HOW RICE FARMERS CLEAN UP THE ENVIRONMENT CONSERVE BIODIVERSITY, RAISE MORE FOOD, MAKE HIGHER PROFITS

Indonesia's IPM - A Model for Asia

PENGENDALIAN HAMA TERPADU
PROGRAM NASIONAL

FAO
FIAT PANIS

Indonesia's Integrated Pest Management - A Model for Asia

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PROLOGUE:

The political stability and economic development of Asia depend more on an assured supply of rice than any other factor endogenous to Asia. With that supply, real development can start. The emergence of the world's first national scale market economy — in southern China during the Song Dynasty about 1000 years ago— was triggered after short duration photoperiod insensitive rice varieties were brought and distributed — by government policy — from Vietnam (Barker and Herdt 1985). These varieties and their management practices — also extended to farmers by government policy — allowed two crops of rice where only one grew before (Bray 1982). In the Green Revolution that followed south China outgrew north China for more than 500 sustainable years. One peripheral side effect of the market engine powering that take off was the gradual integration of tiny towns far to the west, by slow boat and caravan, into their first world economic system; this integration in turn fueled the Italian Renaissance (McNeill 1982).

Rice supply is not the sole factor in Asian development, but without that supply governments dissolve, market trade collapses, the environment is plundered, and development degenerates to survival. Total rice production in an Asian market locality is not a sufficient guarantee of supply to the people living there (Sen 1981) but it is a necessary precondition. Asian self-sufficiency in rice has been taken for granted for about 20 years, with total production from the mid 1960s through the early 1980s staying ahead of population growth by a comfortable margin. For the bulk of Asia that is tropical and sub-tropical much of that margin came from production advances in irrigated rice systems pioneered in the Philippines at the International Rice Research Institute. It is particularly disturbing that recent work by the Program Leader for Irrigated Rice Ecosystems at IRRI and his colleagues shows persuasively that:

* rice production has been tapering off, with growth rates falling from 4% per year to 2.24% per year (dangerously close to population growth and estimated 1990s growth rates of demand of 2.1 - 2.6% per year) in intensified rice growing Asia (Rosegrant and Pingali 1991), and

* yields on research stations have not only **not** exceeded ceilings achieved more than twenty years ago, but the highest yields obtainable on these stations have been falling steadily (Pingali et al. 1990; Pingali 1991).

The major determinant of declining yields identified by Pingali and colleagues is **environmental degradation** caused by intensive rice monoculture. Building on and extending the results of Flinn and co-workers (Flinn et al. 1982, Flinn and DeDatta 1984) Pingali et al. (1990) show that the yields of the highest yielding entry variety in IRRI's long term fertility trials declined by over 1.25% per year from 1966 through 1987. The comparable yields at the three major Philippine rice research stations have either declined (from .38 to 1.01% per year depending on wet or dry season) or remained essentially stagnant (growth less than .2 % per year) (Figure 1).

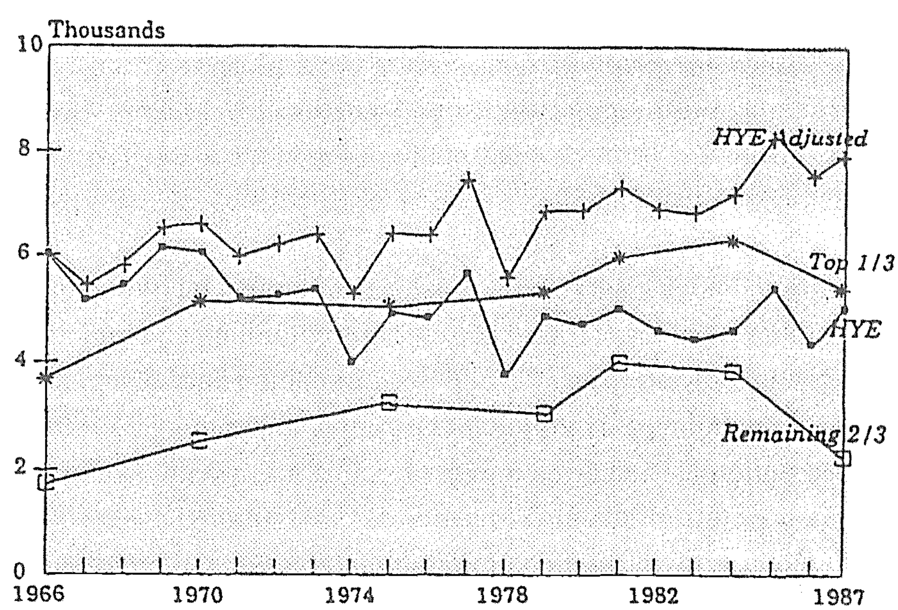


Figure 1. *Trends in highest yielding entry (HYE) at IRRI Farm and Farmers' Yields, Philippines. HYE Adjusted = effect of environmental degradation removed statistically. Top 1/3 and Remaining 2/3 are the means of two corresponding subsets of farmers in Laguna Loop survey. From Pingali et al. 1990.*

The only variety planted in all these trails was IR8, which was the highest yielding entry in 1966 and, though its yield then has not been exceeded, its subsequent yields have declined more precipitously (over 5% per year) than those of each year's new highest yielding entries(Figure 2). Using the drop in IR8 yields as a proxy for the accumulating degradation of the paddy environment — because the genetic composition is presumed to remain about the same across years — and correcting the highest yielding entry each year by this factor allows the authors to conclude that highest yields would have been increasing from .66 % up to 4.6% per year depending on season and location. Degradation of the paddy environment, whether by micro-nutrient depletion, atmospheric pollution, pest pressure, or accumulative toxic changes in soil chemistry, is greater than the capacity for genetic improvements in yield potential that breeders can select. The negative environmental consequence of intensified rice production speeded the depreciation of investment in applied genetic diversity that was the high yielding varieties.

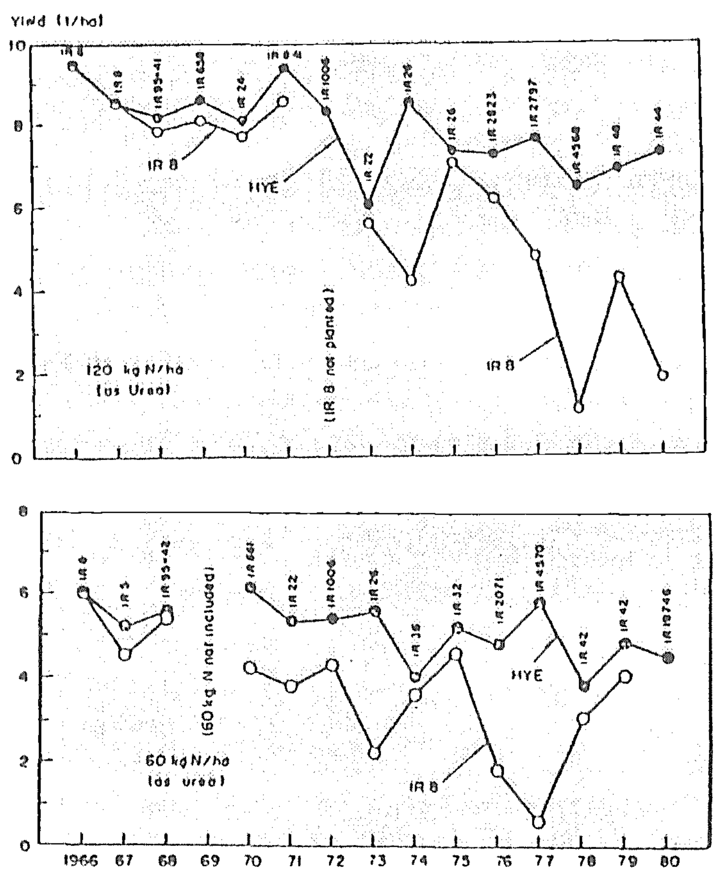


Figure 2. *Yield trends for dry (top) and wet (bottom) season plantings for IR8 and highest yielding entry (HYE), nitrogen response experiments, IRRI farm. From Flinn et al. 1982.*

The same group has examined irrigation infrastructure investment and upper watershed degradation. Between the late 1970s and late 1980s, donor lending in irrigation infrastructure declined by more than 60%, and consequent national investment in construction and maintenance fell sharply (Rosegrant and Pingali 1990, Rosegrant and Pasandaran 1990). For the same period, using a data set from the twelve regions of the Philippines, Pingali et al. (1991) showed that forest production and mineral production in upper watershed areas had significantly negative effects on irrigated rice areas in the same region, while real maintenance expenditures had significant positive effects. Irrigation infrastructure is not a fixed investment; without maintenance and in the presence of exacerbated soil runoff and consequent sedimentation, irrigated areas shrink.

This group has identified one source of yield increase: **expert farmers**. The Laguna loop survey of farmers in the province surrounding IRRI has also been carried out at intervals since 1966. Farmers' yields in that generation have not declined(see Figure 1). The top one-third of the farmers began with an average yield more than 2 tons below IRRI's highest. By 1978 their average yield equalled IRRI's highest entry, and by the late 1980s they were more than one ton higher. The bottom two-thirds of the farmers started with yields about 4 tons below IRRI's. By the end of the study period, their yields had closed to less than 2 tons. The fertility trial data refer to a standard set of management conditions across years, whereas farmers innovated and improved — spectacularly. The yield gap between IRRI and farmers was smaller than the yield gap between the top group of farmers and the rest. The major sources of this gap are suggested to be differential farmer abilities and differential access to irrigation water.

The authors then suggest that it would be a serious mistake to abandon training of farmers (beginning through extension systems) under the presumption that since seeds and fertilizers have been well distributed along with fixed "impact points" to most of the irrigated rice farmers that is enough to ensure rice production. Since there are no "silver bullets" wrapped in the seed-fertilizer technology for the foreseeable future, and the yield gaps that can be demonstrated empirically are among farmers themselves, "training programs become particularly important as the incremental gains in productivity are achieved by adopting .... 'second generation technologies' (such as better fertilizer incorporation technologies, integrated pest management, etc.) ... more knowledge-intensive and location-specific than the modern seed-fertilizer technology that was characteristic of the green revolution." (Pingali et al. 1990).

The conclusions of this broad reaching work of Pingali and colleagues are sobering. Without significant increases in irrigation spending, a halt to upper watershed destruction, a genetic breakthrough raising the irrigated yield ceiling found on lands with the longest , and/or paddy level interventions to reverse long term yield reducing environmental degradation, the agro-ecological vehicles delivering increases in Asia's rice supply for the past 25 years — intensified irrigated production systems or "rice bowls"— will grind closer and closer to a halt. Against this agenda, one group of champions emerges: **"farmers who have the ability to learn about the new technologies, discriminate among technologies offered to them by the research system, adapt the technologies to their particular environmental conditions, and provide supervision input to ensure the appropriate application of the technology."** (Pingali et al. 1990).

INTRODUCTION:

This paper is a case study of the production and environmental consequences of policy decisions by the government of Indonesia, the world's fifth most populous country and its third largest rice producer. In this paper the "agriculture" and the "environment" viewpoints are not just complementary; they are inseperable. Ecological research is used to explain paradoxical agronomic field results and to make agricultural policy recommendations. A policy constituency coalesced around these recommendations and mustered, repeatedly, the political will to implement them. These recommendations led to production and profitability increases that are demonstrably more sustainable — economically, energetically, and in terms of preserving biodiversity — than alternatives. The overall benefits of the policy are still accruing, but an international review team recently estimated them at well over a billion dollars (Whitten et al. 1990).

The specific role of the programme executing team - Government, NGOs, FAO and USAID, has been concrete, constructive, and creative. Sustainability in a program context is not the creation and perpetuation of bureaucratic entities; it is the delivery of benefits to ultimate users. The team'sefforts are directed towards those users: farmers and field level extension workers who are mandated to work directly with farmers in their fields.

The case is immediately generalizable. A brief review of current situations in Thailand, Vietnam, Malaysia, Sri Lanka, and Philippines will suggest strongly that the Indonesian field scenario is being repeated now in each of these countries. The difference in the policy environment is that Indonesia is available as a model of what can go right, given the right choices and the political will to sustain those choices.

PRODUCTION:

After achieving self-sufficiency in rice in 1984, relying on the green revolution rice bowl technology described above, Indonesia was faced almost immediately with ecological consequences of that intensification. The rice brown planthopper, which had cost Indonesia nearly one billion dollars in the late 1970s and caused the country to remain the world's largest rice importer, exploded in 1986 over North Sumatra, Central Java, Yogjakarta, and parts of East Java, and was beginning to threaten West Java. Well over 50% of Java's rice land was planted to varieties that the brown planthopper had evolved the ability to feed on voraciously. Insecticide subsidies had already exceeded US $ 128 million per year, and no control of brown planthoppers by these chemicals was achieved.

Instead of simply pouring on more chemicals or frantically multiplying another rice variety of uncertain agronomic potential and unproven profitability to farmers but with one more gene for brown planthopper resistance, the Government of Indonesia made a profound shift — Presidential Instruction 3/86 — with rich positive consequences for the profitability and the sustainability of rice farming in that country. The national IPM Policy was built on ecological science underlying agronomic science, was carried to maturity by pragmatic macro-economics, and was fulfilled through an empowering, participatory approach to motivating people for action. As it was challenged in the relentless arena of each rice growing season after season, the policy's makers bet more and more heavily on the champions of knowledge-intensive post green revolution technologies: **farmers as experts.**

Getting Policies Right: Building on Ecology and Courage

In 1970 Indonesia had only 10% of its rice area in modern varieties, and brown planthopper was not considered a pest. Indonesia's first policies on rice crop protection were strictly conventional, but on a characteristically impressive scale (Hansen 1978). In the Bimas Gotong Royong program of the late 1960s and early 1970s different multinational chemical companies were given contracts to treat tens of thousands of hectares of rice with aerial applications of organophosphate insecticide. The program eventually collapsed when farmers refused to pay for the package of services, but insecticides had been resoundingly introduced with full government (and international donor) support.

The first indications of population changes in brown planthopper came from field surveys in 1970 and 1971 of sub-districts in West Java with different levels of rice stemborer damage (Soeharjan 1972). Only those subdistricts where farmers themselves use insecticides had heavy stemborer pressure, and in those fields brown planthopper densities were ten times higher than in other fields where insecticides were not used. With the release of locally bred high-yielding varieties, the government's BIMAS program bundled credit, fertilizers, and pesticides. As production went up, so did brown planthopper infestation(Figure 3). An alarming increase in Java in 1975 — after the government first subsidized insecticides directly — saw brown planthopper losses exceed 44% of Indonesia's annual rice imports(Figure 4) . This upsurge led to government aerial applications in 1976 of ultra low volume formulations of insecticide. These allowed huge areas to be treated with small amounts of formulated product, and was followed through 1977 by the largest annual loss to brown planthopper so far recorded in any country in history: over a million tons of rice or enough to feed more than 2.5 million people.

HECTARAGE INFESTED BY BROWN PLANTHOPPER INDONESIA 1974-86

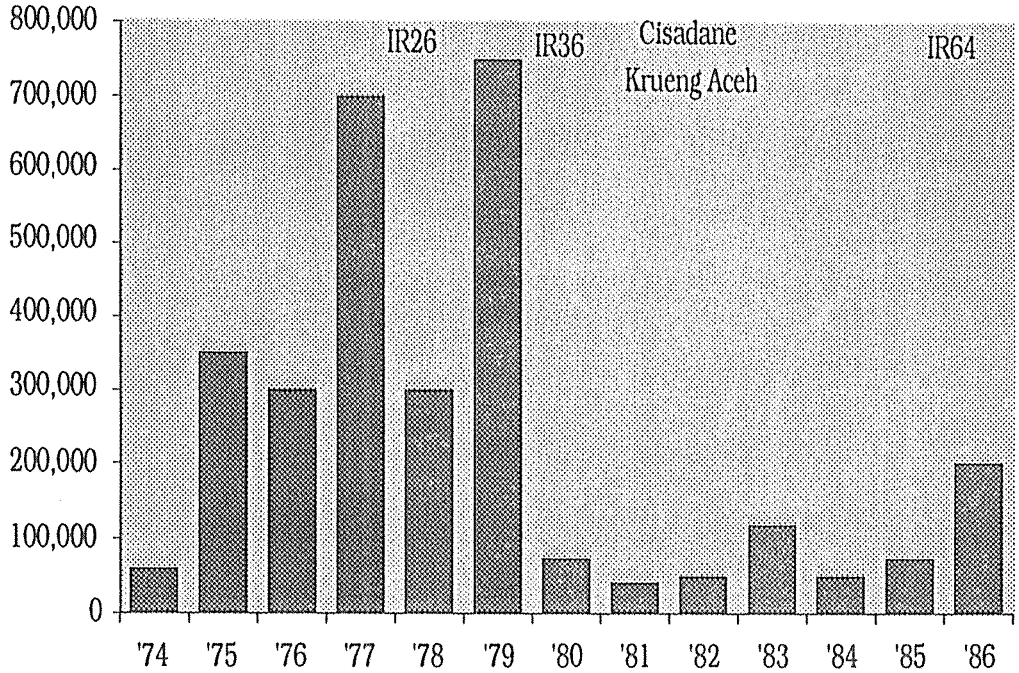


Figure 3.

