week and the corresponding percentage of tungro-infected six-week old plants.

GENERAL DISCUSSION

In the previous chapters the entomological problems of rice in South Sulawesi were provisionally identified. Provisionally, because the pest situation is not stable, and major and minor changes may occur at any time. At present the most important insects are the rice stem borers, predominantly *Tryporyza innotata*, the rice seedbug *Leptocorisa oratorius* and to a lesser extent the rice leaf folder *Cnaphalocrosis medinalis*. A number of other insects species can be grouped as minor pests of which the brown planthopper, *Nilaparvata lugens*, may become a problem in the near future. A problem of paramount importance is the rice tungro virus. This virus, transmitted by *Nephotettix virescens* attained epidemic proportions from 1972 to 1974.

Farmers have tried to control these pests by means of coordinated plantings, flooding and drainage of the fields at appropriate times, moving ropes through panicles, catching insects with nets, removing egg masses, etc. However, with the continuing growth of the human population the urgent need to further reduce the insect pest level had arisen. Pest management now aims at integrating cultural control, chemical control, varietal resistance and biological control in such a way that farmers can grow more rice at a reasonable cost and without endangering the environment. This book deals with the varietal resistance control approach and with chemical control in detail.

Biological control, the utilization of parasites, predators and pathogens for the regulation of insect pests, is beyond the scope of this thesis. This control merits consideration in future research programmes, given the results obtained with other crops in the colonial days (KALSHOVEN, 1950), but it is doubtful whether there is much room left for this because of the prolific use of insecticides. On the other hand, modern means of transport favour the importation of foreign predators and parasites.

Crop loss assessments need full attention because they form the basis for a sound control programme.

It is unlikely that pest outbreaks can be forecast in the near future in South Sulawesi. Data on the phenology of the prevailing insect pest species are far too scanty. Monitoring of population fluctuations in relation to climatic conditions must continue for many years.

No varieties with an appreciable level of resistance against the major insects e.g. white stem borer, seedbug and leaf folder, will be available for a considerable time to come.

For the time being the most effective method to control these insects is by means of insecticides. If the decision to use insecticides is made, than questions arise about the most appropriate application.

It is, for instance, common knowledge that seedbugs congregate in the first flowering fields and disperse as more and more fields come into bloom. It is envisaged, that if these early maturing fields are routinely sprayed by the government, or by a government-sponsored private enterprise, the seedbug population can be kept down to an acceptable level. This has proved to be true with a related species outside Indonesia (VAN HALTEREN, 1972). No such method of control is applicable against stem borers, but here insecticides can be selected that affect the environment as little as possible, for instance with a low toxicity to fish. Broadcasting granules is preferred to spraying under most circumstances, and the root-zone application technique should be used wherever and whenever possible.

It is, however, not difficult to predict that resistance will developed if root-zone applications or granular broadcasts become commonplace. Of course this situation will not happen overnight, especially if insecticides are applied judiciously, and based on careful observations and threshold infestations. Recommendations such as avoidance of peak incidence of pests or avoiding the application of insecticides during periods when parasites are dominant (KULSHRESTHA, 1976) are more easily said than done.

Extension workers and farmers should be thoroughly informed on new developments. Special attention must be given to methods that may not always have a direct and distinct advantage to the individual farmer, but from which the whole community will benefit, such as controlled planting times, the root-zone application technique and 'prophylactic' treatment of seedbugs in early-flowering fields.

It is believed that the best philosophy to be followed is a careful and gradual introduction of seemingly minor improvements into the existing systems.

For the LPPM this would mean close cooperation with the South Sulawesi Extension Service, the Faculty of Agriculture in Makassar and farmers on the one hand and with CRIA and IRRI on the other. Cooperation with the Extension Service has always been good. The Faculty of Agriculture has still little to offer, but this may change in the future, since several foreign university programmes cooperate with the faculty to upgrade its capabilities. Maros has become well-known among farmers and it is justified to assume optimal cooperation in the future.

The Maros Research Institute has grown from a branch-station, conducting trials for CRIA, into an independent institute of similar standards. For new techniques, sophisticated ecological approaches and access to foreign insect-resistant varieties, close linkages must be maintained with institutes abroad, especially IRRI.

