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SPECIFIC EFFECTS OF CARBOFURAN ON RICE AGROECOSYSTEMS IN YOGYAKARTA PLANT GROWTH AND RICE STEM BORER POPULATIONS

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INTISARI

Penelitian bertujuan untuk mengetahui pengaruh karbofuran terhadap perkembangan hama penggerek batang padi dan musuh alaminya. Untuk itu telah diteliti pengaruh perlakuan dosis karbofuran dan kontrol pada padi sawah di Kalitirto-Sleman dan Sewon-Bantul Yogyakarta dengan varietas IR 64.

Hasil penelitian menunjukkan bahwa populasi larva pada tiap perlakuan karbofuran pada umumnya lebih tinggi dibandingkan kontrol tetapi tingkat serangan hama tidak berbeda nyata. Karbofuran tidak dapat menekan perkembangan populasi hama penggerek batang padi di lapangan, diduga karena menyebabkan pengaruh negatif terhadap musuh alami sehingga menimbulkan kematian parasitoid telur dan lainnya. Hal itu diketahui karena tingkat parasitasi telur pada plot-plot perlakuan karbofuran rata-rata lebih rendah dari pada kontrol sehingga menyebabkan populasi larva (L1) meningkat.

Untuk menunjang pelaksanaan program pengelolaan hama terpadu maka penggunaan karbofuran harus dilakukan secara bijaksana.

Kata kunci : Karbofuran, penggerek batang padi, Scirpophaga (= Triporyza) incertulas

ABSTRACT

The effectiveness of carbofuran in controlling lowland rice stem borers in traditional farming systems was studied by looking at its impact on the whole rice agroecosystem. Levels of infestation, rice yield, damage to the plant, parasitism rates, and distribution of damage were compared after medium, high, and no (control) dosages were applied to lowland rice fields near Yogyakarta, Indonesia. Although larvae were found to be more numerous in control plots, the damage attributable to them was not significantly different. Their spatial distribution, however, differed radically. The authors concluded that carbofuran might affect pest populations at two different levels: by discouraging or preventing rice stem borers from laying their eggs on rice, and by delaying or eliminating natural enemies' attacks on rice stem borers. Both levels were determined by comparing the distribution of damage in treated fields with untreated fields. In the treated fields, distributions of larvae seemed to reflect initial grouping of eggs, producing a random distribution of groups, while in the control fields larvae were found in random distribution of individuals.

Key words: Carbofuran, rice stem borers, *Scirpophaga (= Triporyza) incertulas*

INTRODUCTION

The use of systemic insecticides to control insect pests on rice has increased recently. In many South Eastern Asian countries, manual application of chemical pesticides in granular form is often said to be simpler, cheaper, easier and safer to carry out. It provide more uniform and longer lasting control than foliage sprays (Pathak and Dyck, 1973). Systemic chemicals are primarily absorbed through the plant roots and leaf sheets, and act as stomach poisons, but they may also move by capillary actions to act as contact poisons, or through their vapors by fumigation (Koyama, 1971; Pathak and Dyck, 1973).

In the Philippines, research at the International Rice Research Institute (IRRI) from 1969 to 1977 showed that systemic methyl-carbamate insecticides, particularly carbofuran, when applied to paddy soil, were effective against important rice pests such as whorl maggot, rice stem borers, brown plant hopper, and green leaf hopper. Treatments that place carbofuran within or near the root zone of the rice plant, encourage absorption through the roots and provide more effective and longer lasting control than that obtained by broadcast applications onto paddy water (Aquino and Pathak, 1976).

Carbofuran 3G is recommended to Indonesian farmers to control rice stem borers and brown plant hopper (Presidential Decree 3/1986; Wudianto, 1990). Carbofuran is a systemic and stomach poison carbamate insecticide used widely by farmers (Thompson, 1989). Field and laboratory studies on the absorption and translocation of carbofuran in rice plants were conducted by Ashworth & Sheets (1970); and Siddaramppa *et al.* (1979). Studies showed that roots zone application resulted in longer persistence of chemical in the soil and delayed translocation into the plant compared to broadcast application. In another laboratory study, Ferreira and Seiber (1978) demonstrated that concentration in the leaf portions of the plant 10 days after a root application reached significant proportions (32% of the whole product used). Concentration of carbofuran in the leaf tissue may help to provide effective control of foliar feeding insect. But some authors, like Ferreira & Seiber (1978) also noted that the product might be transpirated into the air through the leaf stomata, resulting a possible negative effect on flying natural enemies (e.g. egg parasites).

Negative effect of carbofuran to various species of natural enemies was reported by many authors. The decrease of natural enemies and other beneficial insects related to evaporation of carbofuran was demonstrated by Soekardi *et al.* (1977), and Khusakul *et al.* (1979). Kilin (1978) reported that carbofuran vapor was able to kill brown planthoppers and its predator, *Cytorrhinus lividipennis*. Carbofuran application through broadcasting method may decrease the egg parasitoids and repel natural enemies because of the toxic effect of its vapor (Nurbaeti *et al.*, 1992). Adisoemarto *et al.* (1977) observed that carbofuran treatments may cause population decrease in soil inhabiting organism, including worms.

The study of carbofuran to rice stem borers and their parasitoids and predators were also done in Yogyakarta, Indonesia during 1992 to 1994 by students of the Faculty of Agriculture, Gadjah Mada University (Entomology study program). Those studies showed that treatment of various carbofuran doses (0,5 - 1,0 kg active ingredient per hectare) has no significant effect on stem borers' egg population four weeks after transplanting (Supriyadi, 1992; Astuti, 1993; Purnaningsih, 1994).

An intensive survey was carried out during the wet season in the rice fields of Yogyakarta, Central Java and West Java to study the effect of carbofuran application. No significant difference was found on the rice pest and predator populations after one to three months application by the farmers, either in the intensive or in the non-intensive fields, although the non intensive area showed higher fauna diversity. Using carbofuran continuously may cause carbofuran to be accumulated in the soil. In turn carbofuran may affect soil organisms and their activities (Martono *et al.*, 1993). This study considers effect of chemical control of rice stem borers observed in farmers' rice fields of Java.