IMPORTS OF MILLED RICE ('000 t), INDONESIA 1974-86

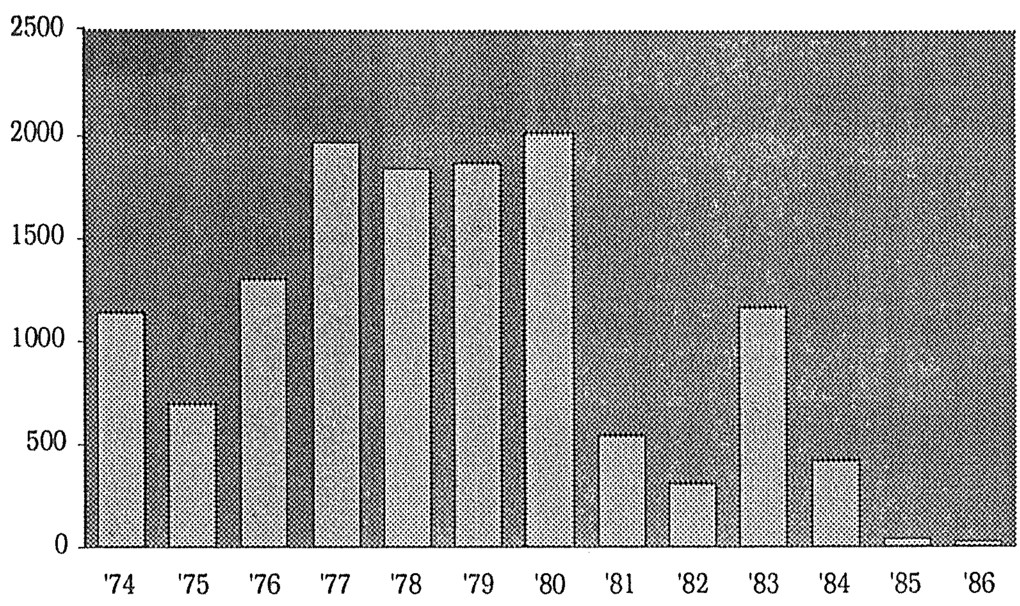


Figure 4.

The sequence of events is less paradoxical in retrospect, and with results from population ecological field research (Kenmore 1980, Kenmore et al. 1984, Ooi 1988, Whitten et al. 1990). The brown planthopper is kept under complete biological population control in intensified rice production fields that are not treated with insecticides. When immigration increases, even over 1000 reproducing adults per square meter, the numerical responses of indigenous natural enemy species exert such massive mortality on the population that densities go down and rice yield is unaffected. (Tables 1 & 2, Figure 5). Insecticide applications disrupt that natural control, survival increases by more than ten times, and compound interest expansion then leads to hundreds of times higher densities within the duration of one rice crop. Trying to control such a population outbreak with insecticides is like pouring kerosene on a housefire.

Field Survival of Brown Planthopper
High Immigration Pressure

Stage	First generation	Second generation
Egg		
Young	.83	.76
Medium	.72	.72
Old	.42	.44
Total Egg Survival	.25	.24
Nymph		
1st	.82	.64
2nd	.74	.58
3rd	.61	.39
4th	.59	.43
5th	.34	.40
Total Nymphs Survival	.07	.025
Total Pre-Adult Survival	.018	.006

Table 1.

Field Survival of Brown Planthopper
Low Immigration Pressure

Stage	No Insecticide	Insecticide
Egg		
Young	.51	.88
Medium	.60	.91
Old	.39	.88
Total Egg Survival	.12	.703
Nymph		
1st	.85	.91
2nd	.78	.79
3rd	.67	.75
4th	.77	.71
5th	.81	.52
Total Nymphs Survival	.28	.20
Total Pre-Adult Survival	.025	.141
Pre Reproductive Females	0.74	0.92
Total Pre Reproductive Survival	0.0185	0.13

Table 2.

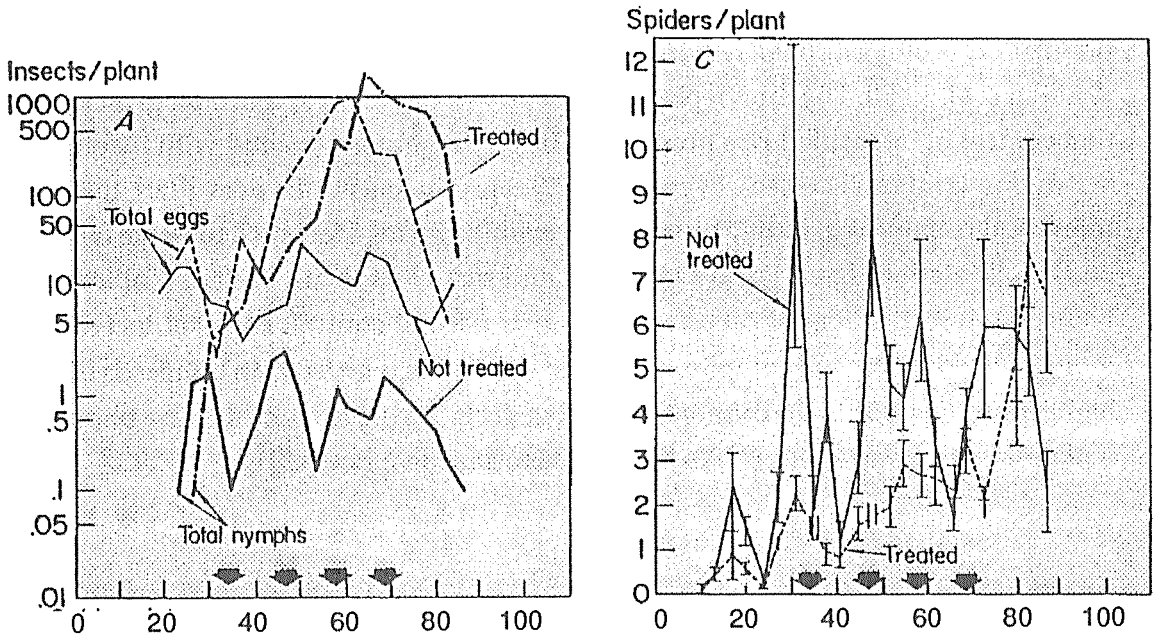


Figure 5. Brown planthopper densities (left) in insecticide treated and untreated fields (logarithmic scale). Spider densities (right) fields. From Kenmore et al. 1984.

Percent hopperburn area at 13 weeks after transplanting (WAT for some commonly used insecticides in the Philippines (plots treated with foliar sprays at 4, 7, and 10 WAT), IRRI, 1976/1977

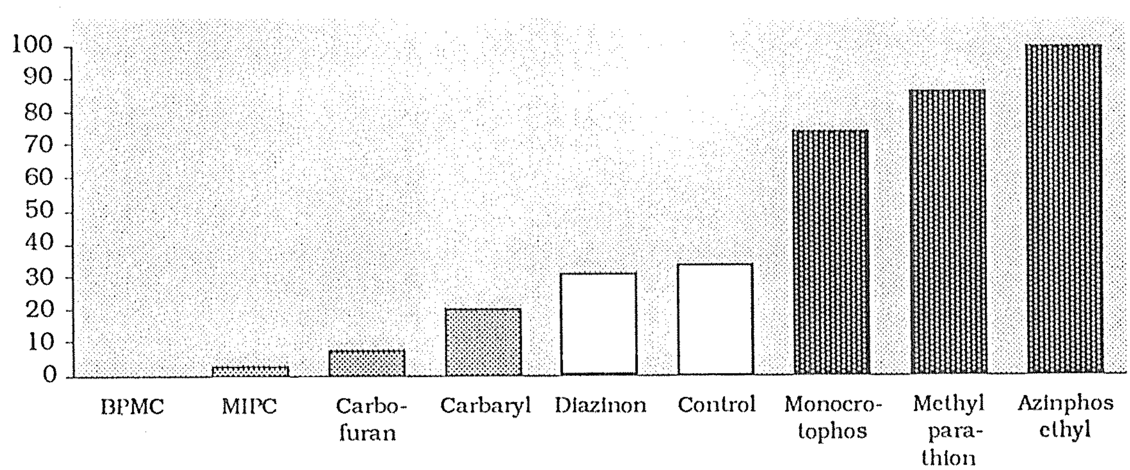


Figure 6.

The second tactic tried in 1977 was large scale multiplication and distribution of seeds of variety IR26, which had genetic material from South Asia that made the rice taste bad to brown planthoppers in Indonesia. In a textbook example of Darwinian evolution, the natural variation within brown planthopper populations allowed directional selection to operate. Within three seasons, brown planthopper populations in most of East and Central Java were able to feed on IR26. In 1978 scientists consulting for IRRI and the World Bank still concluded that the biggest problem facing Indonesia's rice pest control was that more insecticide needed to be available to meet estimated increased demand with growth in production (Mochida 1978). With help from increased insecticide subsidies (Figure 7) and from a domestic insecticide formulation industry since 1976 completely protected from imported competition, 1979 became the second worst year on record.

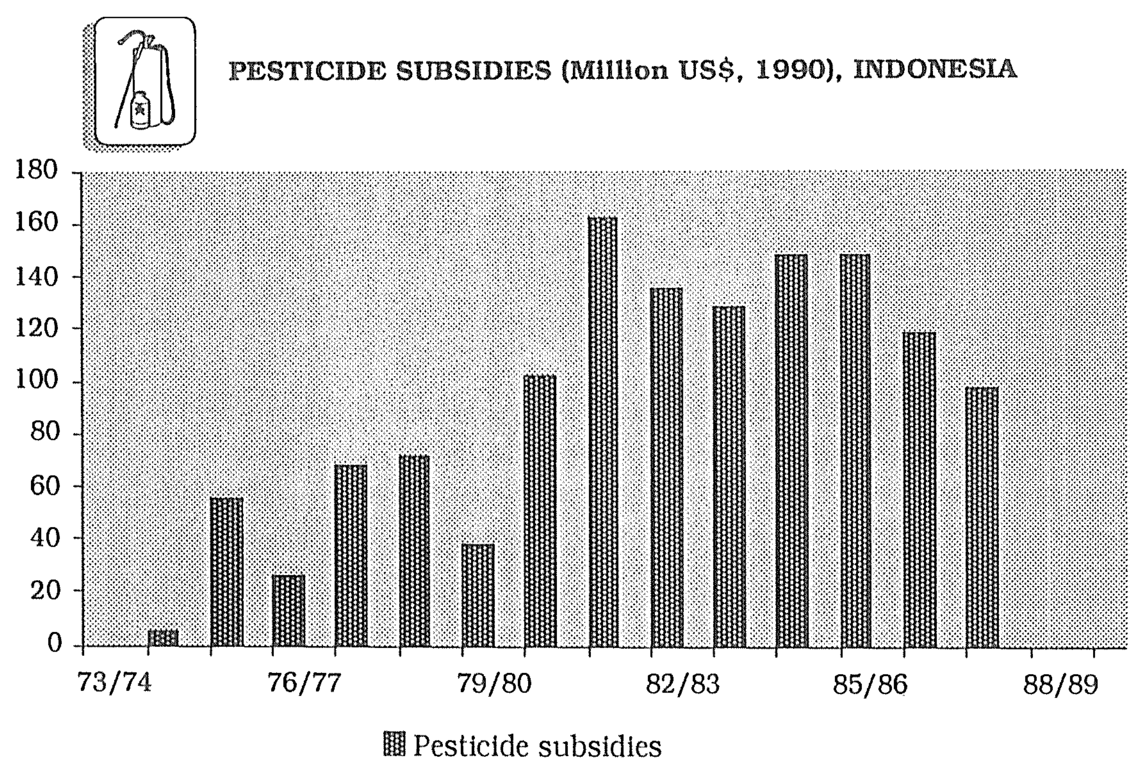


Figure 7.

Indonesia resolved the brown planthopper outbreaks of the 1970s by large scale planting starting in 1980 of IR 36 which had a new gene conferring resistance to Indonesian populations. This variety, internationally the most widely planted rice in history, was resistant and short duration. Indonesia breeders incorporated the same gene for resistance in two nationally produced varieties, Krueng Aceh and Cisadane, both released on large scale in 1981. These varieties generally outyielded IR 36 in Java, and fetched significantly higher prices because the milling quality and taste were preferred by consumers. By 1984 about half the rice area in Central Java was in these two varieties. Brown planthopper had remained apparently innocuous for almost 4 years, despite ever-growing insecticide subsidies.

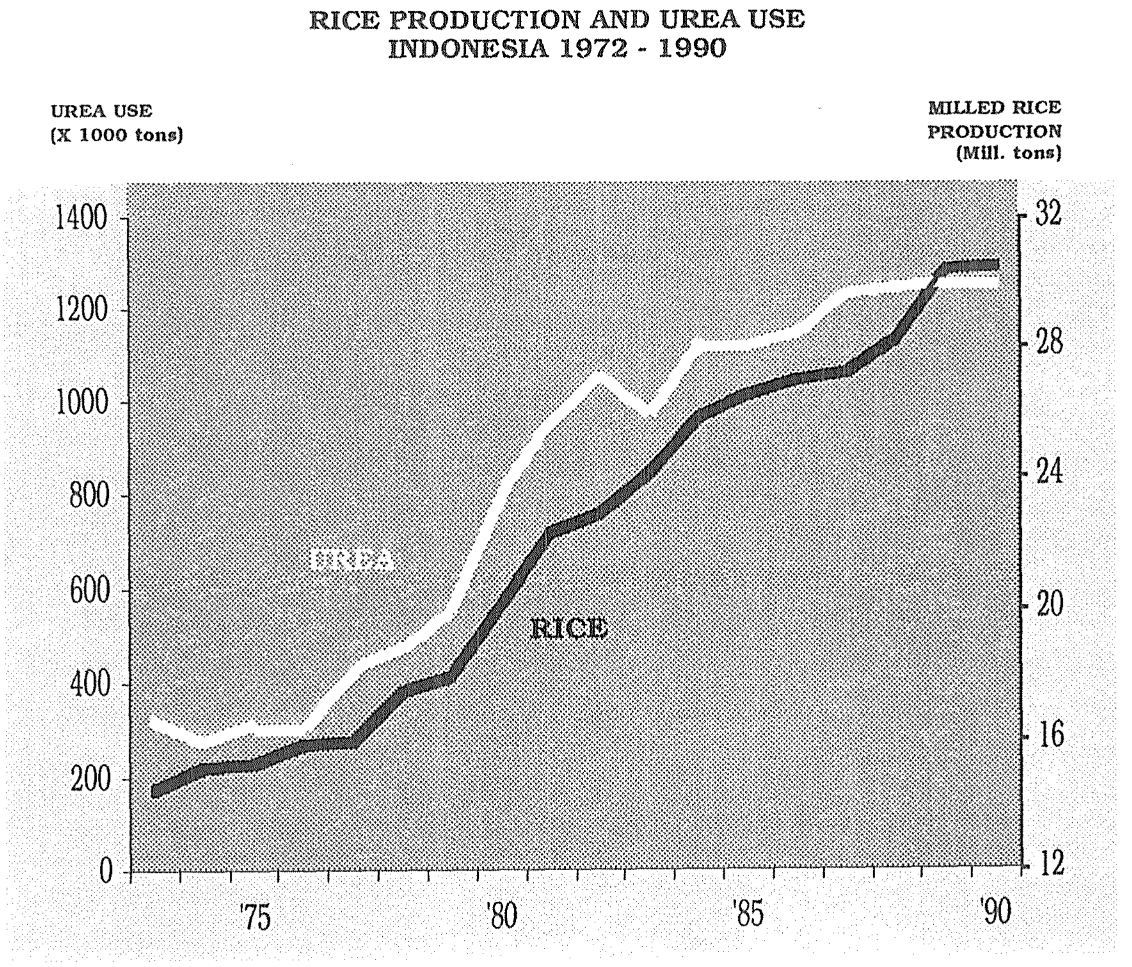


Figure 8.

Thanks to IR36, Krueng Aceh, Cisadane, and a massive infusion of fertilizer to irrigated areas, in 1984 Indonesia became self-sufficient in rice (imports were equalled by exports) (Figure 8). The pesticide part of input subsidies exceeded US$ 100 million per year. Rice was the second ranking crop in the world for its consumption of insecticides — after cotton. Indonesia represented about 20% of the value of the world's market for rice insecticides.

All that began to unravel with reports that brown planthopper was destroying fields of Krueng Aceh and then Cisadane in Central Java and Yogjakarta. By 1986 the areas infested by brown planthopper were approaching the levels of the mid-1970s, except they were doing so on supposedly resistant varieties. Insecticides, despite huge subsidies, were not controlling populations, and the threat of losing hard-won self-sufficiency was looming large in policy makers' thinking.

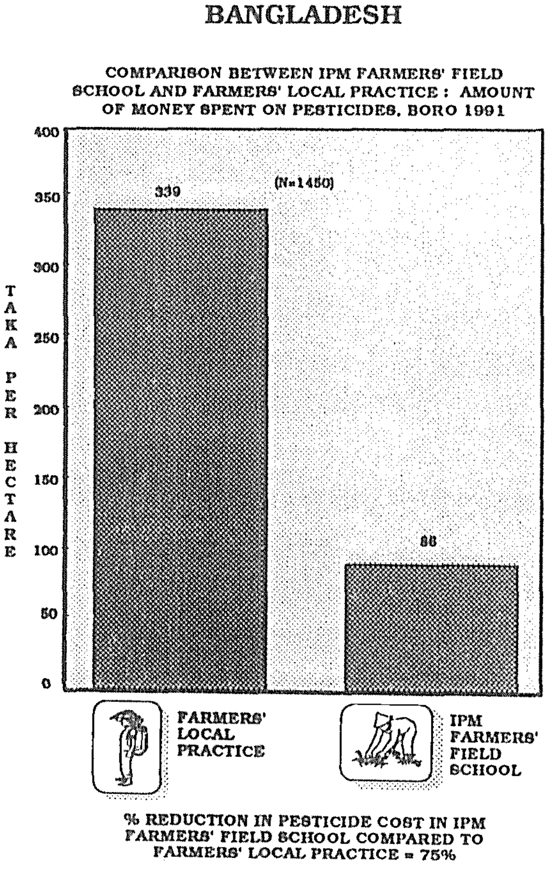


Figure 9a.