Donor countries do not normally support programmes of more than 3 to 5 years. The management of pests and diseases has become an international concern and can no longer be carried out on a local level alone. In view of this it is recommended to allocate funds to IRRI or to the Maros Institute, to ensure that close linkages between the two institutes are maintained after the termination of the Dutch-supported programme at Maros in 1979.

SUMMARY

CHAPTER 1.

The Department of Entomology of the Research Institute for Agriculture at Maros is concerned with insect pests of food crops, and serves the needs of farmers, most of them living near subsistance level, and of extension workers.

South Sulawesi, formerly known as South Celebes, is a major rice-growing province and one of the two provinces of Indonesia that produces a rice surplus. The area planted with rice is about 550,000 hectares, which is more than half of the total arable land. A sketch of the agriculture of South Sulawesi is given.

A justification of the activities is presented by the results that have been obtained while striving for a more up-to-date and varied research programme in order to achieve a better control of rice insects at farmers' level.

CHAPTER 2.

The major and minor insects pests of rice and the rice tungro virus are presented and the nature of damage described.

The white stem borer, *Tryporyza innotata* is the most important pest. The rice seedbug, *Leptocorisa oratorius*, and the rice leaf folder, *Cnaphalocrosis medinalis*, come next. Insects of minor significance include the whorl maggot *Hydrellia phillippina*, the caseworm *Nymphula stagnalis*, armyworms *Spodoptera* spp., the green leafhopper *Nephotettix virescens*, the white-backed planthopper *Sogatella furcifera*, the pink stem borer *Sesamia inferens*, the striped stem borer *Chilo suppressalis*, the brown planthopper *Nilaparvata lugens*, the green stinkbug *Nezara viridula* and grasshoppers.

The brown planthopper is likely to become a major pest in South Sulawesi and it is quite possible that there will be other shifts in the future as well.

CHAPTER 3.

Evaluation systems for infestations in insecticide trials, in phenological studies and in varietal screening tests are described for the whorl maggot, caseworm, stem borers, brown planthopper, green leafhopper, leaf folder and seedbug. These systems include rating scales, assessments and direct and indirect counting methods.

CHAPTER 4.

Experiments to establish the crop losses inflicted by each individual insect species on its specific plant stages were conducted both in the field and in greenhouses.

It was found that roughly 5 to 10 per cent of the crop is lost by the combined effects of normal, light infestations of *Hydrellia*, *Cnaphalocrosis*, *Nymphula* and grasshoppers up to four weeks after transplanting.

Yield losses of 10 to 20 per cent caused by stem borers is the rule rather than the exception. There was a poor correlation between dead heart counts and yield loss, but every unit per cent white head consistently caused about one per cent loss in yield.

Cnaphalocrosis medinalis infestations of the later vegetative and generative stages may often inflict losses of 5 to 10 per cent.

Another 5 to 10 per cent is frequently caused by *Leptocorisa oratorius*, sucking on the ripening grains. Boiling mature grains in a KOH solution provides an easy and reliable method to assess the percentage of infested grains. This percentage of infested grains proved to be silimar to the yield loss inflicted.

Defoliation experiments, designed to simulate the damage caused by leaf-feeding insects, showed that rice does not fully recover after serious defoliations even in very early growing stages. The effect of defoliation is most severe between 7 and 9 weeks after transplanting. Towards maturity of the grains defoliation becomes progressively less damaging.

Every one per cent increase in tungro infection reduces yield by a half or one per cent depending upon the rice variety and the time of infection.

It is concluded that insects alone reduce the potential yield of rice varieties such as Pelita, C4-63, IR5, IR20, IR26, SPR and B462c by 1 to 3 tons per hectare or 30 to 40 per cent in South Sulawesi.

Chapter 5.

Population densities of most of the pest insects and the rice tungro virus incidence were monitored by rating scales and direct counts from the end of 1974 onwards. A light trap was used to monitor fluctuations of *T. innotata*, *Ch. suppressalis*, *Noctuidae*, *Cn. medinalis*, *N. virescens* and *N. nigropictus*.

Of course, not many conclusions can be drawn from graphs that represent the data of less than two and a half years. They form, however, a basis for further work.

Chapter 6.

A great number of insecticide experiments were conducted with insecticides that became available in the late sixties and seventies. Up to about 1973 most of the attention was focussed on conventional applications, later other modes of applications were very successfully investigated.

Insecticides proved to be effective in controlling the pest insects and tungro virus. Carbofuran is an excellent insecticide but chlordimeform, mephosfolan, cartap, diazinon, BPMC, monocrotophos and others are also good.