Species of rice stem borers appear successively throughout the rice cycle and the visible damage they cause may be great (Siwi, 1979; Reissig *et al.*, 1986). In Central Java, usually rice stem borers will start their attack during the early tillering stages of rice with the arrival of *Triporyza* spp., (*T. incertulas*, and *T. innotata*) (Mahrub and Pollet, 1993; Pollet *et al.*, 1992). Few weeks later, when plants become more mature, the structure of rice stem borer populations changes. *Triporyza* spp., are replaced by *Chilo* spp. (*C. supressalis, C. auricilius, C. polycchrysus*), followed by *Sesamia inferens* and ending with *Triporyza* spp., whose return to field marks the last phases of the plant growth (Mahrub and Pollet, 1993).

During early tillering periods of rice, rice stem borers' attacks often cause total death of stems and induce dead hearts. After this period but before the end of flowering periods, damage of rice by stem borers may reduce the number of viable seeds through the sterilization of flowers, which gives a more or less whitish aspect to the panicles (white heads: related to empty seeds) (Pollet 1992; Pollet *et al.* 1992; Mahrub and Pollet 1993).

In earlier studies interesting relationships between rice varieties and their pests were found (Mahrub and Pollet 1993), among them was varietal susceptibility to pest damage. It was also demonstrated that at maturity the number of tillers with panicles, observed near the harvest, depended entirely on direct stem damage which occured during early growth stages. The greater the damage, the larger the losses, although many modifying variables affect this general relationship (Pollet *et al.* 1992, Mahrub and Pollet 1993).

Carbofuran belongs to carbamate insecticide group. This plant systemic product was recommended for years in many tropical countries to control rice pests. Two qualities have made it very popular among communities of farmers and rice producers: very low mammalian oral and dermal toxicity and rather broad spectrum of insect control. In several instances this product can also be used as soil insecticide and nematicide. The recommended dose for rice stem borer is 34 kg/hectare. This can be applied either once, one day before planting; or twice, one day before planting and 3 weeks later. There are always few questions left concerning the whole action performed by such a product when applied in a given agroecosystem. The writers investigated this problem in Yogyakarta for almost four years. Here they report the preliminary results of studies obtained in the first two years.

MATERIALS AND METHODS

Studies of the effects of carbofuran were conducted at two different sites, both located near the town of Yogyakarta: farmers' fields at Bantul and experimental UGM farm at Kalitirto. Both locations have the same climatic condition. Mean temperatures remain high the whole year, 25 to 29° Centigrade or above. There is no prolonged dry season, and although important variations may be observed year to year, Yogyakarta has a long rainy season (October - March) and a long dry season (April - September).

In both Bantul and Kalitirto, the effects of carbofuran on the rice agroecosystem were studied using rice variety of 'IR64', which is very common in Indonesia. Studies were carried out through completely randomized design. Three different treatments were tested, each replicated three times (subplots of 300 m^2). Those were carbofuran 3G applied twice (2*17 kg/hectare), 1 day before transplanting and then 3 weeks after; carbofuran 3G applied once, 1 day before transplanting (34 kg/hectare); and no carbofuran applied. No other pesticide was used.

The same sampling procedure was conducted weekly at the two locations, starting in all subplots 10 days after first transplanting, and ending at the harvest.

Transplanting and harvesting dates were done respectively at Kalitirto October 24, 1991 and February 6, 1992, and at Bantul November 28, 1991 and March 7, 1992.

The same sampling procedures were carried out at the two locations. Numbers of stems and panicles (green or ripe), dead hearts and white heads were calculated weekly from 60 rice hills per subplot. Living larvae, pupae and adults taken from the sampling were all reared in laboratory to study their mortality rates and to obtain data concerning their natural enemies and mortality rates at various stages. Both seed production and number of panicles per hill were estimated a few days before harvest in the different subplots.

Overall action of carbofuran on rice stem borers was studied in analyzing distribution of observed damage on hills.The first larval stage (L1) initiate their attack by selecting and boring into the stems, most of which are located a short distance from the mass of eggs from which the larvae hatched. Depending of the initial mortality of eggs and larvae, there will be hills with 0, or 1, or 2, or 3, ..., or n damage.

Since *Triporyza* egg masses usually comprise a large number of eggs (20 or more, see fig. 7), it can be expected that if little or no mortality of eggs occurs, damage resulting from larvae would be contagiously distributed around the different egg-laying sites. In that case variance of data is greater than their mean. Few contagious laws can be used to describe such data. The negative binomial has been successfully fitted with many contagious invertebrate populations and appears to have a wide application, but there is always a possibility than other models describe the data better than negative binomial.

On the other hand, whenever mortality of eggs and/or young larvae increase, the distribution of larval damage may completely change. Mean and variance may become equal to each other and Poisson law may thus happen to fit the data best. Both possibilities are illustrated in Fig. 1.