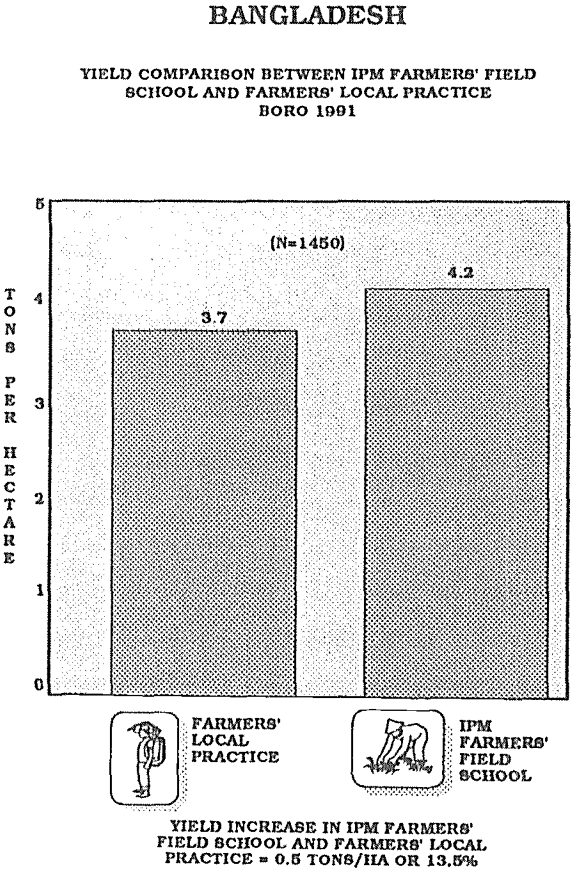


Figure 9b.

CHINA

1989-1990 Benefit Comparison
(between trained and untrained farmers)

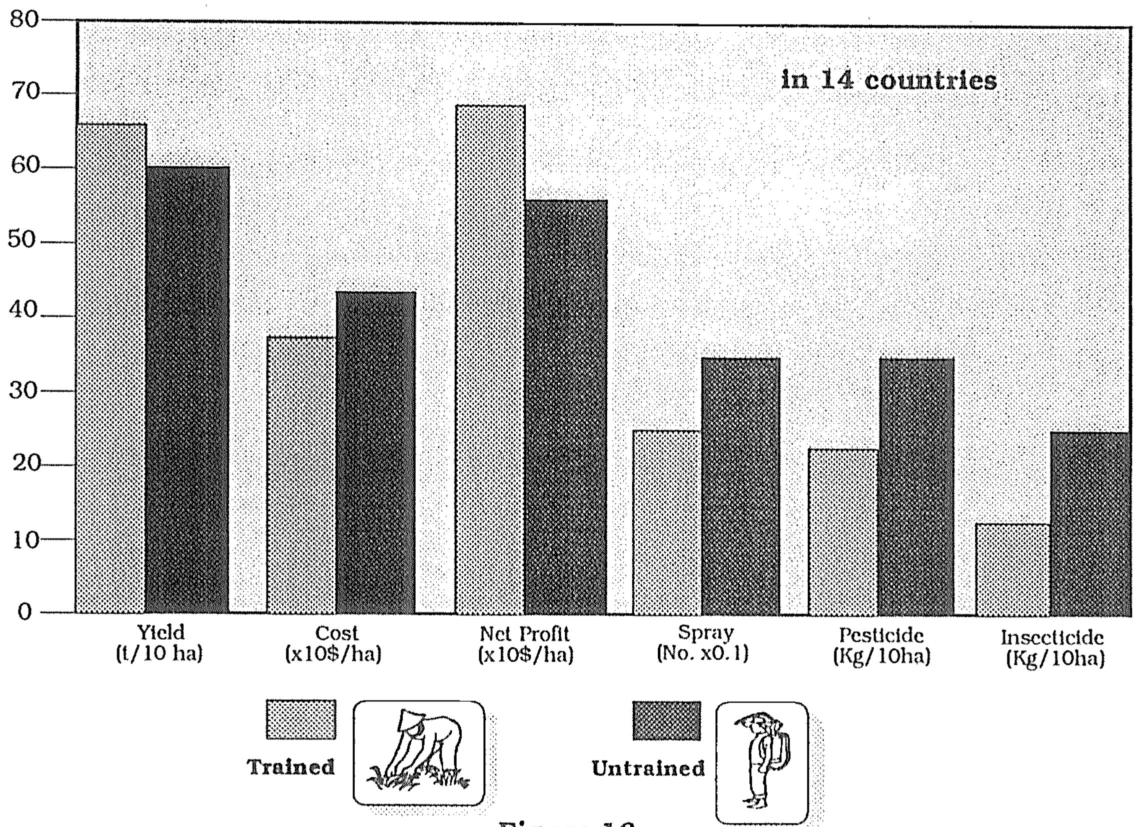


Figure 10.

The examples of thousands of farmers in other countries having learned IPM field skills and reduced insecticide loads together with data from Indonesia pilot field sites showing more than 50% reductions in insecticide frequency and no yield loss helped policy be formed in a positive manner (for examples of these kinds of data see Figures 9a, 9b and 10). Added to these examples were data on essentially all insecticides used on rice in Indonesia, assembled from IRRI and from national and international researchers working in Indonesia (Whitten et al. 1990). These data showed the potential for rapid brown planthopper build up following applications of these insecticides in rice fields.

The Indonesian National IPM Policy was announced in November 1986 as Presidential Instruction Number 3 of 1986. As written it did three major things:

1. On explicit ecological grounds (brown planthopper multiplication by destruction of natural enemies) banned 57 trade formulations of insecticides from use on rice and ordered that resistant varieties of rice be grown in affected areas;

2. Increased from less than 1300 to over 2900 the numbers of official field pest observers assigned to rural extension centers; and

3. Ordered that these and other extension staff and farmers be trained in IPM

PESTICIDE PRODUCTION AND RICE PRODUCTION INDONESIA
(Ministry of Finance "Nota Kuangan" 1972 - 1990)

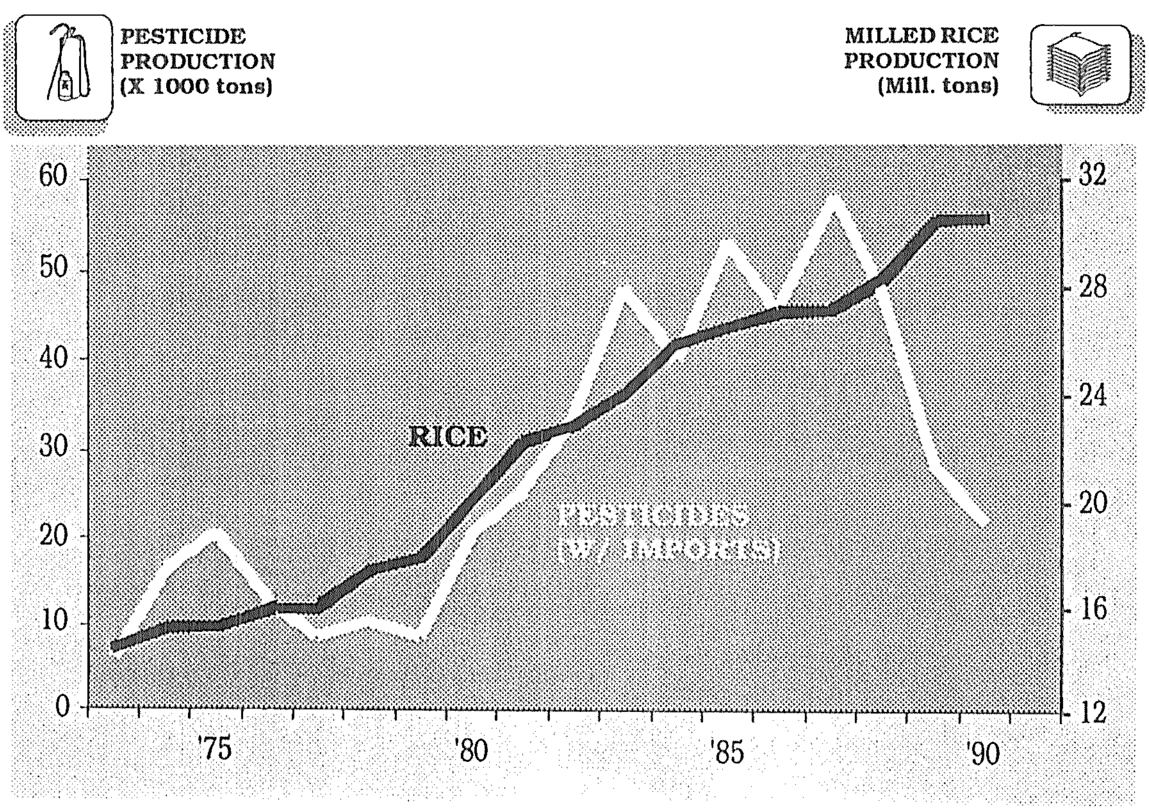


Figure 11.

An inter-sectoral group of ministers were named to implement that policy. Along with recruitment and training an early move was the elimination of the 85% insecticide subsidy by steps over 2 years. At farm level, numbers of insecticide applications per field fell from over 4 per season to less than 2.5. The production result of the macro-policy is shown in Figure 11. Since the policy, rice production has increased more than 12% while formulated pesticide production has decreased more than 50%. Rice production in Indonesia has been massively decoupled from insecticides. Brown planthopper infestation declined quickly and steadily since 1986 (Figure 12).

HECTARAGE INFESTED BY BROWN PLANTHOPPER
INDONESIA 1986-90

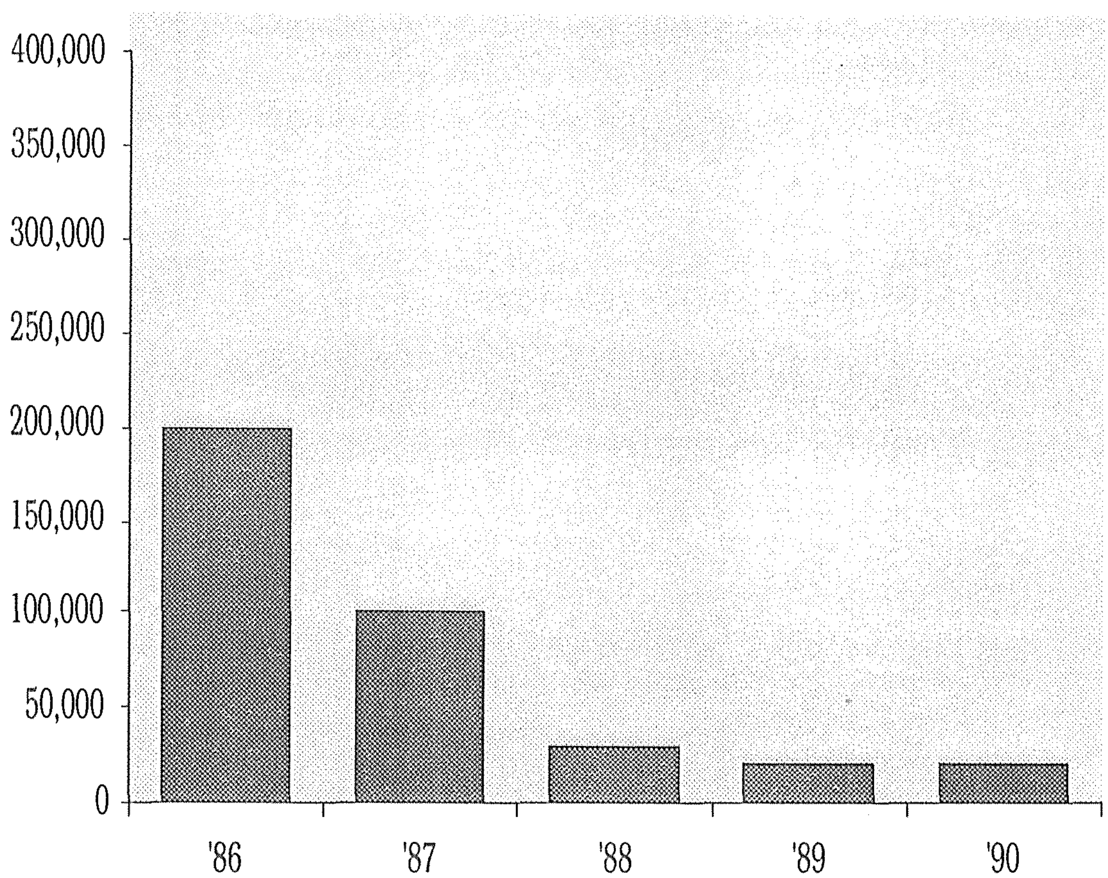


Figure 12.

Keeping IPM Strong: Developing People and Political Will

The major human resources development activity for Indonesia's policy is the National IPM Training Program, which is coordinated by a Steering Committee led by BAPPENAS (the National Development Planning Board). The Program is largely funded under a policy support grant from the Jakarata USAID Mission. An internationally recruited team of specialists assists under an Indonesia—FAO Unilateral Trust Fund arrangement. A recent Tripartite Review Mission evaluated the first two years of this project and recommended a five year extension. One finding of the Review was that, after completing a Farmers' Field School that combines local ecological knowledge created through field exercises with strong culturally appropriate group building exercises distilled from NonFormal Education practitioners, farmers further reduced their insecticide application frequency per field from about 2.2 to .8 per season (Figure 13). Yields and profits in fields operated by IPM Field Schools are both higher than with the standard package recommendations (Barfield et al. 1991).

Number of Applications Per Field

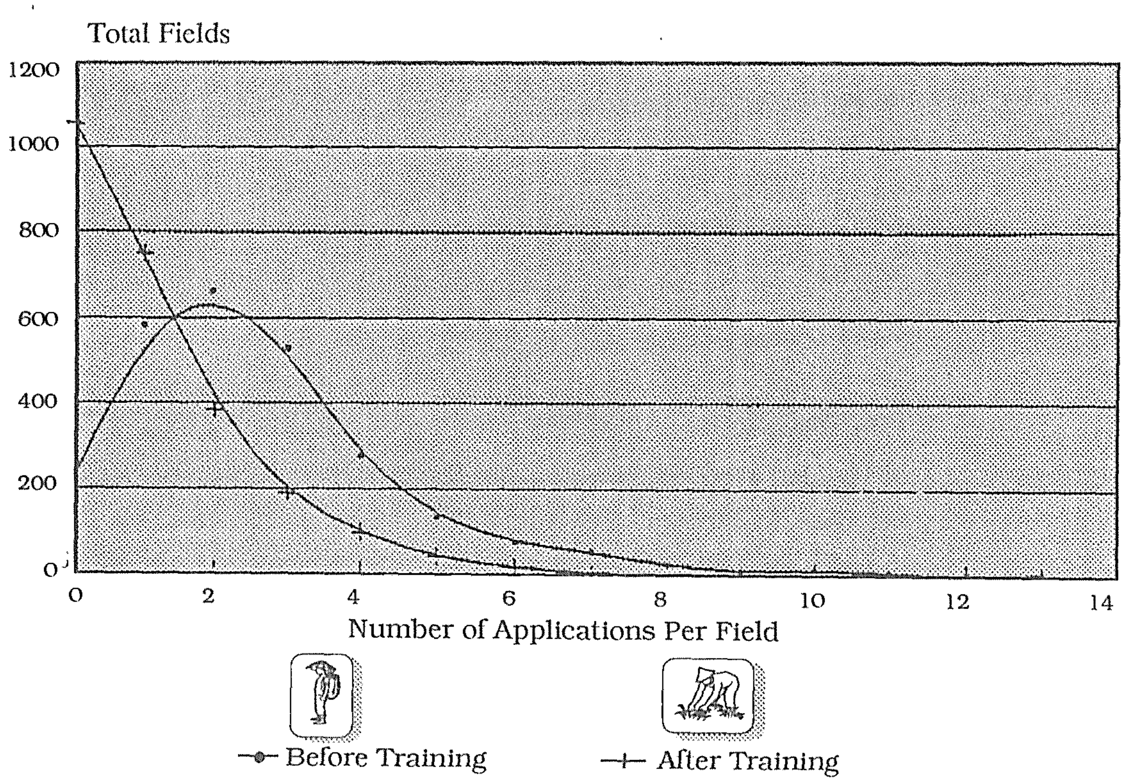


Figure 13.

While a complete summary of even preliminary conclusions from the two years of intense implementation towards the human resource development goals of Indonesia's IPM policy is beyond the scope of this paper, a list of more salient accomplishments indicates the flavor of this pioneering effort.

- Over **one million** person-days of high quality IPM field training have been experienced by farmers, local government officials, extension staff, crop protection staff and researchers in 1990 and 1991.

- The costs per person-day of training range from $US 3.43 for full time residential training in Field Training Facilities for IPM Trainers to US$ 0.73 for Farmers' IPM Schools run by Farmer Trainers.

- As farmers' profits after training increase by about US$ 18 per farmer, **the return (dollar for dollar) on training investment ranges from 4.6 to 8.6.**

- The success of the Farmers' IPM Field Schools sparked genuine **political support,** unanticipated **administrative commitment,** and gratifying **financial buy-ins from local governments:**

    - Village heads (Lurahs and Kepala Desa), Sub-district Chief (Camats), and District Administrators (Bupatis) publicly endorsed IPM Field Schools as the most effective village agricultural training program ever experienced.

    - With this positive political climate District Administrators have, on their own, **increased by 75%** the numbers of extension staff assigned to receive IPM Field School Trainers' Training. These staff receive credit towards promotion requirements - a longer term commitment.

    - In Central Java, East Java, Yogjakarta, and North Sumatra Governors and District Administrators **spent discretionary** funds and diverted funds from other uses to **accelerate IPM implementation** over the National funded timetable. These **buy-ins ranged** (for one season's implementation) from **US$ 1000** to over **US$ 30,000**. These buy-ins equalled from 30 to 50 percent of the National funding.

- A follow-up survey of some 400 Farmers' IPM Field Schools including over 10,000 farmers indicated that, depending on location, **from 60% to 70% of the trained farmers' groups had spontaneously started giving season-long field training activities with other farmers' groups.** This lateral spread is unprecedented anywhere in extension. **IPM in Indonesia is a movement.**

- A case study of one village, Kebun Agung in Imogiri SubDistrict, Bantul District, Yogjakarta, showed how the members of **one farmers' group paid over 25% of their monthly incomes for 3 months to support a full season of IPM Farmers' Field School.** The village's resident Mentri Tani (designated agriculture leader), primarily a livestock raiser, stimulated the group to set up the school after observing nationally funded school with other groups. He believed the training was effective for all aspects of farm management, and that reducing pesticide use would be better for the village's livestock.