Granular broadcast applications are superior to spraying. By far the best method is the root-zone application of systemic insecticides. The insecticide is applied between the roots and taken up by the plant. The Maros Research Institute developed and concentrated on the mud ball technique.
If a lump, plucked from a big moist mud ball containing insecticide, is applied soon after transplanting, it often gives protection up to harvest time. The quantity of insecticide required is quite low, there is no equipment needed, it cannot be washed away, one application suffices and the secondary effects are probably negligible. The root-zone application almost invariably gives the highest yields and in many cases doubles even the best spray or granular application. It requires more labour, which is advantageous macro-economically, but is of course disliked by the farmer.

It is envisaged that with the growing concern for the environment and ecosystems and the increasing prices of insecticides, there is a future for this root-zone application technique, in spite of its prophylactic nature. Several methods, such as mud balls and liquid applicator, and time and density of application are discussed.

The total insecticide consumption in South Sulawesi is low, less than one litre per hectare per season. There is a discrepancy between what is available, what should be used and the actual demand. The situation is slowly changing for the better.

CHAPTER 7.

The incorporation of insect-resistant genes into high-yielding rice varieties has only recently been given much attention. Because of a coincidence, the search for varietal resistance has been most rewarding for Maros in the case of the leafhopper-transmitted tungro virus. Many thousand varieties and lines have been evaluated and the information has been incorporated into breeding material and varieties of the International Rice Research Institute and other institutions.

From the screening for varietal resistance against the brown planthopper, *Nilaparvata lugens*, at least two local Sulawesi varieties were found promising for breeding activities. Biotype 1 is the predominant planthopper in South Sulawesi.

The impact of the release of tungro-resistant varieties in South Sulawesi and brown planthopper resistant varieties elsewhere in Indonesia, has been enormous. In the latter case only temporary, due to the development of new biotypes. Voluntary restraints are suggested with the introduction of resistant material to places where that particular pest is not (yet) a problem, such as the brown planthopper in South Sulawesi.

Chapter 8.

A detailed account is given of the recent tungro outbreak transmitted by the green leafhopper, *Nephotettix virescens*, in South Sulawesi with special reference to some ecological and phenological aspects.

Discouraging the growing of Pelita and increasing the growing of resistant varieties, especially C4-63, IR20 and some local varieties have been the main reason for the decrease in tungro incidence.

Insecticide sprays and broadcast applications are fairly effective in controlling the virus. The root-zone application of carbofuran, BPMC, cartap and mephosfolan proved to be extremely effective. When these insecticides are applied to the root-zone, the green leafhopper is killed before it can transmit sufficient tungro inoculum.

Rice plants are infected by tungro in the field after transplanting and not in the seedbed. Also, direct-seeded rice is less infected than transplanted rice.

SAMENVATTING

HOOFDSTUK 1

Zuid Sulawesi, vroeger Zuid Celebes, is een belangrijk rijstgebied en één van de twee provincies in Indonesië met een rijstoverschot. Het rijstareaal is ongeveer 550.000 hectare, dat is meer dan de helft van het gehele landbouwareaal. Enkele landbouwkundige aspekten van Zuid Sulawesi zijn in het kort beschreven.

De afdeling Entomologie van het Proefstation voor de Landbouw in Maros houdt zich bezig met insektenplagen van voedselgewassen en ondersteunt de (veelal kleine) boer en de landbouwvoorlichtingsdienst van Zuid Sulawesi.

Een rechtvaardiging van de aktiviteiten wordt gegeven door de resultaten die zijn verkregen bij het streven naar een moderner en gevarieerder onderzoekprogramma met als einddoel een betere bestrijding van rijstplagen.

HOOFDSTUK 2

Het schadebeeld van de belangrijkste en een aantal minder belangrijke insektenplagen en van het 'rice tungro virus' wordt beschreven. De witte rijstboorder, *Tryporyza innotata*, is de belangrijkste plaag, gevolgd door de zaadwants *Leptocorisa oratorius* en de bladroller *Cnaphalocrosis medinalis*. Insekten van minder betekenis zijn de bibitvlieg *Hydrellia philippina*, de kokerrups *Nymphula stagnalis*, de legerrups *Spodoptera mauritia*, de groene cicadellide *Nephotettix virescens*, de delphaciden *Sogatella furcifera* en *Nilaparvata lugens*, de stengelboorders *Sesamia inferens* en *Chilo suppressalis* en de zaadwants *Nezara viridula*.