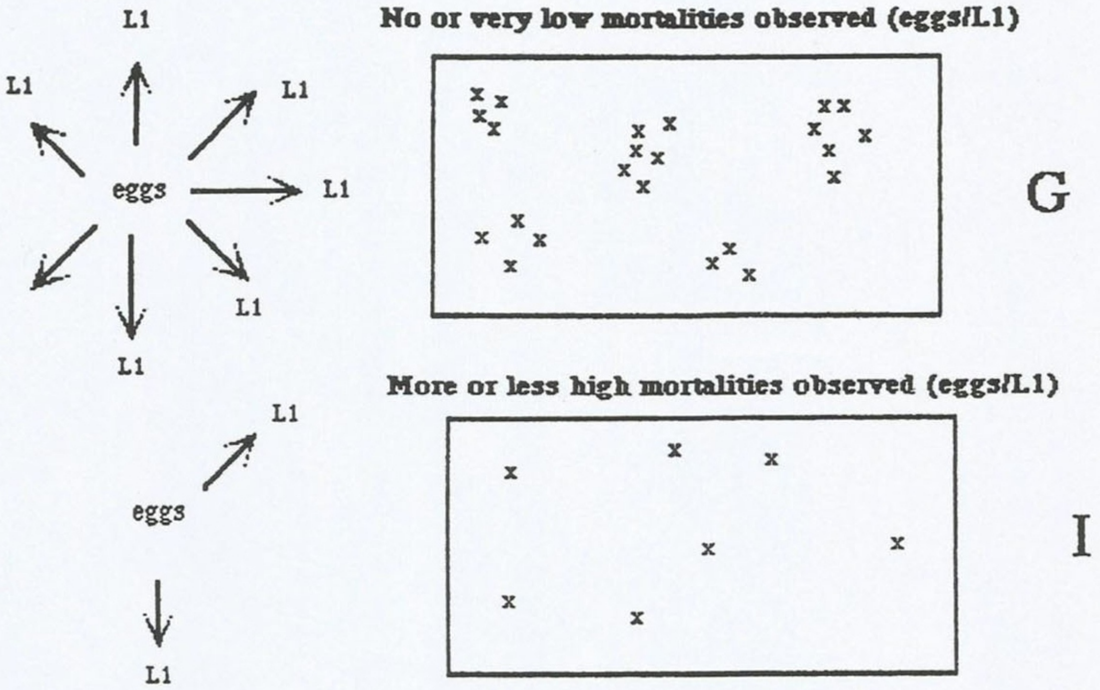


Fig. 1. Possible infestation patterns of rice hills related to mortality of individuals (eggs, L1) (after Pollet 1993)

These two possible distributions were applied to data collected at the two places during the rainy season of 1991-1992. For example at Kalitirto, on December 5, 13, and 19, 1991; groups of hills were sampled in each treatment plots (double dosages, single dosages, and control), i.e. 10 hills per subplot. All hills were kept separated, and stem damage for each hill was recorded. Numbers of hills that could be characterized by 0,1,2,3, ..., or n damage for each treatment were estimated on each sampling day. Fitting the most appropriate distribution was done by using standard procedure (Bliss & Fisher 1953; Elliot 1977; Pollet,1993; Pollet & Nasrullah, 1994).

RESULTS AND DISCUSIONS

Effect of Carbofuran 3G on numbers of tillers and panicles

Any significant phytotoxic effect that could be attributed to carbofuran was not observed. Conversely, the writers were unable to observe any positive actions on rice growth, as Venugopal and Litsinger did in 1980. Total numbers of stems, as well as variations in their seasonal curves, were not significantly different from each other for any of the three treatments: F tests Bantul, dosage effects (*F*=1,54,; df = 2,22; *P*>0,25); F tests Kalitirto, dosage effect (*F*= 0,65; df = 2,24; *P*>0,25). Near harvest, the writers were also unable to find any significant relationship linking treatments to numbers of panicles per rice hill as shown by the negative result obtained when trying to analyze 20 hills sampled in each subplot a few days before harvesting. Although control plots seemed to provide a slightly greater numbers of panicles, this is not really significant. As shown in Table 1, neither the nature of the treatments nor their frequency seemed to have had any noticeable effects on the numbers of panicles: F tests Bantul, dosage effects (*F* = 1.11; df = 3,175; *P*>0.25).

Table 1. Mean numbers of panicles per rice hills, one week before harvest.

Application	Mean number panicles
control	16.47 a
double	15.72 a
single	16.47 a

Effects of Carbofuran 3G on stem infestations and yields of rice

Occasionally at Bantul, treated fields seemed to show greater rice stem borer damage than control fields with some of their damage curves falling above the control curves (Fig. 2, see January 4 to February 18). But the real observable differences between treatments when tested by ANOVA were not found significant: F tests Bantul, dosage effects (*F*=1.21,; df = 2,22; *P* > 0,25); F tests Kalitirto, dosage effects (*F*=2.58; df 2,10; *P*> 0.10). For both locations days of sampling were to play the only major role in determining the levels of damage: F tests Bantul, dosage effects (*F*=6.55,; df = 11,22; *P*< 0,005); F tests Kalitirto, dosage effects (*F*=8.89; df = 5,10; *P*<0.005).