Meeting an Old Adversary: The White Stemborer in Jalur Pantura

In the Jalur Pantura (northeastern coastal) region of West Java, a 13,000 hectare outbreak of white rice stemborer, a traditional but sporadic pest throughout the colonial period, in early 1990 garnered media attention and generated national concern. Frequent calls from various sources to relax the Presidential IPM Policy - and allow the use of banned organophosphates - were resisted by the sustained action of a number of Cabinet Ministers. National funds were used for a additional training program on how to recognize the egg masses of white stem borer in seedbeds and newly transplanted seedling fields. Farmers then could remove egg masses by hand — much surer kill than applying insecticides in hopes of reaching the larvae inside stems already causing damage. Over 75,000 farmers in affected district were trained during 3 weeks of Ramadan.

Despite calls for massive pesticide distribution, local government officials continued to support IPM. By the following 1990 dry season crop, nearly all the White stemborer larvae were in diapause and area affected near zero. Over 300,000 people mobilized to destroy egg masses during the critical late 1990 immigration period, and less than 1000 hectares were damaged in 1991 during the wet season corresponding to the upsurge of 1990 — a resounding affirmation of the IPM Policy.

Post analyses of the white stemborer outbreak showed that subdistrict (kecamatan) with highest damage were those that had, for at least three prior seasons, had the highest dosages of carbofuran insecticide applied to them. Carbofuran is one of the very few insecticides still allowed on rice under the IPM Policy; it has been included under the latest intensification program (SUPRAINSUS), and the major formulation plant for the insecticide is in Jalur Pantura.

Even during the outbreak it was clear to farmers and scientists that farmers who had continued to plant the variety Cisadane had much lower damage from stemborers than those who followed central government recommendations to plant IR64. Although in West Java Cisadane was never as badly damaged by brown planthoppers as it had been in Central Java and Yogjakarta, the major reason IR64 had been pushed was insecticide-induced outbreaks of brown planthopper. This variety has yet another gene for brown planthopper resistance. By trying to sidestep the brown planthopper's punch, farmers walked straight into the white stemborer's. This is a precise example of the limits of applying that specific form of **biodiversity** called **genetic diversity**, and will be treated in more detail below.

Other Countries: Learning the Lessons of Indonesia

The brown planthopper syndrome is perhaps the best example on earth of a controlled experiment in agricultural macro- policy change with unequivocal production, economic, and environmental results. Taking Indonesia's policy as the treatment (especially Figure 12) then Thailand, Vietnam, Malaysia, and Sri Lanka are untreated controls. None of them have national IPM policies, none have banned rice insecticides for ecological reasons, and , like Indonesia and the rest of Asia, all have at one time or another had considerable government support for the distribution of insecticides in rice. Philippines is a special case, where a policy was declared, but implementation has lagged.

Thailand had the largest brown planthopper outbreak in its history in 1989 - 1990. Over 250,000 hectares of the Central Plain region were infested, surpassing the worst years of the 1970s (Figure 14). Thailand is still in the early phase of the varietal resistance treadmill: the major resistant variety before the outbreak, RD 21, was bred from IR26 that collapsed in Indonesia in 1979. During the outbreak, which was largely sustained on a preferred non-resistant variety, Suphanburi 60, vigorous efforts were made to multiply the seeds of RD 23, which has (from IR32) the same resistance gene as did IR36. The extent of the outbreak in 1991 will probably be much less than 1990, because of wide planting of RD23. Field result from Chainat by den Braber and colleagues in 1991 showed a 15 times increase in BPH densities on RD23 with insecticides (Figures 33 and 34). How long RD23 and an even more recent variety, Suphanburi 90, last compared to Krueng Aceh and Cisadane in Indonesia will depend on national policy — policy on IPM and policy on insecticides.

RICE AREA (HA) INFESTED BY BPH IN CENTRAL THAILAND 1978-90

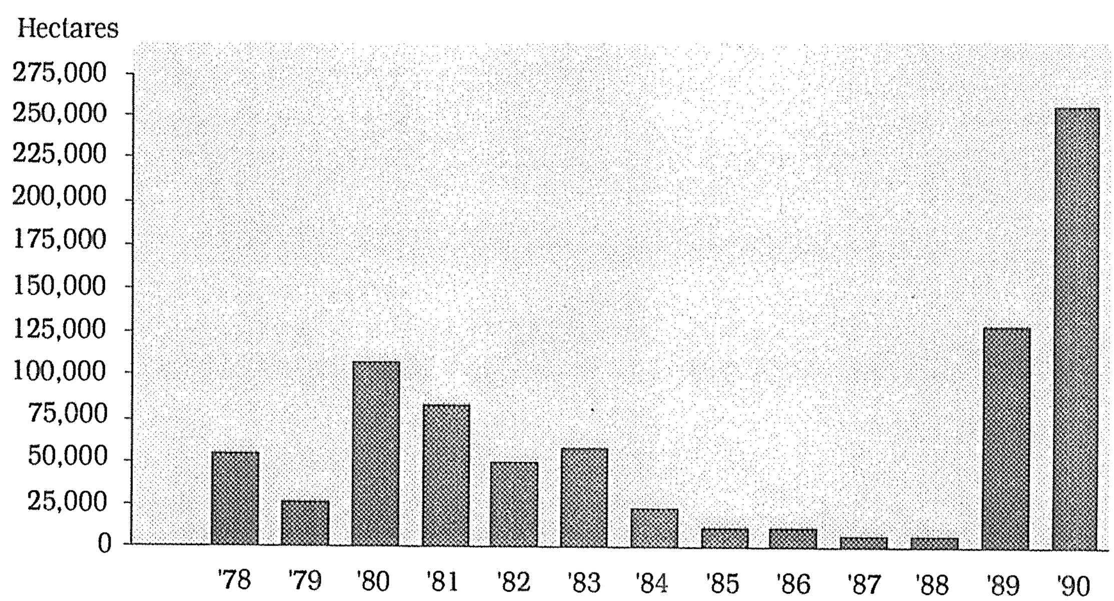


Figure 14.

Thailand is a perennial exporter of rice. Its rice area so exceeds its domestic demand (same population as Philippines with nearly 3 times the rice area) that the price of rice on the world market is a significant factor even in the life of the rice farmer. Figure 15 again shows the areas infested over time by brown planthopper, but overlays the trend in insecticide use. Driven (along with fertilizer and other inputs use) in large part by world price shifts, insecticide use in Thai agriculture — the majority on rice — neatly leads rather than lags brown planthopper infestations. Both the late 1970s/early 1980s outbreak and the 1989-1990 outbreak were preceded by upswings in insecticide use. This picture agrees with the pre-policy case in Indonesia — insecticide-induced population explosions not controllable by insecticides but for the moment by varietal resistance.

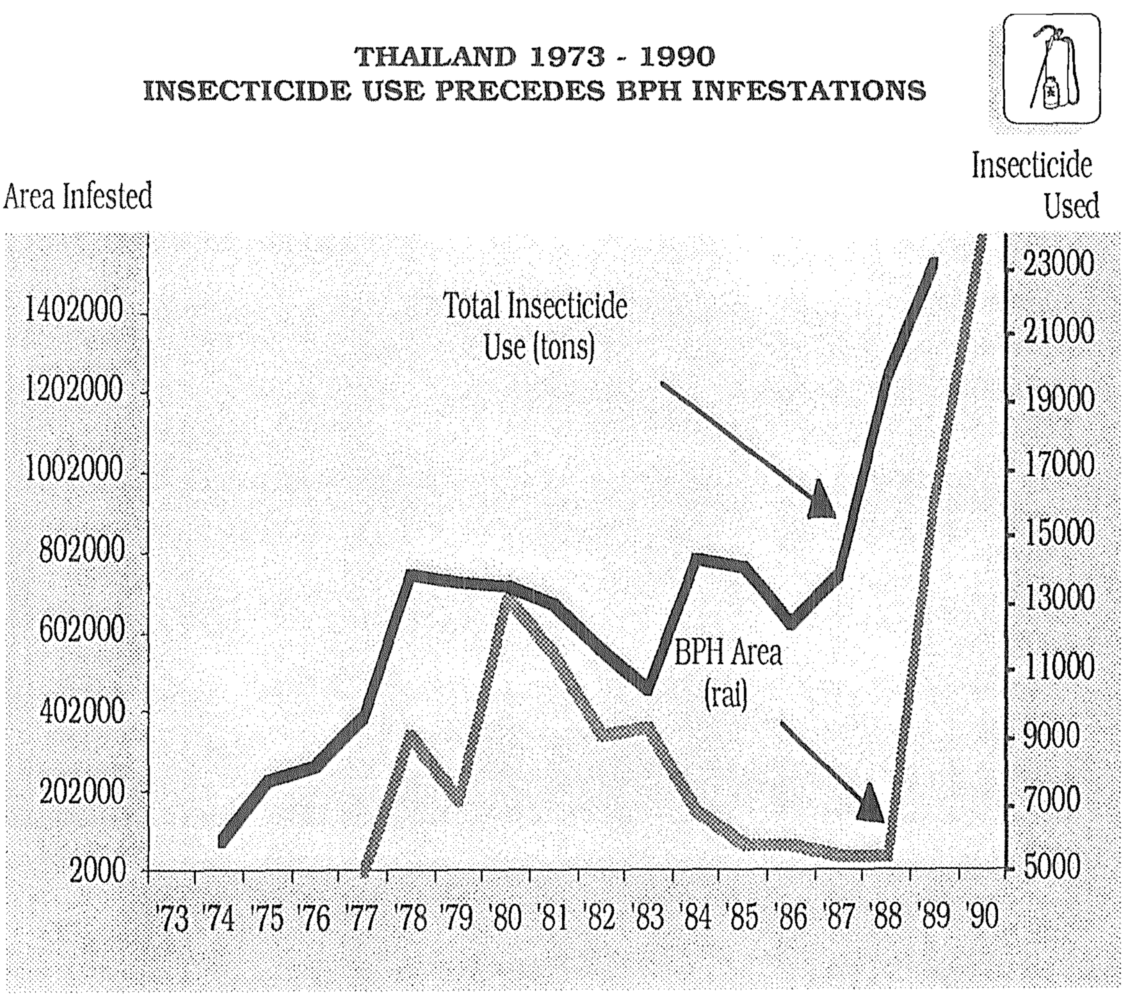


Figure 15.

Thailand enjoys a relatively free economy, and there are over a thousand legally registered rice insecticide formulations and hundreds more unregistered ones. As first observed by Waibel (1990), however, pesticides have a significant hidden subsidy compared to other agricultural inputs like fertilizers and machinery because the tariff and tax totals for them are less than 7% while those for other inputs are over 25%. More locally distorting are what he calls indirect subsidies enjoyed when governments declare an outbreak and, usually with a compliant bilateral donor, release free insecticides in arbitrarily defined localities. The picture at farmer level is kaleidoscopic: there are over 270 legal trade names for methyl parathion -an insecticide banned for health reasons in Indonesia, Malaysia, Bangladesh, Korea, and Japan- in Thailand (ESCAP - ARSAP 1990). In this confusing situation, a farmer who simply treats insecticides as fertilizer - - more is better — runs the risk of problems. Figure 16 shows data from a preliminary survey of farmers by den Braber and colleagues in one outbreak-afflicted province of Thailand. The greater the number of insecticide applications, the lower the yield, regardless of variety. den Braber's team is following up with detailed field studies of population dynamics on resistant and susceptible varieties subjected to insecticide pressure.

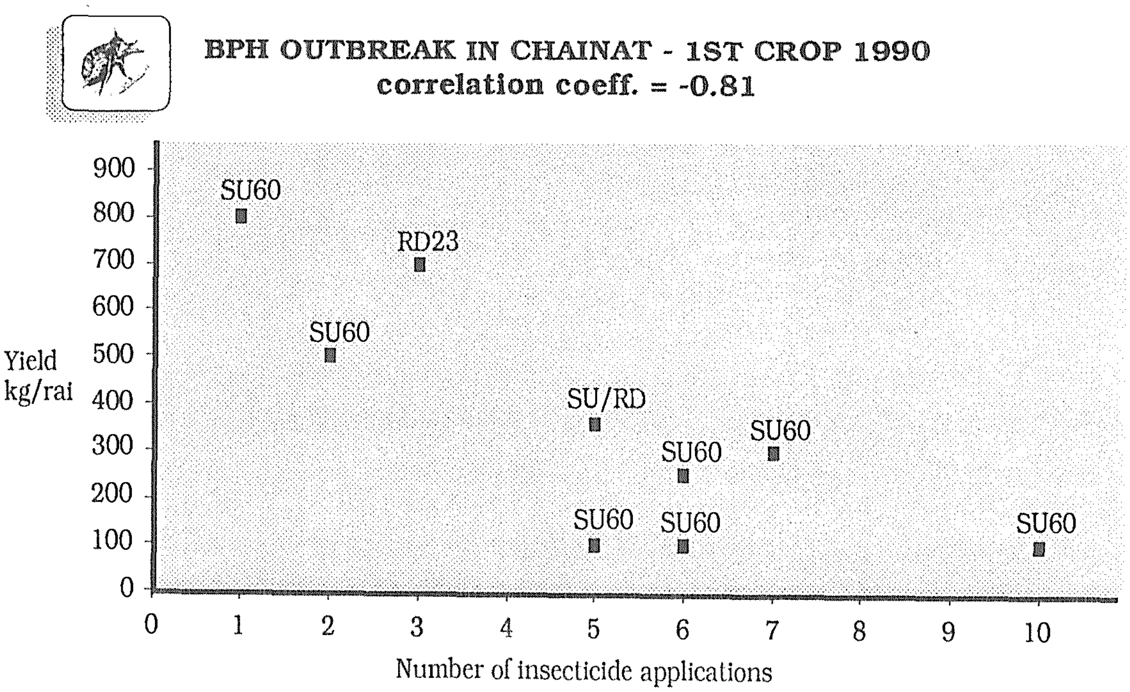


Figure 16. *Farmers' Interviews, Chainat, Central Thailand 1991.*

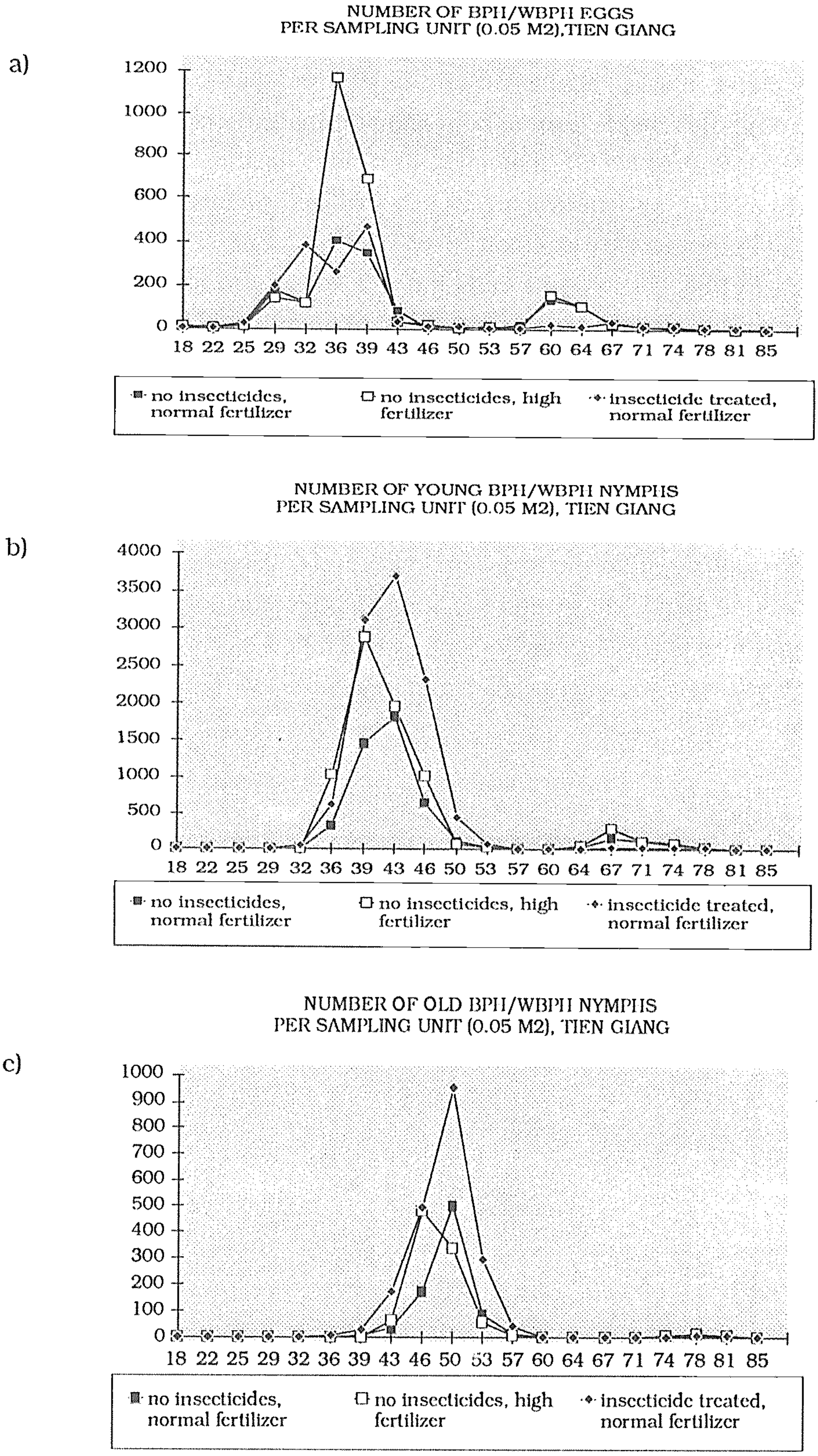
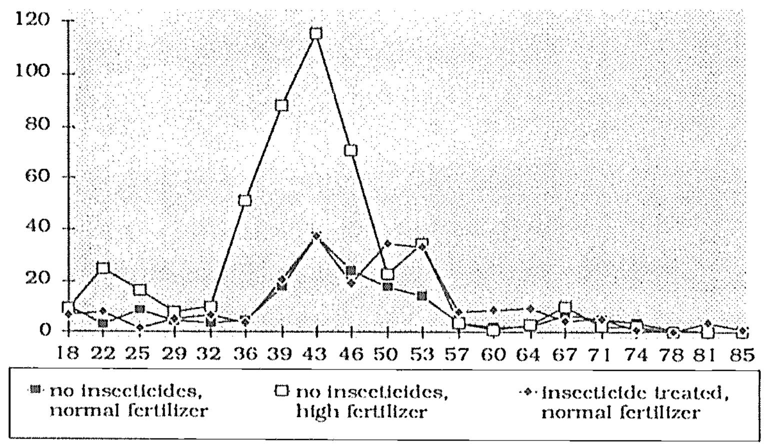