N. lugens ontwikkelt zich waarschijnlijk tot een ernstige plaag en het is mogelijk dat de economische betekenis van sommige andere soorten eveneens aan het veranderen is.

HOOFDSTUK 3

Methoden worden beschreven om de aantasting door in Hoofdstuk 2 genoemde soorten vast te stellen ten behoeve van proeven met insecticiden en resistentie- en fenologisch onderzoek.

HOOFDSTUK 4

Kas- en veldproeven zijn uitgevoerd ten einde de relatie te bepalen tussen een bepaalde populatiedichtheid van het insekt en de schade.

Ongeveer 5 tot 10 procent opbrengstverlies wordt veroorzaakt door het gekombineerde effekt van veel voorkomende lage populatiedichtheden van *H. philippina*, *C. medinalis*, *N. stagnalis* en sprinkhanen in de eerste vier weken na overplanten.

Opbrengstverliezen van 10 tot 20 procent door stengelboorders zijn eerder regel dan uitzondering. Er is een geringe korrelatie gevonden tussen percentage dode harten en opbrengstverlies, maar ieder procent voze pluimen veroorzaakt bijna altijd een opbrengstverlaging van één procent.

Aantastingen door *C. medinalis* in het laatste vegetatieve en de generatieve stadia hebben zeer frequent opbrengstverliezen van 5 tot 10 procent tot gevolg.

Eveneens 5 tot 10 procent verlies wordt regelmatig veroorzaakt door de zaadwants *Leptocorisa oratorius*. Door rijstkorrels in een kaliumhydroxide oplossing te koken kan op eenvoudige wijze het percentage aangetaste korrels bepaald worden. Dit percentage blijkt nagenoeg gelijk te zijn aan het toegebrachte verlies aan opbrengst.

De resultaten van mechanische ontbladeringsproeven wijzen erop, dat de rijstplant zich niet geheel herstelt van een ernstige ontbladering, zelfs niet als deze in een heel jong stadium plaats vindt. Het effekt van ontbladering is het grootst tussen de 7e en 9e week na overplanten.

Met ieder procent door 'rice tungro virus' aangetaste planten vermindert de opbrengst met een half tot een heel procent, dit afhankelijk van de rijstvariëteit en het tijdstip van de infektie.

De konklusie is, dat alleen al insekten de potentiele opbrengst van rijstvariëteiten als Pelita, C4-63, IR5, IR20, IR26, SPR en B462c in Zuid Sulawesi met 1 tot 3 ton per hektare of 30 tot 40 procent verminderen.

HOOFDSTUK 5

De populatiedichtheden van de schadelijkste insekten en de percentages door 'rice tungro virus' aangetaste planten in Maros zijn vastgelegd in evaluatieschalen of direkte tellingen vanaf eind 1974. Een lichtval is gebruikt om vluchten te registreren van *T. innotata*, *C. suppressalis*, *Noctuidae*, *C. medinalis*, *N. virescens* en *N. nigropictus*. Hoewel deze gegevens slechts betrekking hebben op twee en een half jaar onderzoek vormen zij een belangrijke basis voor verder werk.

HOOFDSTUK 6

Er is een groot aantal proeven uitgevoerd met insecticiden die in Indonesië aan het einde van de zestiger jaren en in het huidige decennium beschikbaar zijn gekomen. Tot ongeveer 1973 ging de aandacht uitsluitend uit naar conventionele toepassingen, daarna zijn ook andere methodes, met veel succes, onderzocht.

Carbofuran is een uitstekend rijstinsecticide, maar chloordimeform, mephosfolan, cartap, diazinon, BPMC, monocrotophos en andere zijn eveneens goed. Strooien van een granulair insecticide blijkt beter te zijn dan spuiten. Verreweg de beste methode is de toepassing van systemische middelen aan de wortelzone. Het Proefstation te Maros heeft met succes een techniek ontwikkeld, waarbij een granular insecticide vermengd wordt met vochtige klei. Als een kleine hoeveelheid klei met dit insecticide vrij snel na het overplanten tussen de wortels wordt gedrukt, is de rijstplant tot bijna aan de oogst tegen insekten beschermd. Voordelen van deze methode zijn, dat de benodigde hoeveelheid insecticide laag is, er geen machine of apparaat voor nodig is, het insecticide niet kan weg spoelen bij hevige regenval, één behandeling voldoende is en dat neveneffekten vermoedelijk afwezig of minimaal zijn. De wortelzone-methode geeft altijd de hoogste opbrengsten en verdubbelt dikwijls zelfs die van de beste granulaire toepassing. De methode vereist meer werk; de gemiddelde indonesische boer ziet daar tegenop, maar macro-ekonomisch is het aan te bevelen.