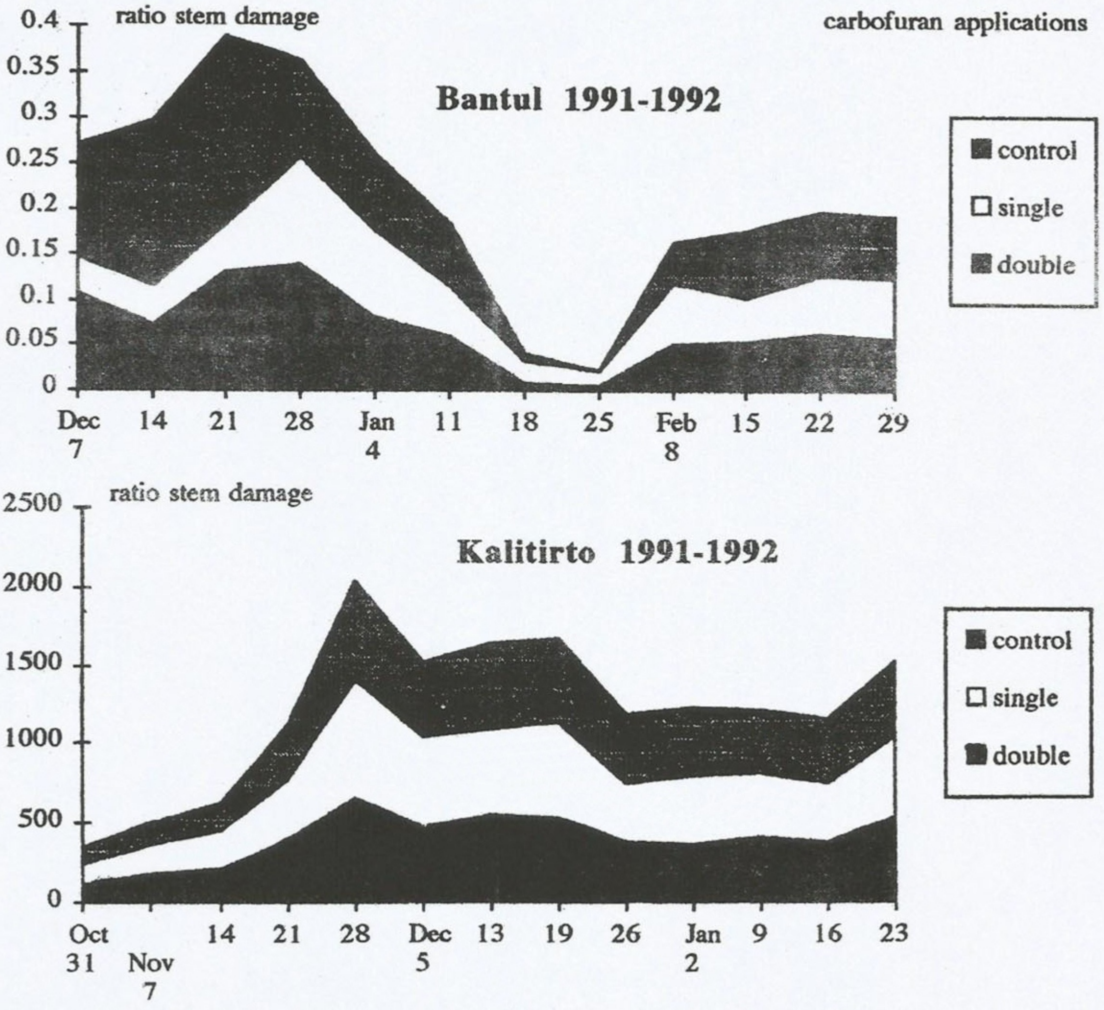


Fig. 2. Seasonal variations of stem infestations rates observed weekly at Bantul and Kalitirto (sampling started on December 7, rainy season 1991/1992).

No dosage tested had any measurable effect in determining the yields of studied plots. Thus at Bantul there writers were unable to show any differences between the three treatments tested (no significant effects of treatments), and there were no more any significant field effects: dosage effects ($F = 1.54$; df = 3,6;P near 0.25), field effects ($F = 0.42$; df = 2,6; P near 0.25). At Kalitirto, although there were significant field effects carbofuran treatments and control were no longer different: dosages effects ($F = 2.01$; df = 3,24; $P > 0.15$); field effects (heterogeneity test) ($F = 10.13$; df = 2,24; $P < 0.005$). Such heterogenecity between plots might have been a major contributor to the variations observed between the damage curves.

Such results are all the more surprising, because populations of rice stem borers larvae at Bantul were larger in control than they were in any of the other two treatments studied. Thus, for instances, when considering both total levels (Table 2) and seasonal variations of their rice stem borers (Fig. 3), it could be reasonably expected that the control plots might be more damaged than others, but that was not true. Although they had the highest populations of rice stem borers, stems from control plots showed no more damage than those sampled in any of all treated plots. Similar result were also observed on the yields from all Bantul plots (Fig.2).

Table 2. Total rice stem borers populations sample
for the whole period, Bantul, Rainy seaso
1991-1992

RSB species	Applications		
	double	single	control
Scirpophaga incertulas *(Tryporyza incertulas)*	265	228	405
Chilo sp	30	72	64
Sesamia sp	10	29	28
Sum	305	329	497

Effects of Carbofuran 3G on rice stem bore populations

Populations of rice stem borers larva sampled in treated plots and control, as well as th ratio among species involved and their seasona variations, were quite different from each other (Fig 3 and Table 2).

When comparing distributions of all larvae (mainly *T. incertulas*), the writers obtained quite different figures. During most of the rice cycle especially from the growing through the end of the flowering phases, pest populations in control plots were slightly less important than those in any of the treated plots (Fig. 4.). As shown by many authors this period, which in graph usually runs from December 28 to February 18, is the "producing phase" of rice, i.e. the one which will usually determine the future yield of the rice field. Before and after this specific time, damage to the plants will have no noticeable effect on production (Pollet 1980).