Figure 17. *Planthopper densities at days after planting 3 treatments. Farmers' fields Tien Giang, Mekong Delta, Vietnam 1991.*

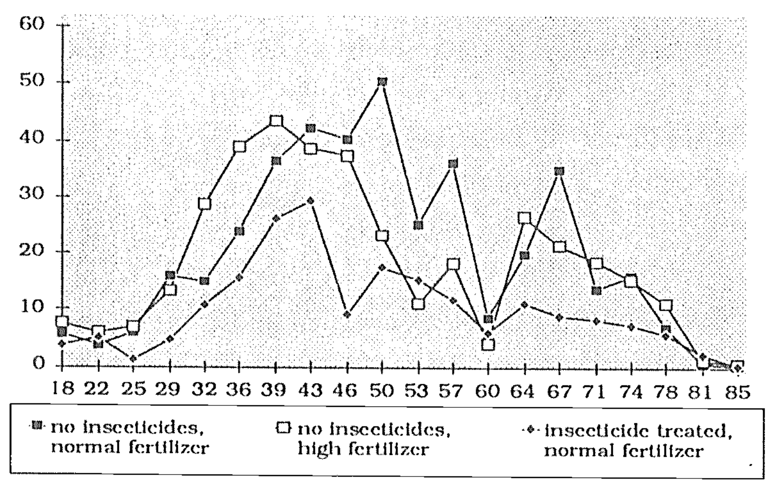
NUMBER OF CYRTORHINUS
PER SAMPLING UNIT (0.05 M2), TIEN GIANG

a)



NUMBER OF WATERBUGS
PER SAMPLING UNIT (0.05 M2), TIEN GIANG

b)



TOTAL NUMBER OF SPIDERS
PER SAMPLING UNIT (0.05 M2), TIEN GIANG

c)

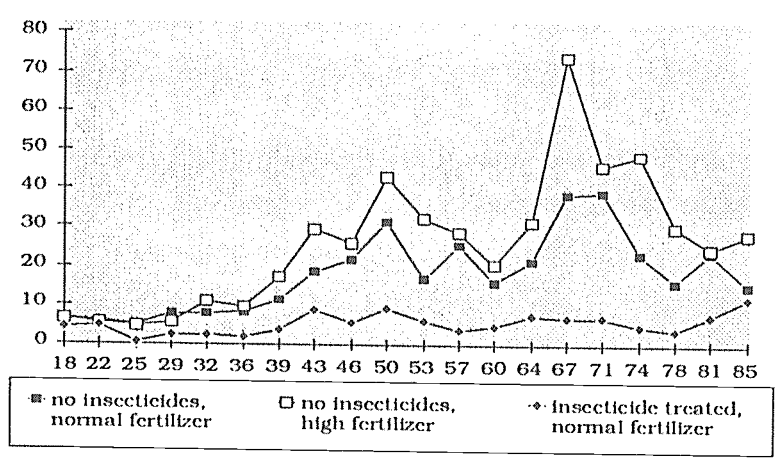


Figure 18. *Predator Densities at days after planting 3 treatments. Farmers' fields Tien Giang, Mekong Delta, Vietnam 1991.*

Results of this kind prompted a national conference held in October 1990 in Bangkok on brown planthopper and IPM. Indonesian scientists and policy makers as well as scientists from IRRI presented experiences and research results. The audience included Members of Parliament, provincial agriculture and administration officers, and a range of policy analysts. One concrete output of the Conference and a later study tour to Indonesia by field trainers and policy makers emerged when a proposal to eradicate brown planthoppers over 5 years was set forth by some staff of the Ministry of Agriculture. When staff of the Budget Bureau who had attended policy meetings noticed that the proposal allocated over 70% of its funds for insecticides, the proposal was sent back with a gentle suggestion that IPM training might more quickly bring the problem to manageable proportions.

Vietnam also had very large outbreaks of the brown planthoppers in 1990 that continued into 1991, reaching over 400,000 hectares of the Mekong Delta so far. The choice of insecticides in Vietnam is quite broad; there are dozens of different chemicals, mostly highly toxic organophosphates. Farmers often begin the season using these to treat defoliator damage that would be compensated by later growth of a normal crop. When brown planthoppers surge in the absence of their natural enemies more expensive carbamate insecticides are tried in order to suppress brown planthopper.

The elegant field work of Fredrix and colleagues over the latest (1991) rice season in the Mekong Delta gives graphic"snap-shots" of how brown planthoppers are released by insecticides all across Asia. Figures 17a and 18a show how a pulse of planthopper eggs in a high fertilizer field is wiped out by egg-feeding predators (called *Cyrtorhinus*). These predators were missing from the insecticide treated field, so that the next "shot" in the sequence (Figure 17 b) shows young brown planthoppers in insecticide fields surpassing those of the high fertilizer field. The water strider bugs that specialize in killing newly hatched brown planthoppers are also suppressed by insecticides (Figure 18 b). By the last "shot" (Figure 17c) the insecticide treated field has suffered a serious outbreak, with older, more voracious brown planthoppers in large numbers facing no significant natural enemies. The spiders that normally concentrate their killing power on older planthoppers are near local extinction (Figure 18c). The results at harvest (Figure 19) are easy to understand: natural enemies protect rice yields, even when extra fertilizer makes the plants a better food source for insects.

YIELDS (KG/HA, 14% MOISTURE CONTENT) IN THE DIFFERENT TREATMENTS IN TIEN GIANG

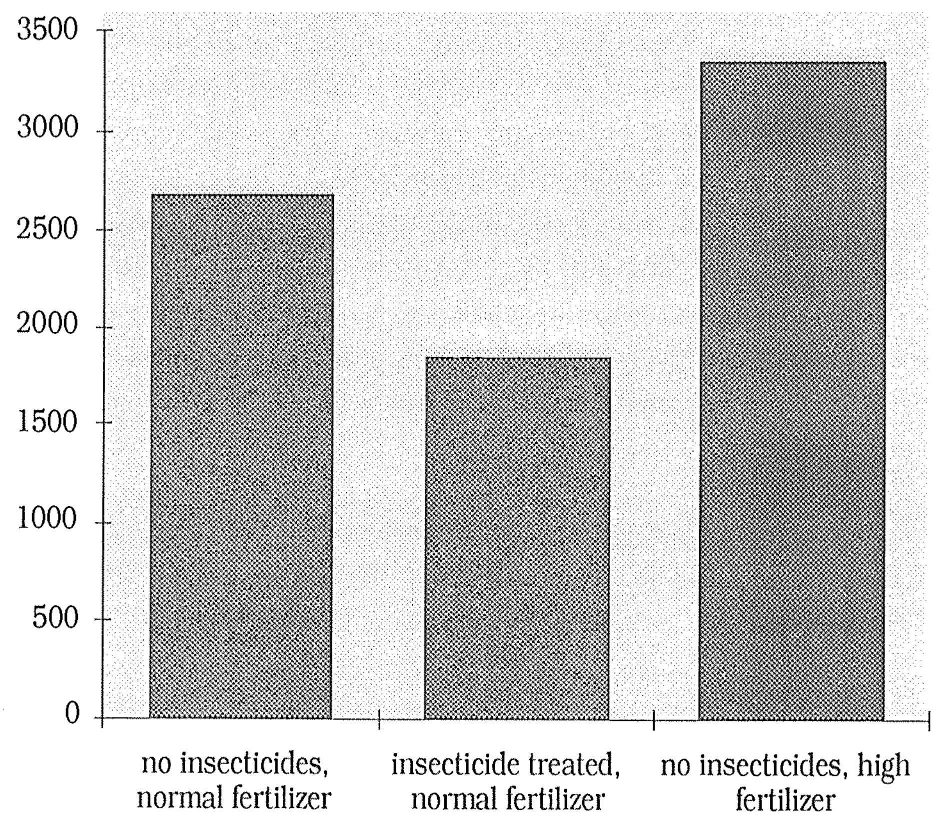


***Figure 19.** Yields from farmers' fields in Tieng Giang, Mekong Delta, Vietnam 1991.*

With these data and the presentations of experts from Indonesia, Thailand, and IRRI, a Conference on Brown Planthopper and IPM for the Mekong Region was held under the Chair of a Vice Minister of Agriculture in Ho Chi Minh City in August 1991. With over 75 attendees, the strongest responses came from the provincial adminstrators and agriculturalists who are increasingly responsible for Vietnam's rice production in a period of economic decentralization. At the national level, the Chair of the State Planning Committee and his key staff visited Indonesia early in 1991 and were given policy and field briefings on IPM.

Malaysia shares the same agro-ecosystem as North Sumatra. Yet here too, in the absence of a national IPM policy, 1990 was a banner year for brown planthopper (Figure 20). As work by Booty and co-workers made clear (Booty et al. 1990) this was primarily due to one chemical, monocrotophos, which has been implicated for over 15 years as causing outbreaks of brown planthopper. This chemical was used much more in the last 4 years in rice, despite being banned for any use in Malaysia except trunk injections of oil palms. It is marketed in rice areas with proper label warnings, but in small bottles of 250 or 500 milliliters. These are too small to load a trunk injection machine; nonetheless sales were brisk in rice areas. More disturbingly, over 70% of the farmers interviewed by Booty could describe accurately and precisely, from their own experience of being poisoned, at least three of ten major symptoms of monocrotophos poisoning.

HECTARAGE DAMAGED BY BROWN PLANTHOPPER TANJUNG KARANG, MALAYSIA 1985-90

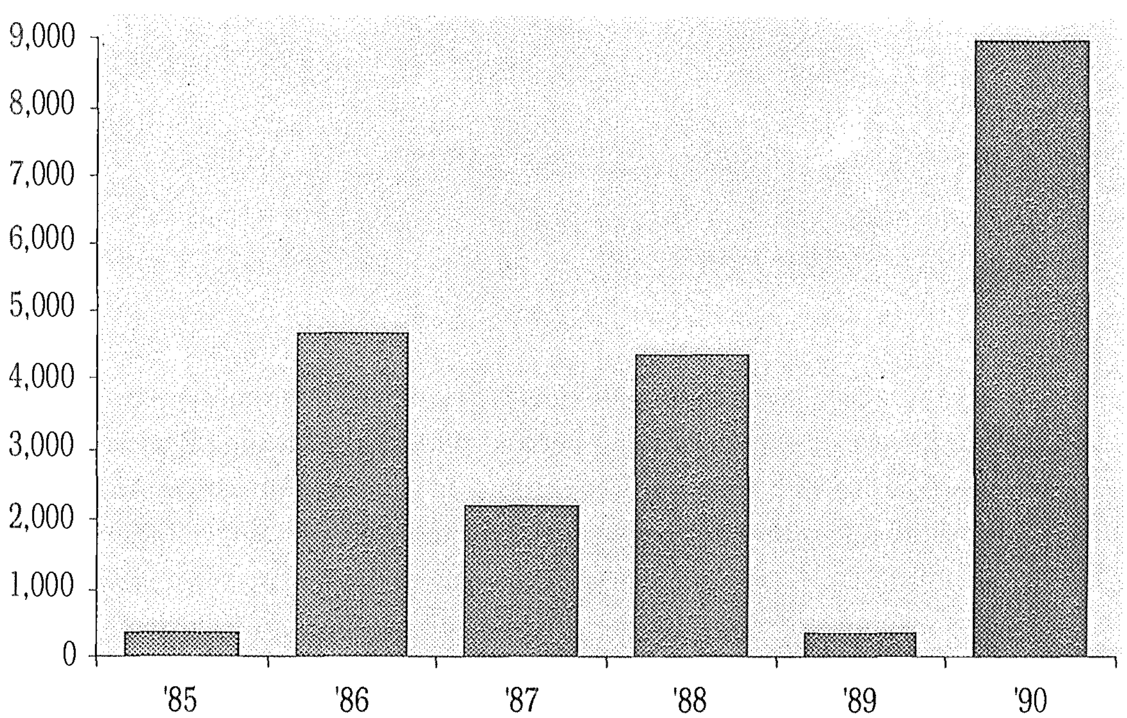


Figure 20.

Although the Philippines has had a national IPM policy on paper since 1986, it includes no reference to pesticides. There has been no intersectoral steering committee, and no coordinating mechanism --no MIS -- for deploying training funds. The Philippines now uses about the same amount of formulated insecticide each year as Indonesia -- 8,000 tons. Rice production in Philippines is less than 22% of Indonesia's, which indicates a large potential for increased efficiency. The brown planthopper did not exceed 1,000 hectares infestation nationally in any year from 1979 through 1990. By February 1991, infested area in one province, Sultan Kudarat, exceeded 3,000 hectares (Figure 21). Interviews with farmers confirmed that those municipalities having more area damaged used relatively more of the insecticides (organophosphates and pyrethroids) more toxic to predators (Figure 22).

BROWN PLANTHOPPER INFESTATION IN EIGHT MUNICIPALITIES OF SULTAN KUDARAT, MINDANAO

Varieties: IR70, IR72, IR74, & Selections. February 1991

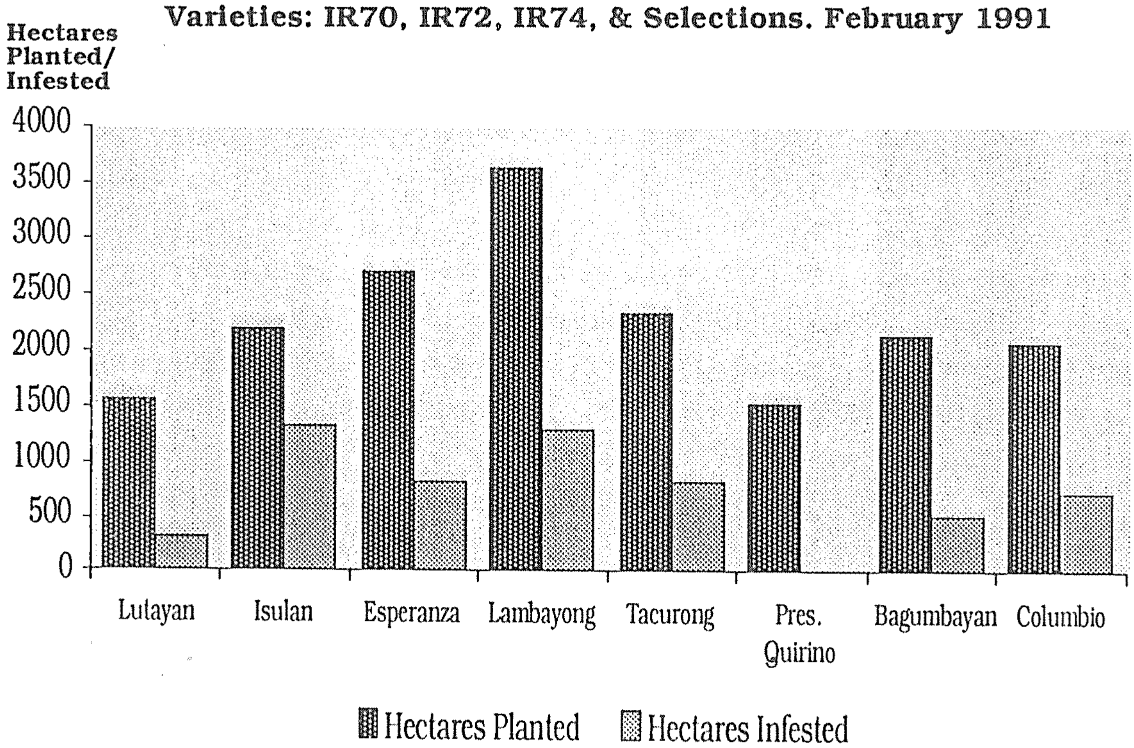


Figure 21.

BROWN PLANTHOPPER INFESTATION (% Area Planted) IN TWO GROUPS OF MUNICIPALITIES USING (Predominantly) DIFFERENT CLASSES OF INSECTICIDES.
Sultan Kudarat, Mindanao. February 1991

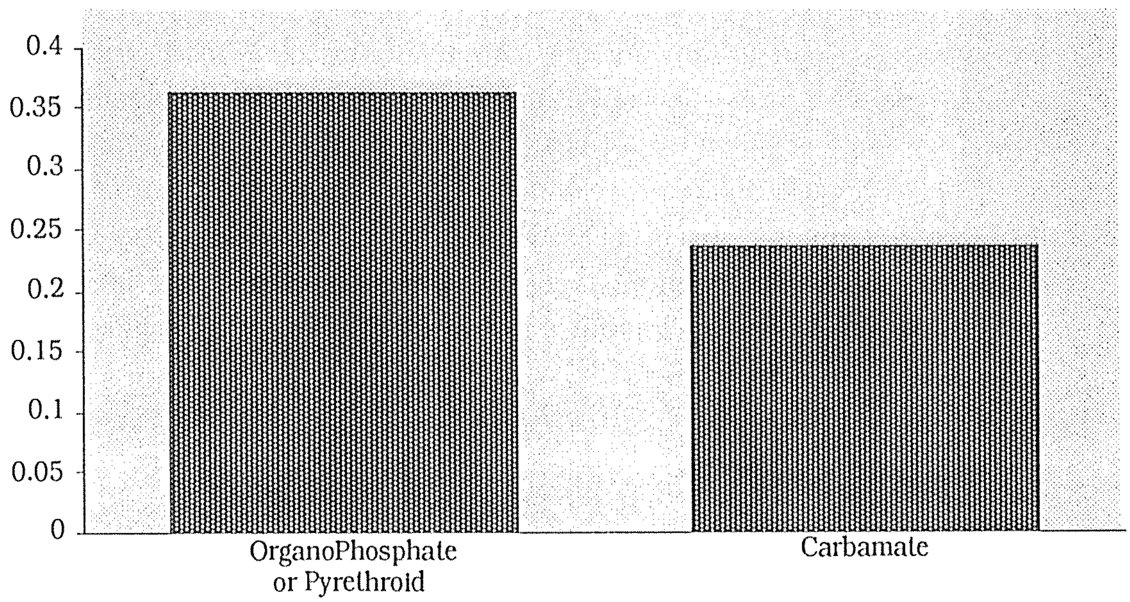


Figure 22.