Met de groeiende aandacht voor het milieu en de stijgende prijzen van insecticiden lijkt er een grote toekomst te zijn voor de wortelzone-techniek, ondanks het feit dat de methode prophylactisch is en niet curatief. Verscheidene toepassingstechnieken worden er besproken.

Het totale verbruik aan insecticide in Zuid Sulawesi is laag, gemiddeld minder dan een liter per hektare. Er is een duidelijke discrepantie tussen wat beschikbaar is, wat gebruikt zou moeten worden en wat er in werkelijkheid wordt toegepast. Deze situatie verbetert geleidelijk.

Hoofdstuk 7

Het inbouwen van genen die resistentie veroorzaken tegen insekten in hoogwaardige rijstvariëteiten heeft de laatste tijd meer aandacht gekregen. Door een samenspel van faktoren heeft het resistentieonderzoek naar tegen 'rice tungro virus' resistentie variëteiten in Maros een grote vlucht genomen. Duizenden rijstvariëteiten en lijnen zijn op resistentie eigenschappen onderzocht en de geselekteerde genen zijn ingekruist in variëteiten van het International Rice Research Institute en van andere instituten.

Het onderzoek naar resistentie tegen *N. lugens* heeft twee lokale variëteiten van Zuid Sulawesi opgebracht. Deze zijn in het veredelingsprogramma opgenomen. Biotype 1 is in Zuid Sulawesi het algemeen voorkomende type van deze delphacide.

Het effekt van de tegen 'rice tungro virus' resistentie variëteiten in Zuid Sulawesi en van *Nilaparvata*-resistente variëteiten elders in Indonesië is zeer groot. In het laatste geval helaas slechts tijdelijk door het opkomen van nieuwe biotypes. Het betrachten van enige terughoudendheid bij de introduktie van resistent materiaal in gebieden waar het betreffende insekt (nog) geen probleem is, zoals bijvoorbeeld *N. lugens* in Zuid Sulawesi, lijkt op zijn plaats.

HOOFDSTUK 8

Een uitgebreid verslag is gegeven van de recente 'rice tungro virus' epidemie in Zuid Sulawesi.

Het minder aanplanten van de variëteit Pelita en het stimuleren van de resistente variëteiten, zoals C4-63, IR20 en enkele lokale variëteiten is de voornaamste oorzaak geweest van het afnemen van deze ziekte.

Insecticiden, gespoten of gestrooid, onderdrukken de 'rice tungro virus'-ziekte tamelijk effektief. De wortelzone-toepassing van carbofuran, BPMC, cartap en mephosfolan is zelfs uitstekend. In dat geval worden de groene cicadelliden, die het virus overbrengen, gedood voordat ze voldoende inoculum hebben overgebracht.

Rijstplanten worden geinfecteerd in het veld na overplanten en niet in het zaaibed. Breedwerpig gezaaide rijst wordt eveneens minder aangetast dan overgeplante rijst.

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APPENDIX

List of articles through which the Entomology Department has published its research findings from 1972 to 1977:

The Tungro disease in South Sulawesi (1972/73). (B).
Report issued for the staff meeting in July 1973, in Bogor; 51 p. P. van HALTEREN and SHAGIR SAMA.

Annual report Maros Research Institute for Agriculture 1972/73: 60–88. (B).

Tungro di Sulawesi. (B).
Lembaga Penelitian Pertanian Maros, Bulletin **1**: 1–4. P. van HALTEREN and SHAGIR SAMA.

Annual report Maros Research Institute for Agriculture 1973/74: 22–88. (B).

The Tungro disease of 1972–1973 in South Sulawesi. (B).
Lembaga Penelitian Pertanian Maros, Bulletin **3**: 2 p. P. van HALTEREN and SHAGIR SAMA.

The application of insecticides to the root-zone of rice plants in 1973 and 1974. (B).
Lembaga Penelitian Pertanian Maros, Bulletin **4**: 14 p. P. van HALTEREN and SHAGIR SAMA.