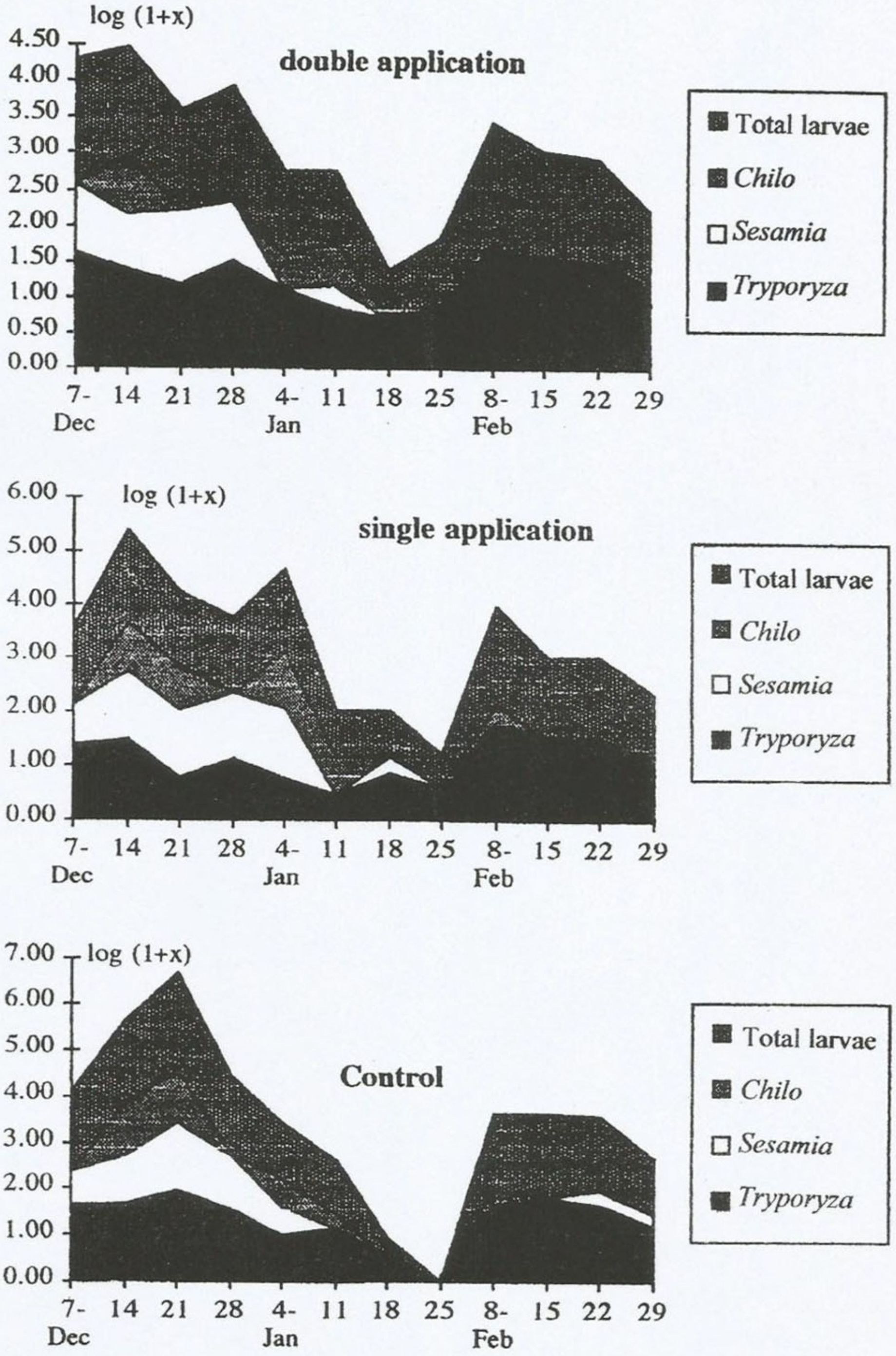


Fig. 3. Seasonal variations of stem borers larval populations at Bantul (weekly sampling started on December 7, rainy season 1991/1992).

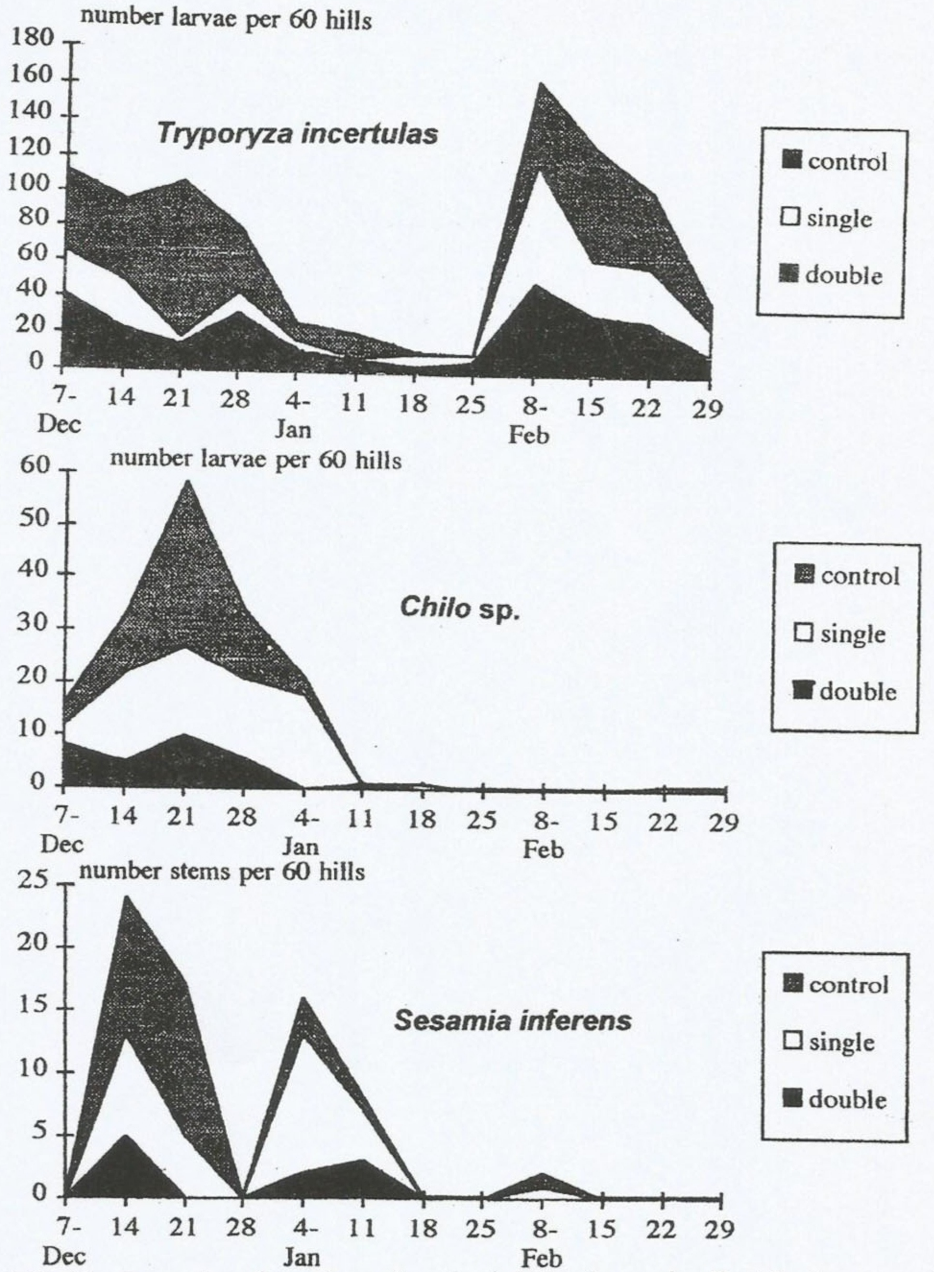


Fig. 4. Weekly observation of stem borers larval population, by species, Bantul, rainy season 1991/1992.