The previously dominant molluscicides for control of the exotic Apple Snail (Pomacea), TriPhenyl Tin products, which had been banned from importation since October 1989, were completely banned from sale on 1 January 1991. This was after intensive consideration by experts from UP Medical School, the DA, the Fertilizer and Pesticide Authority and FAO with special information from the US EPA which is completing a 5 year special review of these chemicals.

With mounting evidence of insecticide - induced outbreaks of BPH in Mindanao, adverse health consequences of exposure to the major commercial insecticides, and the problems with molluscicides, the Secretary of Agriculture in March directed his policy staff to draft the first national pesticide policy statement for the Philippines. This effort has been endorsed by National Economic Development Authority, and an inter-departmental task force established with Departments of Health, Agriculture, Environment and Natural Resources, and the appropriate University experts.

Despite political turmoil and administrative restructuring, Sri Lanka has maintained a core of IPM expertise under the Assistant Director for Plant Protection in Peradeniya. This expertise is now being called upon by Provincial Agriculture units and by the Mahaweli Economic Authority to begin farmers' training again after a 3 year hiatus. In August 1991 two weeks of trainers' IPM field training for MEA staff were given by specialists from Indonesia, Philippines, and Bangladesh.

VARIABLE	TRAINED FARMERS	UNTRAINED FARMERS
Area cultivated (ha.)	1.81	1.79
% Cultivated area affected by BPH [a]	18.8	48.6
Number of Insecticide Applications per season [a]	0.6	1.6
Cost of Insecticides in the season (Rs/ha) [a]	229.24	736.37
Amount of Insecticide used in the season (ml. formulated product/ha.) [a]	356	1526
Yield (kg./ha.) [a]	4654	3455

[a]: *means are significantly different at the 1% level.*

Table 3. *Area cultivated, BPH affected area, insecticide use and yield for IPM trained and untrained farmers in the BPH "outbreak" season in Polonnaruwa (Maha (wet) season 1989/90).*

In the interim, a good field test of earlier IPM training took place in the 1989-90 Maha season in Polonnaruwa District. A brown planthopper outbreak caused significant losses, and critics of IPM asked in public what had after all been the results of repeated training efforts. A survey by researchers from the Post Graduate School of Agriculture revealed that IPM trained farmers had significantly less brown planthopper, significantly more yield, and used significantly less insecticides (Table 3 and Figure 23). While there is as yet no IPM policy in Sri Lanka, the technical resources and increasingly the training resources are available to draw upon.

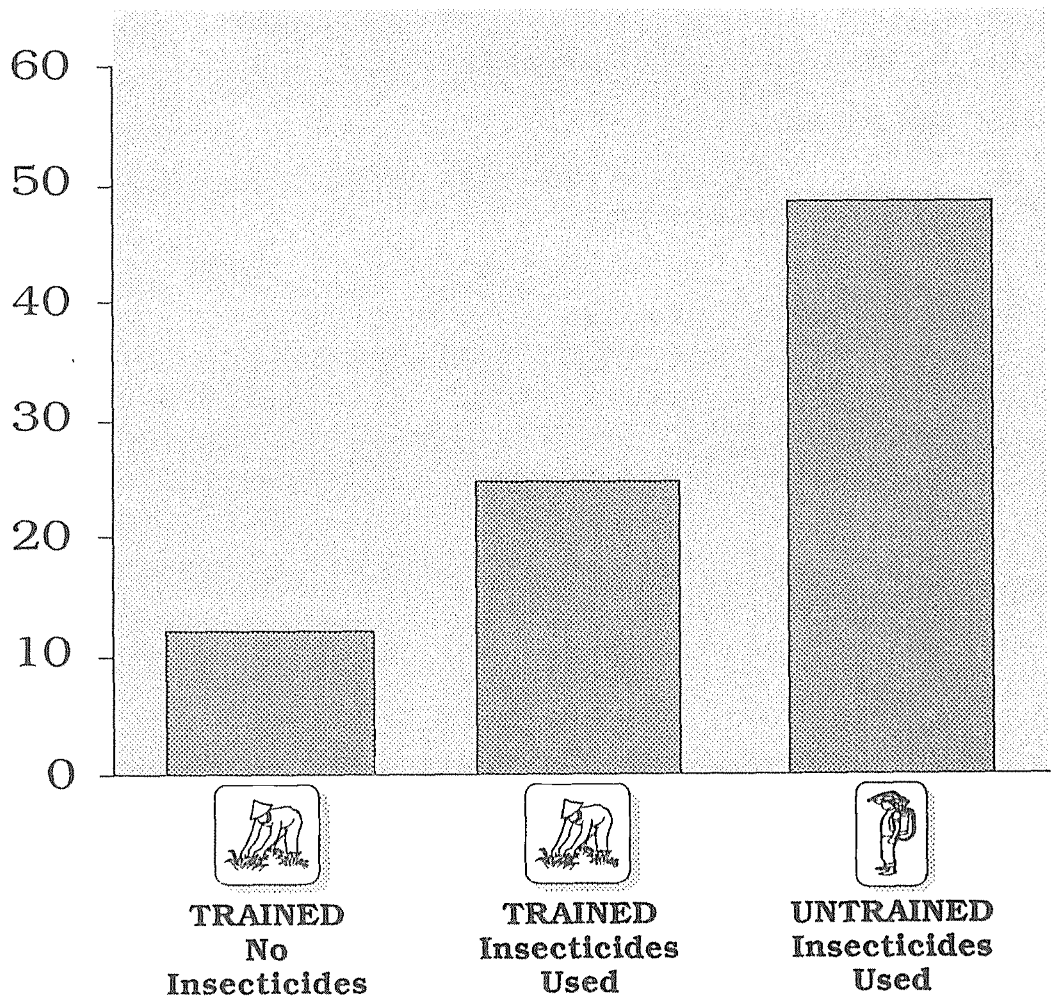


Figure 23. *Area affected by Brown Planthopper (% cultivated area) for IPM trained and untrained farmers, Polonnaruwa, Maha 1989/90*

ENVIRONMENT

Pesticide Load

The politics of environment began with pesticides; Carson's *Silent Spring* and van den Bosch's *The Pesticide Conspiracy* are more valuable now than ever, as developing countries that hold most of the world's people move enviroment into the political arena. It was a great honor for the Indonesian IPM program to be associated with Mochtar Lubis's Indonesian edition of *Silent Spring*, and we have also translated van den Bosch's work.

Not enough is known about the broader environmental effects of pesticides, including especially herbicides as they increase rapidly, on rice ecosystems. The Rockefeller Foundation is funding an international team coordinated at IRRI to begin environmental and health hazard studies. The Indonesian National IPM Program has begun, with a team from Harvard's School of Public Health, to conduct a large prospective epidemiological study of occupational hazards from pesticide use in the crops grown in rotation with rice for which the insecticide bans of the IPM Policy do not yet fully apply.

In the narrower sense of conserving and sustaining rice production systems more is known. Rice, with more than 700 animal species per hectare in highly intensified fields in Philippines and over 1000 so far described Asian species of higher trophic level predators and parasitoids (Barrion pers. comm) contains some of the best understood community relationships in the tropics. The work reviewed above on brown planthopper population regulation in a range of countries is unmatched in any other tropical ecological analysis.

These relationships of indigenous naturally occurring pest control are what the World Conservation Strategy (IUCN 1980) calls essential ecological processes, the conservation of which ranks with the most important work on conserving biodiversity. The Indonesian National IPM Program is, in human terms, one of the largest conservation training efforts in the world. The ecological core of a Farmers' Field School in Indonesia is the recognition and management of THREE trophic levels -- rice, herbivores, and carnivores -- rather than only one or two trophic levels.

As older work by Rosenzweig (1973), Wollkind (1976) and Gilpin (1979), and recent work by Hastings (1990) has shown, the dynamics of three trophic level systems are considerably more complex than two level systems. Trained farmers concentrate on the changing ratios of the two top levels in relation to the steadily increasing biomass and quality of the bottom level. Using agroecosystem diagrams to express the ratio for group discussions puts natural control front and center, and eliminates the pesticide triggering concept of "economic thresholds."

Pesticide load is not only felt in qualitative destruction of essential ecological processes, but also in energetic currency. The economic costs of insecticides rarely exceed 10% of the cash budget budget of intensified rice production. Recent work by Huke and Huke (1990) assigned caloric equivalents to human labor, animal labor, machinery, and chemicals to typical production budgets for three levels of intensity from Central Luzon, Philippines. In this analysis (Table 4) pesticides and sprayers represent 20% of the energy budget of the highest intensity rice system. Not surprisingly, the return of calories output for calories input declined as production intensified. When insecticides are eliminated, as 9 years of data from the Philippine IPM system have shown they can be in the majority of crops, the highest input level system reaches a higher return than the middle level, as well as much higher total production.

Biodiversity

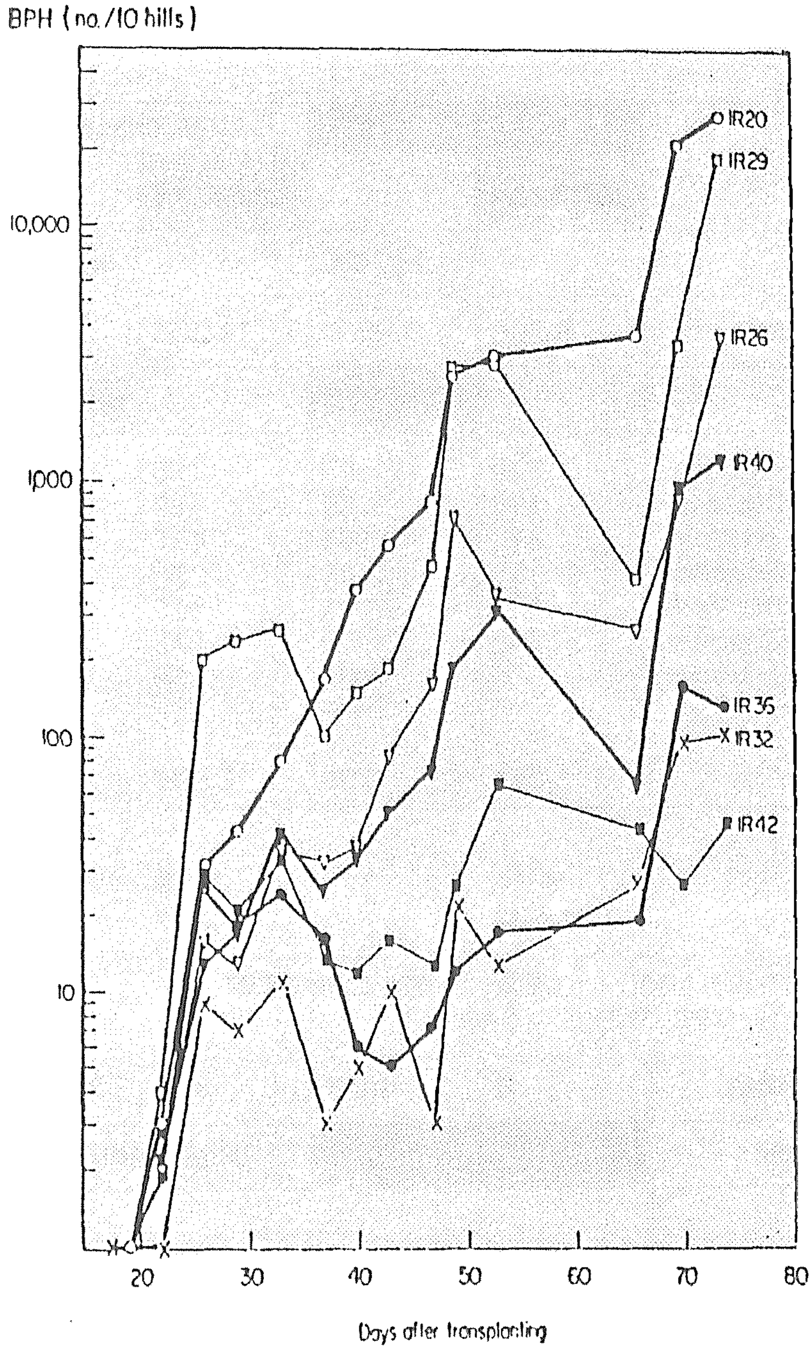
The two higher categories of biodiversity as defined by OTA (1987) -- ecosystems diversity and species diversity -- have been mentioned above. Both are being actively researched across a range of rice agro-ecosystem habitats and landform types in the Indonesian National Program.

All the standard discussions of biodiversity (Ehrlich and Ehrlich 1981; Myers 1979, 1983, 1984; Norton 1988; OTA 1987; Soule 1986; 1987; Wilson 1988) list as the first direct benefit of conserving biodiversity the use of genes from a wide range of sources to improve crop plants. This genetic diversity is among the most concrete examples of farmers as experts. Rice varieties represent the labor of farmers over more than 4000 years selecting locally adapted strains. Rice presents the best documented case of international agricultural research funds being used to deploy this farmer-conserved genetic diversity in the service of more secure food supplies. If, however, subsequent

ENERGY INPUTS AND OUTPUTS FOR MEDIUM AND HIGH INPUTS FARM OPERATIONS IN TARLAC, PHILIPPINES

	Medium Inputs		High Inputs	
Souce of Energy	**kcals/ha**		**kcals/ha**	
Output		**kg/ha.**		**kg/ha.**
Yield of rough rice	8,568	3,6000	14,256	5,600
Inputs		**percent**		**percent**
Human labour	220	21.63	195	9.75
Animal labour	100	9.83	140	7.00
Fertilizer	210	20.65	777	38.87
Plow depreciation	55	5.41	55	2.75
Tractor fuel	187	18.39	187	9.35
Tractor depreciation	245	24.09	245	12.26
Sprayer depreciation	0	0.00	50	2.50
Pesticides	0	0.00	350	17.51
Total	1,017	100	1,999	100
Caloric Output: Input Ratio	**8.42**		**7.13**	
Net Caloric Gain	**7,551**		**12,257**	
from HUKE AND HUKE 1990 -- **RICE: THEN AND NOW.** (published by IRRI: TABLE 9 page 29)				
pesticide sub-total	**0**	**0.00**	**400**	**20.01**
Without Pesticides :	**Medium Inputs**		**High Inputs**	
Caloric Output: Input Ratio	**8.42**		**8.92**	
Net Caloric Gain	**7,551**		**12,657**	

TABLE 4.



Brown planthopper populations on susceptible (IR 20) and resistant varieties sprayed with a resurgence-inducing insecticide, Aquino and Heinrichs, IRRI, 1979.

FIGURE 24

Insecticide-induced brown planthopper outbreak on IR 36 (with bph2 gene) in the Philippines, Peralta et al. 1983

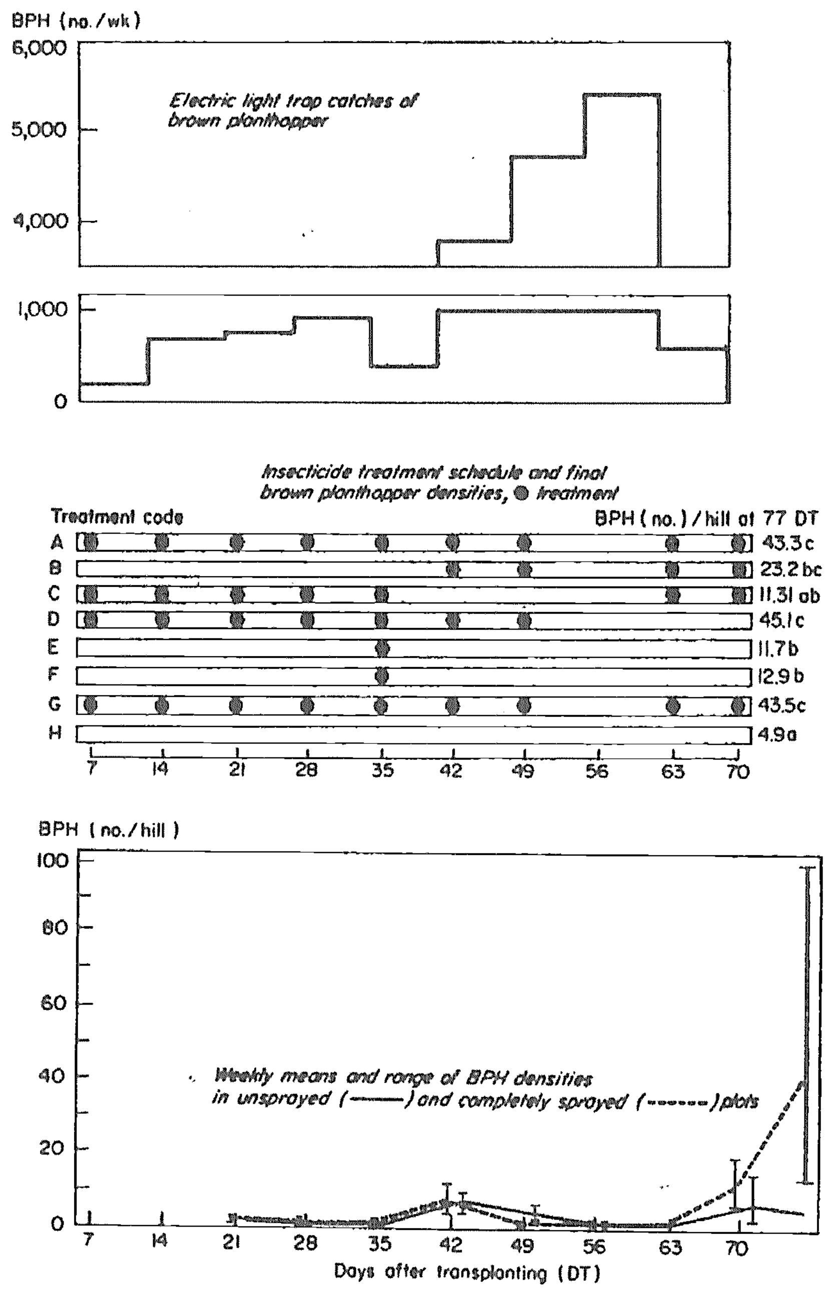


FIGURE 25.