Insecticide application in the rice plant root-zone. (A).
Agricultural Cooperation Indonesia- the Netherlands, Research Reports, 1968–1974: 90–94, SHAGIR SAMA, P. van HALTEREN, KOESNANG M. SALEH.

Insecticide selection for stemborer and other rice insect control in Indonesia. (A).
Agricultural cooperation Indonesia- the Netherlands, Research Reports, 1968–1974: 63–72. P. Panudju, J. LEEUWANGH, S. SAMA, K. M. SALEH and P. van HALTEREN.

Response of rice, maize, sorghum, groundnut and soybean to foliage losses. (A).
Agricultural cooperation Indonesia the Netherlands, Research Reports 1968–1974: 185–189. KOESNANG M. SALEH, P. van HALTEREN and SHAGIR SAMA.

Pemberantasan hama padi dengan insectisida cara kapsul dan cara klei. (C).
Lembaga Penelitian Pertanian Maros, Bulletin **5**: 8 p. SHAGIR SAMA, P. van HALTEREN and KOESNANG.

Current status of brown planthopper infestations in South Sulawesi. (C).
Paper issued at IRRI Annual Conference, April 1975: 2 p. SHAGIR SAMA and P. van HALTEREN.

Screening varitas/galur padi terhadap penggerek batang. (B).
Lembaga Penelitian Pertanian Maros, Seminar, October 1975: 13 p. SHAGIR SAMA, M. NATSIR and P. van HALTEREN.

Severe infestations of the rice bug, *Leptocorisa acuta*, in Sulawesi, Indonesia. (C).
The rice Entomology Newsletter **2**: 5–6. P. van HALTEREN and SHAGIR SAMA.

Hasil penelitian tahun 1974/1975. (C).
Preliminary report LPPM: 28–42.

On yield losses of the rice seedbug, *Leptocorisa acuta*, in South Sulawesi. (B).
Lembaga Penelitian Pertanian Maros, Seminar, January 1976: 8 p. P. van HALTEREN.

Hasil penelitian tahun 1975/1976. (C).
Preliminary report LPPM: 28–42.

Green leafhopper infestation in South Sulawesi, Indonesia. (C).
The Rice Entomology Newsletter **4**: 5. P. S. RAO, SHAGIR SAMA, KOESNANG and P. van HALTEREN.

Laporan pengamatan serangan wereng padi di Kabupaten Gowa. (C).
Lembaga Penelitian Pertanian Maros, mimeograph 3 p. SHAGIR SAMA, P. S. RAO, KOESNANG and P. van HALTEREN.

Hama wereng dan penyakit virus padi di Sulawesi Selatan. (B).
Paper presented at seminar on brown planthopper, Jogyakarta, June 1976: 2 p. IBRAHIM MANWAN and SHAGIR SAMA.

Screening varietas/galur padi terhadap wereng coklat, *Nilaparvata lugens* Stal du rumah kaca. (B).
Lembaga Penelitian Pertanian Maros, Seminar October 1976: 14 p. MAMIEK SLAMET and WAFIAH AKIB.

The place of the root-zone application method in an integrated insect control program for rice in South Sulawesi, Indonesia. (A).
Paper presented at IRRI Annual Conference 1976: 15 p. P. van HALTEREN and SHAGIR SAMA.

Additional investigations on the application of insecticides to the root-zone of rice plants. (A).
Contr. Centr. Res. Inst. Agric. Bogor **18**: 15 p. SHAGIR SAMA and P. van HALTEREN.

Preliminary investigations concerning the biology of and the damage caused by the rice whorl maggot, *Hydrellia philippina* (Ephydridae, Diptera). (B).
Lembaga Penelitian Pertanian Maros, Seminar February 1977: 23 p. D. L. SCHUILING.

Insect population fluctuations in relation to crop growing and prospects of an insect-outbreak fore-casting system. (B).
Lembaga Penelitian Pertanian Maros, Seminar, April 1977. P. van HALTEREN and SYAMSUDDIN MAS.

Potential yields of rice crops, yield losses inflicted by insects and the problem of economic and critical thresholds. (B).
Lembaga Penelitian Pertanian Maros, Seminar, April 1977. P. van HALTEREN.

(A) widely distributed, also outside Indonesia
(B) limited, local distribution
(C) summary or short communication