Effects of Carbofuran 3G on natural enemies of rice stem borers

Changes in rice stem borers populations and concomitant rice stem borers damage to fields may be explained by our study of the natural enemies of rice stem borers, which clearly showed that carbofuran treatments reduced the parasitism rates of rice stem borers larvae mostly *T. incertulas* (Fig. 5 and 8).

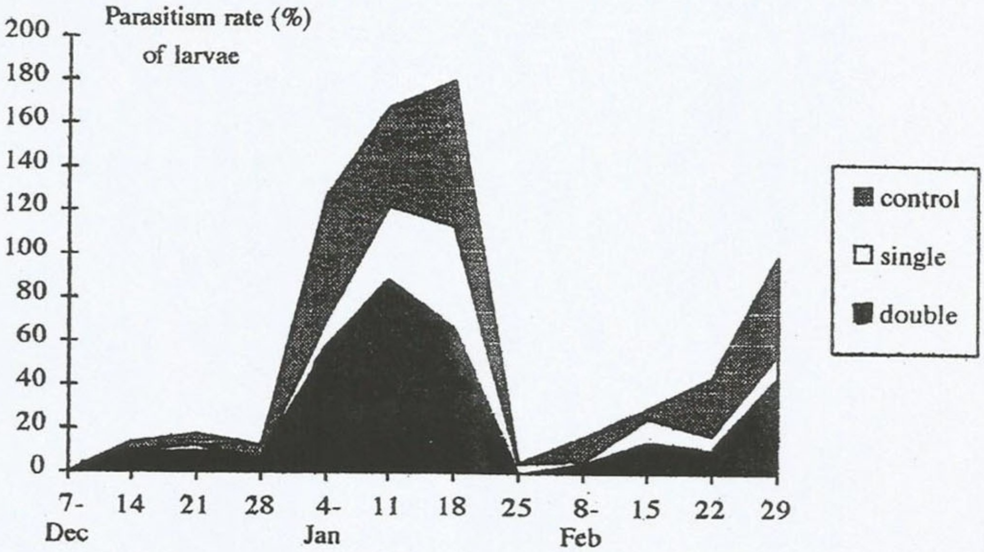


Fig. 5. Seasonal variation of parasitism rates of larvae, weekly registered on 'IR64', at Bantul for the whole species of rice stem borers, in case of the 4 treatments studied (rainy season 1991/1992).

For example, in the case of *Triporyza incertulas*, which was the most numerous species of rice stem borers found in three out of the four treatments considered, carbofuran applications at all dosages tested completely changed the structures and levels of the natural enemies. When the product was applied at any of the three dosages tested, it generally seemed to depress parasitism rates of egg masses with the result that greater numbers of L1 hatched in treated plots than in control plots (Figs 6 and 8).

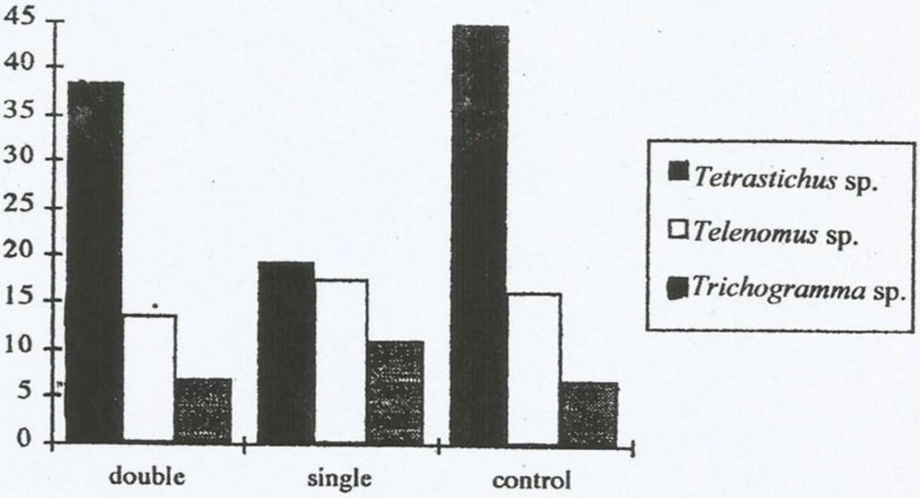
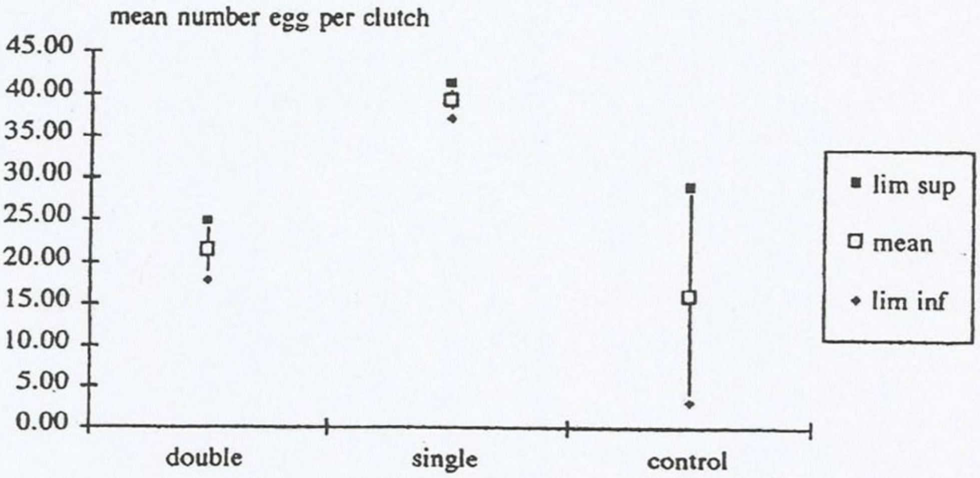


Fig. 6. Total egg parasitism rates of *T. incertulas* and species involved, registered on 'IR64' at Bantul, for the 3 treatments studied. (rainy season 1991/1992).