INSECTICIDES ACCELERATE EVOLUTION OF VIRULENT PHENOTYPES AND DEPRECIATE HOST PLANT RESISTANCE DERIVED FROM GENETIC DIVERSITY, PHILIPPINES

Mendellan Resistance Designation	Peak Density BPH per Plant	Phenotypic Ratio Estimated	Relative Protection Prodide by Genetic Diversity
1979 - LAGUNA			
No BPH genes	2,7000	No Gene : bph2	**270**
Bph 1	300	No Gene : Bph1	**30**
bph 2	10	Bph 1 : bph2	**9**
1982/3 - COTABATO			
bph 2	45		
1986 - COTABATO, LAGUNA, AND BOHOL			
No BPH genes	16	No gene : bph2	**2**
Bph 1	17	No gene : Bph1	**2**
bph 2	8	Bph 1 : bph2	**1**
Bph 3	5	No Gene : Bph3	**3**

Sources :
Aquino & Heinrichs 1979
Peralta et al. 1983
Gallagher 1988
Joshi 1988

TABLE 5.

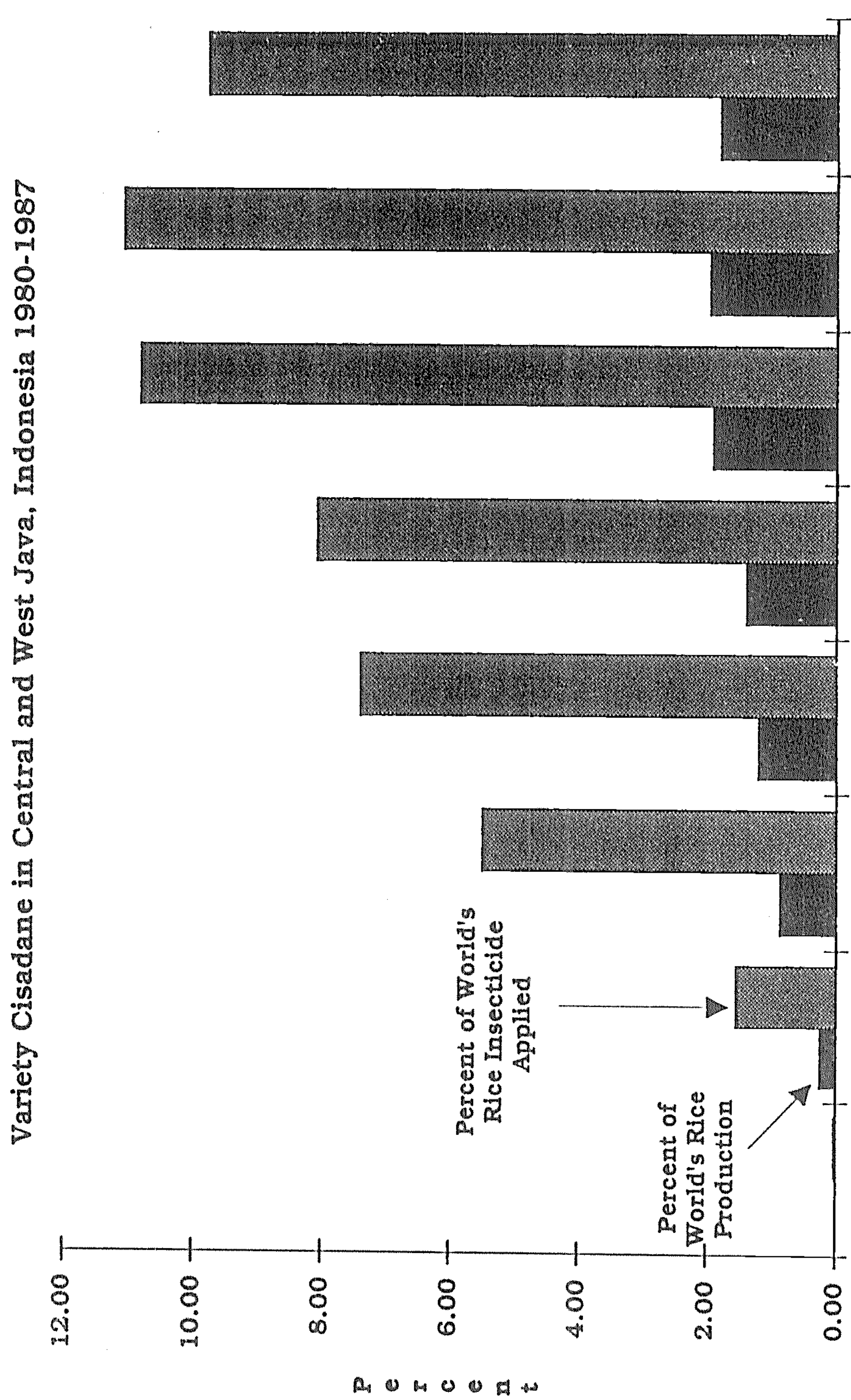

Variety Cisadane in Central and West Java, Indonesia 1980-1987
Percent
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1980
1981
1982
1983
1984
1985
1986
1987
Percent of World's Rice Insecticide Applied
Percent of World's Rice Production

FIGURE 26.

YIELDS (TON/HA) OF IR36, CISADANE AND KRUENG ACEH IN UNTREATED FIELDS, YOGYAKARTA, INDONESIA, 1987

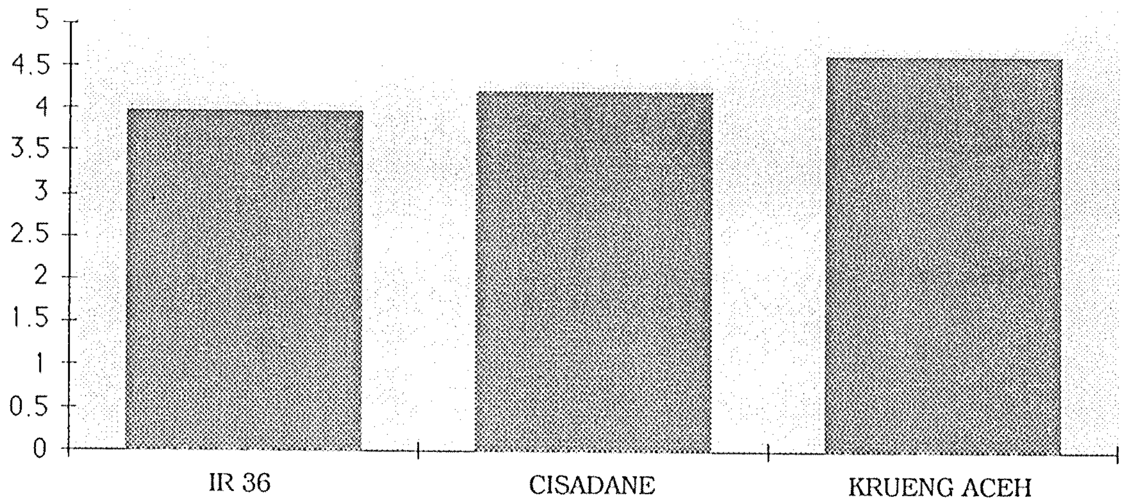


Figure 27.

YIELDS (TON/HA) IN UNTREATED, DIAZINON AND FENITROTHOION TREATED FIELDS, VARIETY CISADANE YOGYAKARTA, INDONESIA, 1987

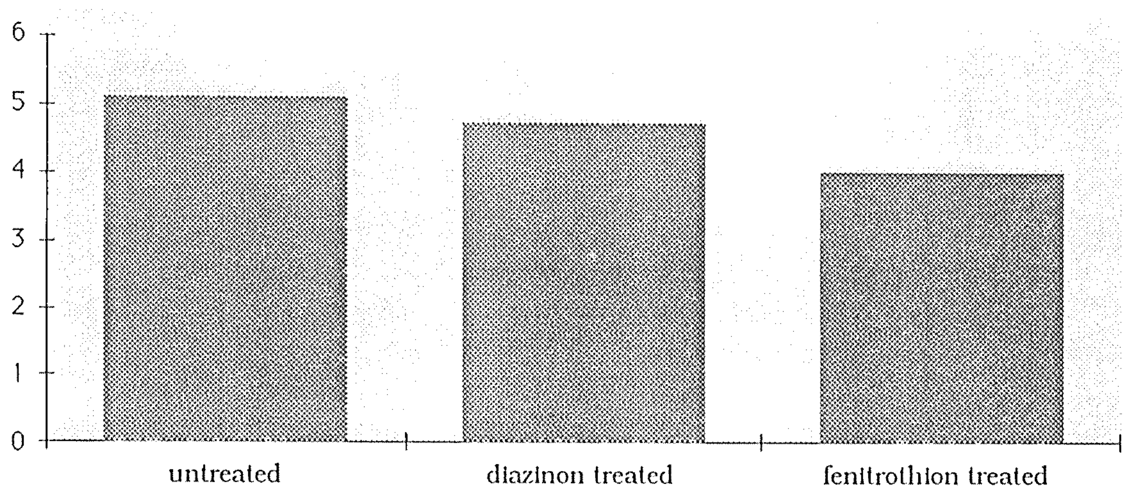
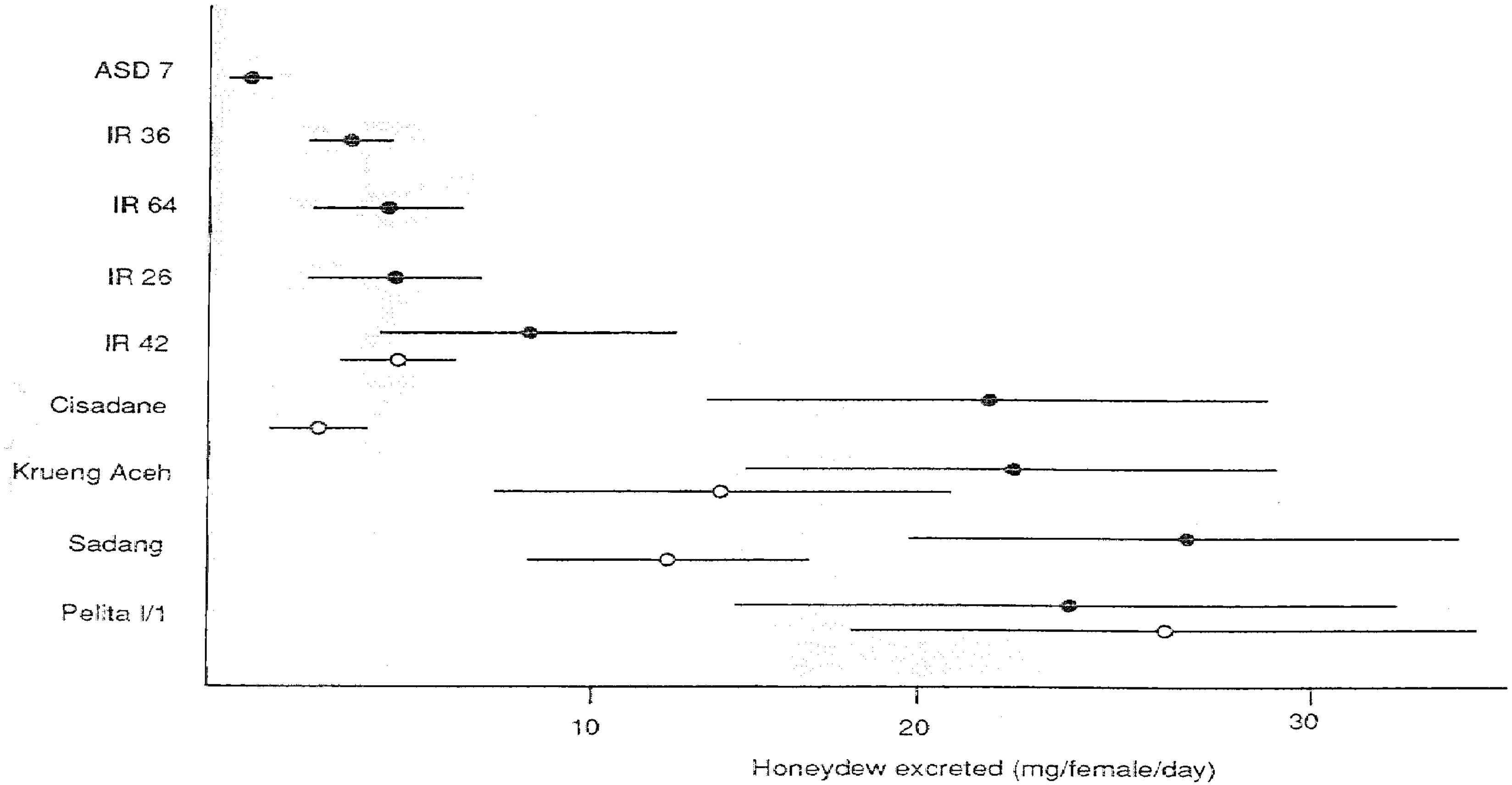


Figure 28.



Honeydew excretion by adult females of Yogyakarta (-o-) and Jatisan (-•-) population of the BPH on selected varieties. Mean and 95% confidential ranges are indicated by spot and line, respectively. Sogawa, 1986.

FIGURE 29.

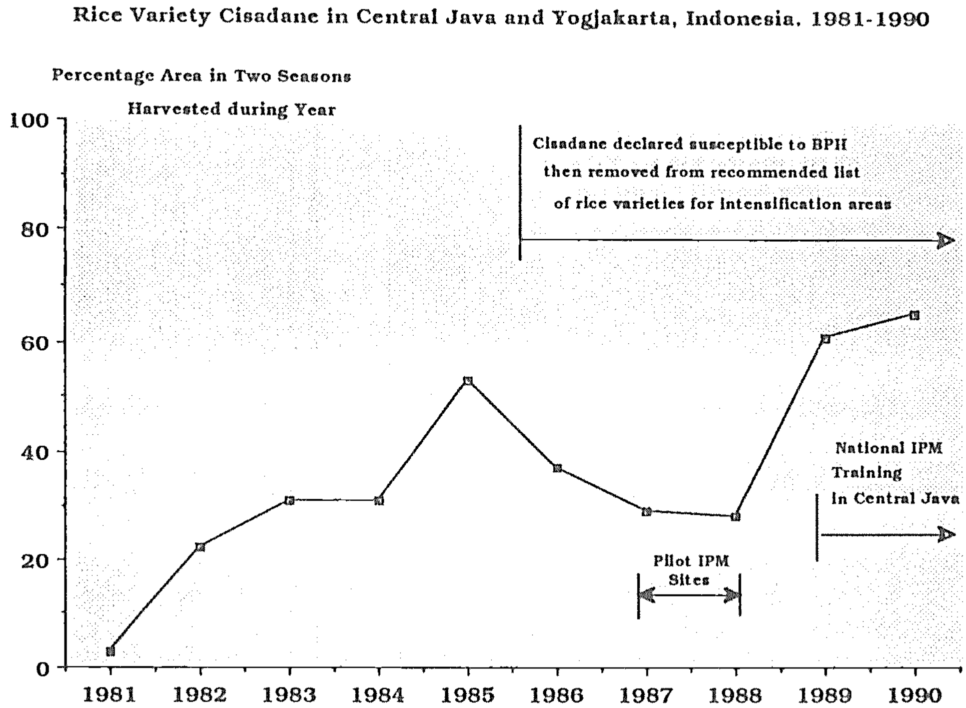


FIGURE 30a.

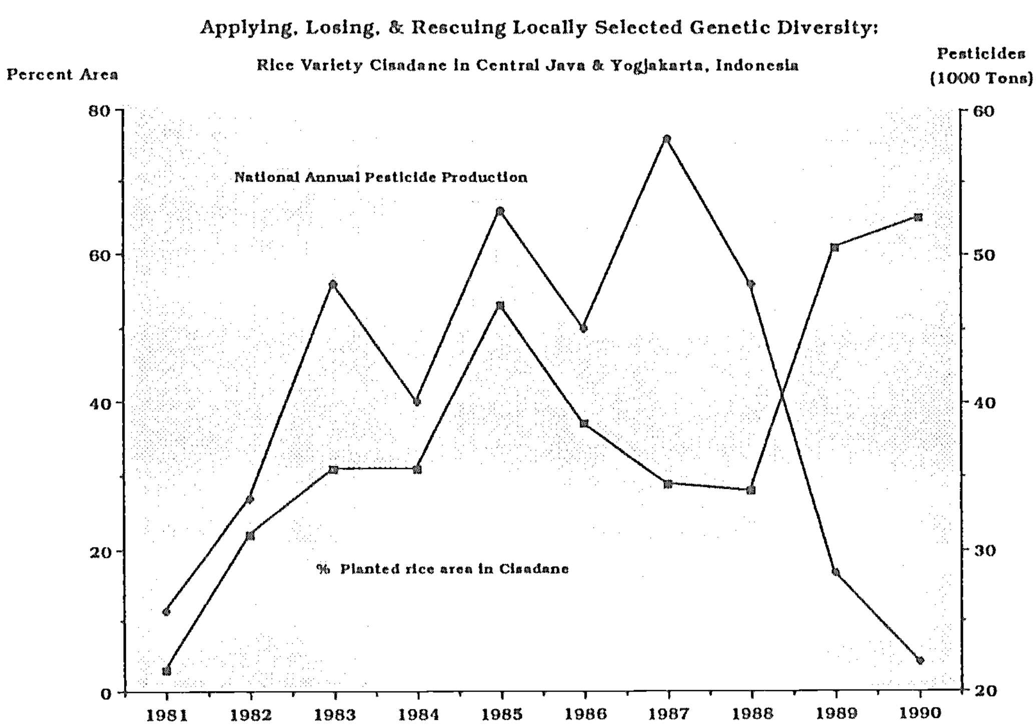


FIGURE 30b.

management of those varieties renders that genetic diversity useless or unavailable, then a large amount of the research investment was wasted. On the other hand if, by better management, the genetic diversity that a rice variety represents can be deployed for a significantly longer time, then the value of the initial investment goes up accordingly.