Figs. 7. Mean numbers of L1 per egg-masses registered on 'IR64' at Bantul for the 3 treatments studied (rainy season 1991/1992).

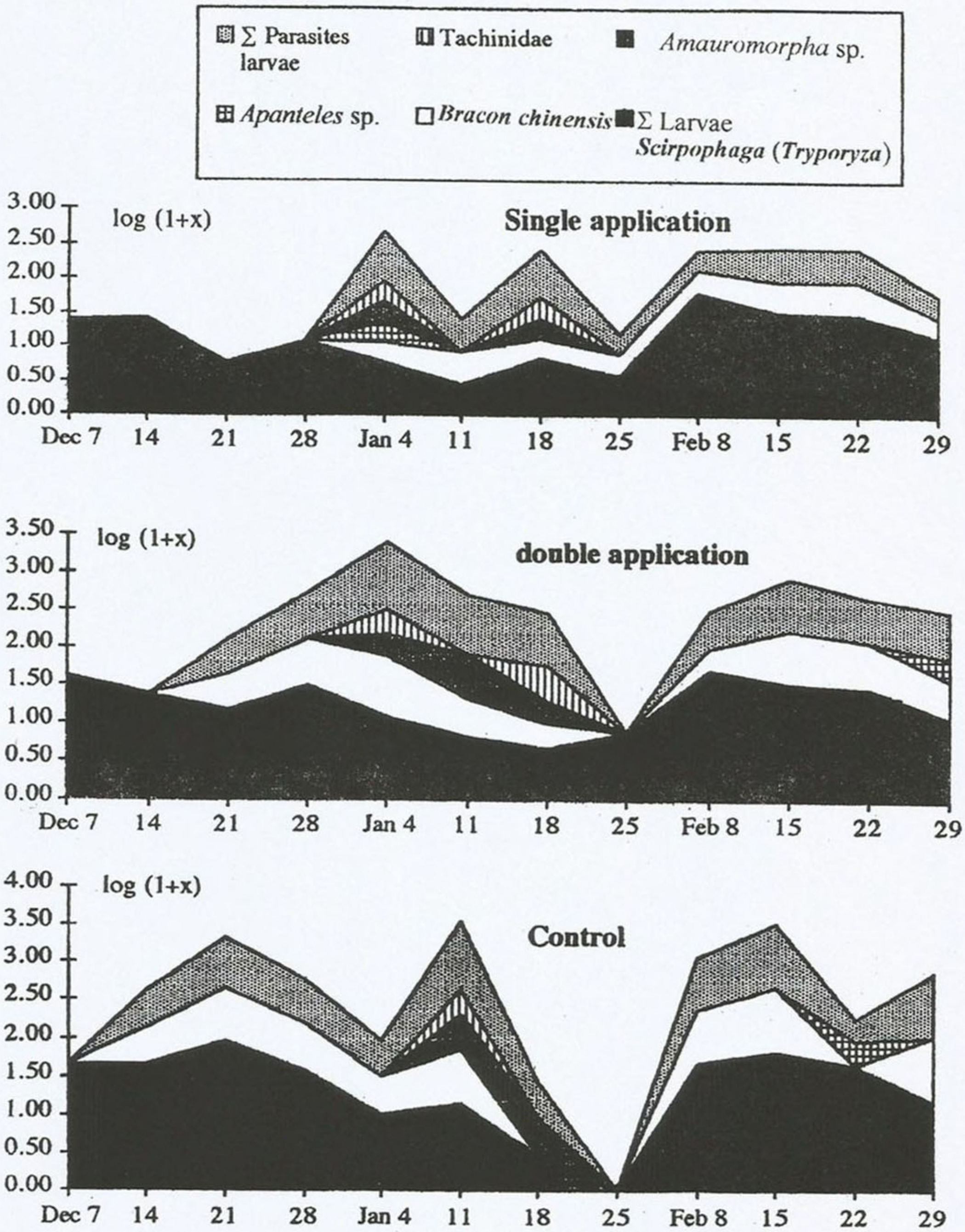
Study of the parasites of larvae of *T. incertulas* led to another interesting conclusions. The product soon changed the structure of the whole pest/natural enemy system. The ratio and distribution of species changed, carbofuran delaying the attacks of larval parasites until the third week (single) or the fifth week (double), while in the control plots the first parasitized larvae were observed as early as the second week (Figs 8). The larger the dosages tested, the more delayed the attack and the arrival.

Statistical approaches to the effects of carbofuran 3G on stem infestations of rice stem borers

The 3 days of sampling having been done to compare distribution of data in different treated plots, provided us not exactly the same kind of results. For example, for the second day, i.e. two week after planting, all treated fields showed much smaller mortality of eggs and L1 than controls, mainly because, as shown in Table 3, treatments showed contagious distribution of damage (type G,Fig. 1) (fitting of data to negative binomial laws = low mortality rates of eggs/L1); while controls exhibited mostly singular distribution of stem damage (type I, Fig. 1) (fitting of data to Poisson law = high mortality rates of eggs/L1).

Data sampled on December 13, showed real intermediate and transitional steps between those obtained on December 5 and further on December 19. As shown in Table 4, carbofuran seemed to have delayed action of natural mortality factors. Poisson distribution of damage which might be related to higher mortality of eggs and L1 (Type I, Fig. 1.), could be noticed in control sooner than in other plots. But the third day (December 19), in any cases all data were fitted better by Poisson (Table 4),

Those results also verify previous results presented in Figure 8. Because of the treatments, any effects of natural control factors in the treated plots were delayed.



Figs. 8. Larvae of *T. incertulas* and their corresponding parasites, weekly measured on 'IR64' at Bantul, for the four treatments (rainy season 1991/1992). (Sum of all *Triporyza* larvae and corresponding parasites, i.e. *Amauromorpha* sp., *Apantheles* sp./*Rhaconotus* sp.; *Bracon chinenesis; Tachinidae).*

Table 3. Observed distribution of stem damage in treated plots and control, on December 13, 1991. The expected frequencies for the negative binomial and the Poisson were computed independently for each treatment with the statistics given in the bottom of the table[Chi², P(Chi²)] and corresponding k for the negative binomial). In case of control since k > 5, n' was computed by using transformed value x'i as follows.

$$x'_i \rightarrow \sinh^{-1}\sqrt{\frac{xi + 0.375}{k-2*0.375}} \text{ (after Elliot. 1977)}$$

No stem damage per	double			single			control		
unit sampling	Obs.	Neg.bin	Poisson	Obs.	Neg.bin	Poisson	Obs.	Neg.bin	Poisson
x	n	n'	n"	n	n'	n"	n	n'	n"
0	13	14.40	12.20	11	10.43	6.69	11	22.98	10.32
1	13	8.73	10.98	6	8.05	10.04	9	5.37	11.01
2	1	4.07	4.94	7	5.06	7.53	7	1.13	5.87
3	2	1.71	1.48	3	2.94	3.76	3	0.22	2.09
4	0	0.68	0.33	1	1.64	1.41			
5	0	0.26	0.06	1	0.89	0.42			
6	1	0.10	0.01	0	0.47	0.11			
7				1	0.25	0.02			
Sum	30	29.95	30.00	30	29.73	29.98	30	29.70	29.30
Chi²		4.59	4.64		1.29	5.14		73.45	1.02
P(Chi²)		0.248	0.137		0.23	0.07		<0.005	0.85
k		0.57			1.59			16.78	

Table 4. Distribution of damage correlated to nature of plots tested and timing of sampling, studied 1, 2,and 3 weeks after planting

	Best fitting of data		
Sampling d	double	single	control
December 5	negative binomial	negative binomial	negative binomial
December 12	negative binomial	negative binomial	Poisson
December 19	Poisson	Poisson	Poisson

CONCLUSIONS

The pesticide tested in this study affected the whole "rice plants-pests-natural enemies" system and not just the rice stem borers as its intended target. The fact was equally true at both places studied, Kalitirto and Bantul, during the rainy season 1991/1992.

No phytotoxic effects of the product that changed the result of carbofuran action could be observed. But any positive effect on the growth of treated rice were not noticed either, contrary to the findings of Venugopal and Litsinger (1980), who found that carbofuran produced greater root development in rice seedlings, enhancement of plant height, more rapid maturation of panicles, and noticeably increased yields, at least in greenhouse-grown plants.

The writers also failed to show that carbofuran could always be used and recommended to control populations of rice stem borers. Significant differences in the ratio of stem damage between treated and control fields in the two test sites could not be noticed either. Both places led us to exactly the same conclusions: when used at commercial levels, carbofuran did not reduce rice stem borers damage to the plants.

In fact, when used at commercial dosages, carbofuran did not seem to inhibit efficiently the growth of rice pests. Either by killing many natural enemies (almost all the flying ones) or by delaying the attacks of others, carbofuran might instead contribute to the increases of those pest populations *living in traditional farming systems*. In carbofuran treated fields, general mortality of eggs decreased, which resulted later in more larvae and plant damage which appeared to be contagiously distributed in the fields (fitting of observed data with negative binomial); whereas in control fields, Poisson distributions of damage were observed, which one would be expected as the main consequence of high egg mortality rate. Population levels of stem borers were generally higher in controls than they were in any one of the treated fields. This might be possibly the result of a combination of the following two main effects of carbofuran: 1) repellent and/or toxic effects of carbofuran on female rice stem borers, which virtually prevent them from laying their eggs on rice, as indicated by lower densities of egg masses on treated rice area compared to control; 2) toxic effect of carbofuran on natural enemies of rice stem borers, which were indicated by lower mortality of rice stem borers eggs and L1 on treated rice than in control.

This is not the first time that such situations, which challenge the usefulness of the systematic application of carbofuran, have been concluded in Indonesia. Our latest studies also give us the same kind of results. Quite similar results were obtained in West Africa (Cote d'Ivoire), years ago (Pollet, 1975-1981). At that time, while studying the control of pests of 'IR5','CS6' and 'Jaya' rice varieties by using the product at commercial dosages, it could be even found that treated fields seemed to be attacked more often that controls. Although data were not always statistically significant, plots with carbofuran had the largest populations of larvae as well as the smallest yields (Pollet, 1980).

Such results challenge the assumption that carbofuran in any cases, is almost useful to control of rice stem borers. When tested at a commercial dosages to control pest of rice, effectiveness of the product is not always clearly proven.

Management of pesticides is rapidly becoming, one the major concern of all rice cultivation systems. Farmers and scientists throughout the world are recommending a reduction in pesticide uses. As stated in a recent FAO (Kenmore, 1991):

1)...."Reducing pesticide uses in tropical rice fields actually increases production while simultaneously protecting the environment"........

2)...."The pesticide made the crops more vulnerable to parasites attacks ...."

In Indonesia, since the early 1980's, average pesticide used in the country has been reduced from four applications per season to less than one. In 1986 a ban was even put on 57 of 63 pesticides that were used on rice, but in the meantime rice yields increased 10% (Jakarta Post News, 1992).

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