This section outlines the contribution of IPM to farmers' conservation and deployment of genetic diversity. Data from original source are combined to show that excessive pesticide use accelerates the evolution of virulent phenotypes of brown planthopper, and thus accelerates the depreciation of investment by researchers and donors to research in the production of varieties, not only of rice, but by extension to other annual and perennial crops. The sudden loss and eventual rescue by farmers in Central Java (a province with a population of 23 million people) of the excellent Indonesian variety Cisadane is documented. The Cisadane case is followed by a brief picture of evolution in action in Chainat, Central Thailand. This evolution of virulence repeats closely the experience of Philippines in 1983 and Indonesia in 1986. This is a controlled experiment in large scale applied evolution amplifying the national scale "experiment" in applied ecology discussed above.

The first study of insecticide-induced brown planthopper outbreak on rice varieties resistant to brown planthoppers was Aquino and Heinrich (1979, Figure 24). This study showed populations 270 times higher on "susceptible" varieties than on the most resistant ones, but also showed significant increases over time on the resistant lines. There was also biologically significant variation in the brown planthopper populations so that at least one line containing the stronger known gene for resistance (bph2 from South Asia) supported a much higher density than the other lines.

The first record of insecticide-induced outbreak of brown planthoppers on IR36 -- containing the bph2 gene -- in farmers' fields was that of Peralta et al. (1983 , Figure 25). Paddies separated by less than 5 meters had population densities 10 fold different from each other, based only on the level of natural enemy activity and its disruption before immigration by brown planthoppers. The population densities in this study were more than 4 times higher than the study 4 years earlier, suggesting that, as well as geographic variation, selection pressure in a heavily treated locality was accelerating. The mechanism of this acceleration operated on the few individuals were able to feed on the resistant variety. Under natural conditions without insecticides the mortality inflicted by natural enemies upon the few individuals in the population able to feed on the resistant variety would have eliminated them. With natural enemies killed by insecticides those few individuals were able to multiply without restraint: their descendents more quickly dominated the field population.

Gallagher's exquisite work 3-4 years later (1988 and Table 5) resolved the issue. By 1986, across the Philippines under insecticide pressure, the ratio of densities on IR36 to those on susceptible variety was only 2, down from 270 seven years earlier. The relative protection provided by the deployment or genetic diversity costing tens of millions of dollars in the most popular variety ever released had been weakened by more than 100 times. Disturbingly, the comparable ratio for a variety containing a later gene for resistance, Bph3, under insecticide pressure, was only 3. The field populations of brown planthopper evolved virulence to this gene much faster than to the earlier bph2 gene.

Cisadane was released in Indonesia in the 1980-81 season, and within 3 seasons was planted in about 40% of Central Java's reported rice area (Figure 30a). By 1985, the production of Cisadane in West Java and Central Java alone equalled over 1.9% of total world rice production. The more than US$ 125 million per year insecticide subsidy meant that Cisadane in these two provinces received more than 11% of the world's rice insecticides (Fig 26). Cisadane had the bph2 gene from south Asia parent material, as did Krueng Aceh, the second most popular variety in Central Java. Research from Gajah Mada University in Yogjakarta shows why farmers preferred these two varieties to IR36 (Figure 27). As well as higher yields, they also received up to 30% higher price for Cisadane because the quality was so much better.

But evolution continued to accelerate, and by this time, brown planthoppers in Central Java were able to feed well on Cisadane. Figure 29 shows the relative feeding by West Java and Central Java brown planthoppers on selected varieties. Cisadane was no longer resistant in Central Java. Farmers growing Cisadane in Central Java reduced their yield 10 to 20% by applying common insecticides (Figure 28). That Cisadane fell quickly from 48% of Central Java's rice area to 27% between 1985 and 1987 is easy to understand. Insecticide subsidies had ruined that variety's performance.

The rice variety promulgated by national intensification programs to replace Cisadane was IR64 containing the Bph3 gene. Of the 100 crosses in the lineage of IR64, only ten included Indonesian varieties as parents, or 10%. For Cisadane, produced by the Indonesian national rice breeding system, the figure was ten out of 30, or 30% of the crosses. The system of bulk selection used for much of the 20th century in Java insured high local environmental selection pressure, and correspondingly high degrees of local adaptation.

The potential impact of this local selection pressure in the lineage was indicated in 1990 -91, when a traditional Indonesian herbivore, the white rice stemborer had a local outbreak in West Java. This outbreak was far more severe for farmers growing IR64 than for the fewer farmers still growing Cisadane. Figures 31 and 32 a and 32b present data from the work of Triwidodo and colleagues and of Rubia collected during the next main season after the outbreak was controlled in the popular manner described above. White stemborer survival on Cisadane during the critically vulnerable reproductive stage of the crop was less than half that on IR64. Then, given similar levels of infestation after that stage — whitehead damage — the yield in Cisadane was higher for the given levels, so even if the larvae survived, they did not reduce yield as much as in IR64. In shifting to IR64, farmers rendered themselves more vulnerable to attack by white stemborer.

35 DAYS SURVIVORSHIP OF STEMBORER LARVAE ON IR64 AND CISADANE INFESTED AT DIFFERENT DAYS AFTER TRANSPLANTING, INDONESIA MAIN SEASON 1990-91
(from Triwidodo, in prep.)

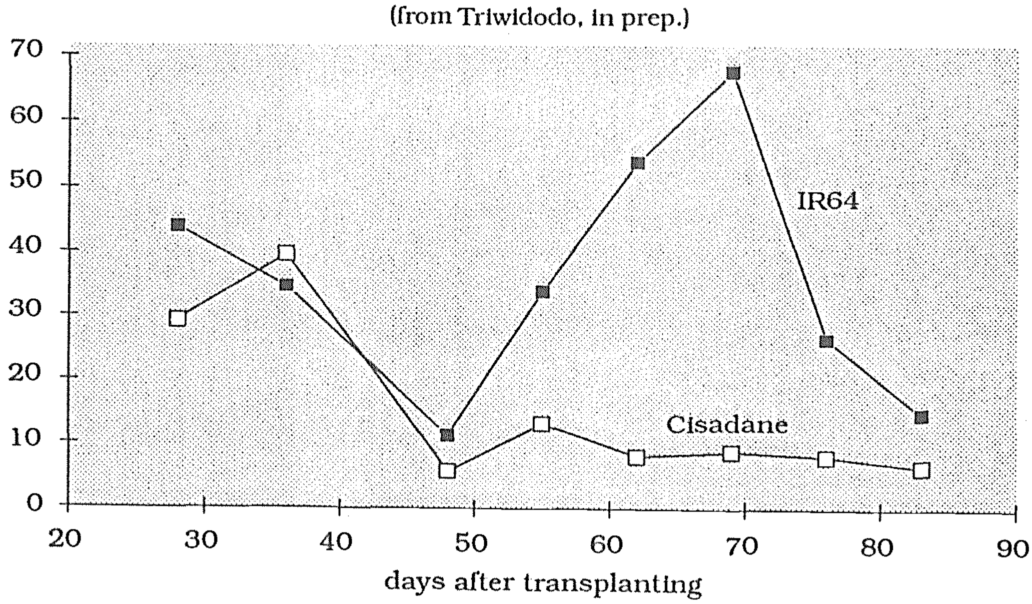


FIGURE 31

YIELD REDUCTIONS IN RICE VARIETIES CISADANE AND IR64 INFESTED WITH WHITE STEMBORERS IN WEST JAVA, INDONESIA, 1990-1991

(from Rubia, in prep.)

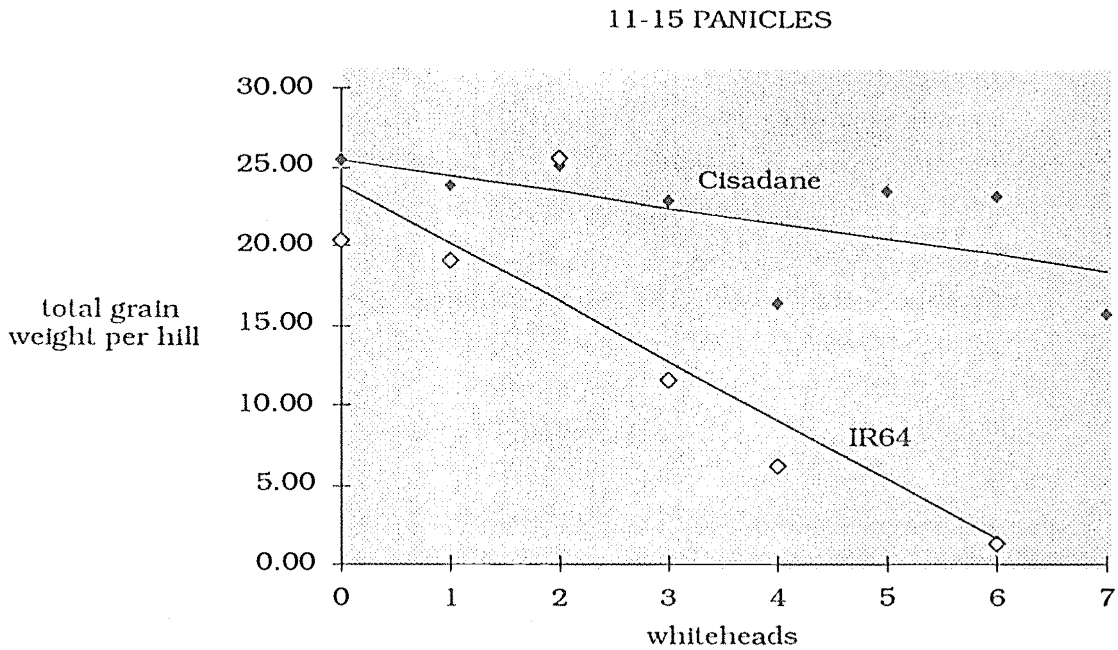


Figure 32a. Smaller Individual Plants

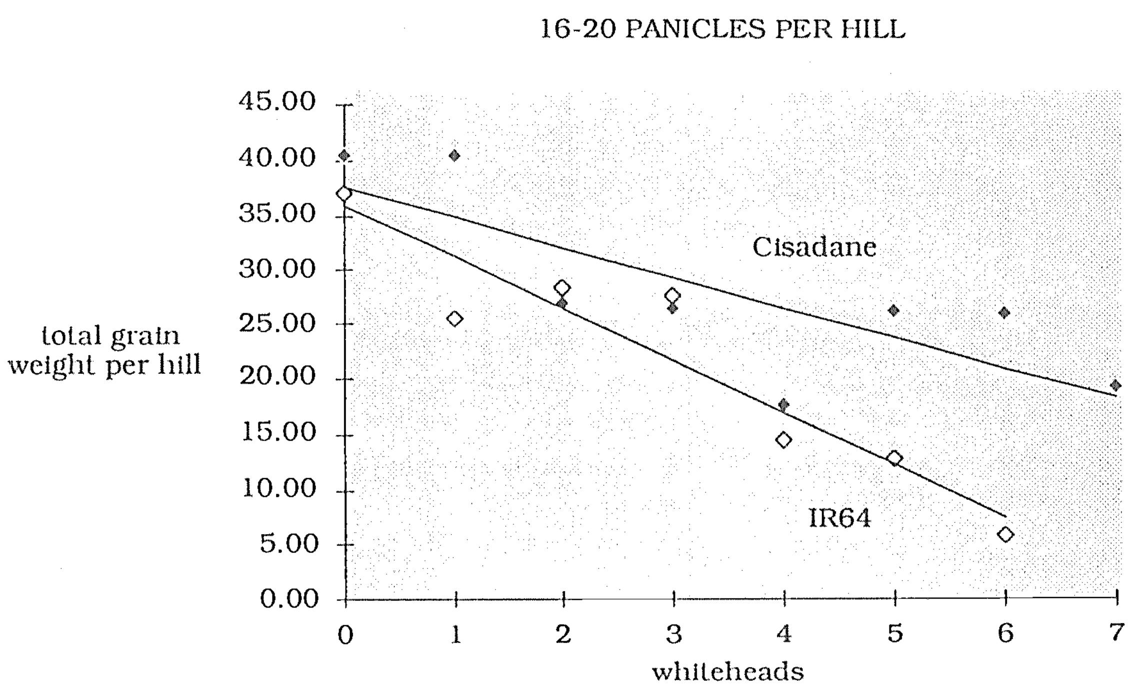


Figure 32b. Larger Individual Plants

The crucial importance of effective national policy for conserving and deploying valuable genetic diversity is now shown in Figure 30a and 30b (from the national Sub-Directorate of Seed Supply and the Provincial Agricultural Department of Central Java). Once pesticide subsidies were removed, price increased, insecticides banned, and farmers trained, pesticide production and use declined. With a more than 75% drop in insecticide load for trained farmers, and generally at least 50% drop across the province, farmers in Central Java went back to Cisadane. By 1991, over 60% of the rice area was planted to Cisadane, a remarkable testimony to the farmers' preference and the impact of IPM in allowing them to choose locally adapted genetic diversity that pays off for them.

As described above, 1989 -90 was the largest brown planthopper outbreak in the history of Thailand, which does not have an IPM policy. A rice variety called RD23, carrying the bph2 gene for brown planthopper resistance, was released and planted specifically to control the huge brown planthopper outbreak. Very recent results from den Braber's group suggest than the insecticide pressure common to Central Thailand (Figure 16)induces a 10 to 20 times increase in the density and thus accelerates the proportional domination of virulent phenotypes of the pest. Figures 33 and 34 present data from Chainat Province showing evolution in action. The Philippine and pre-IPM Indonesia case is just starting to be repeated. This is a matter for concern by the Ministry of Agriculture, as its strategy for brown planthopper control rests on the bph2 gene.

TOTAL NUMBER OF BPH/WBPH EGGS PER SAMPLING UNIT (0.05 M2), CHAINAT, CENTRAL THAILAND ("RESISTANT" VARIETY RD 23)

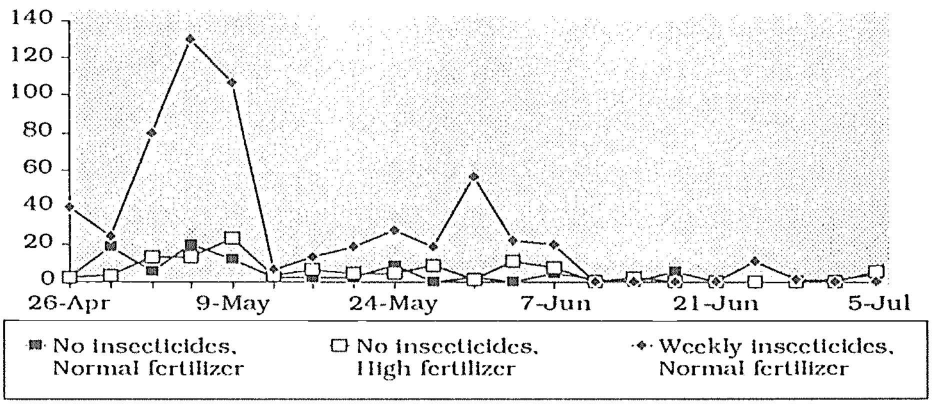


Figure 33a.

TOTAL NUMBER OF YOUNG BPH/WBPH NYMPHS PER SAMPLING UNIT (0.05 M2), CHAINAT, CENTRAL THAILAND ("RESISTANT" VARIETY RD 23)

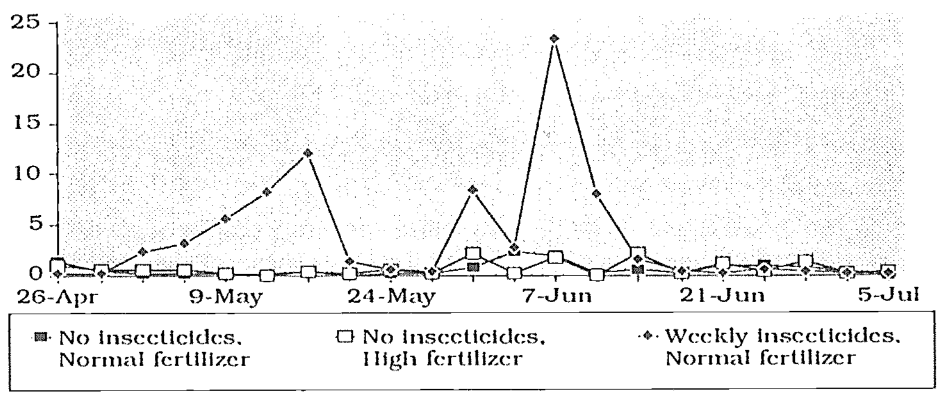


Figure 33b.

TOTAL NUMBER OF OLD BPH/WBPH NYMPHS PER SAMPLING UNIT (0.05 M2), CHAINAT, CENTRAL THAILAND ("RESISTANT" VARIETY RD 23)

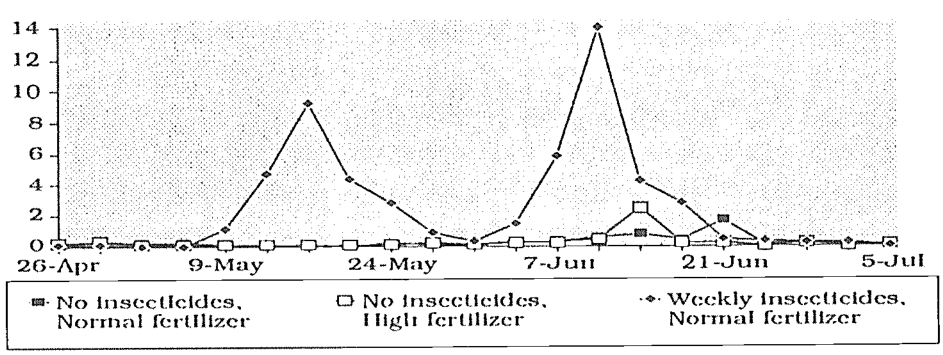


Figure 33c.

Insecticide-accelerated evolution of virulent population of brown planthopper. Rice variety RD23 (carrying bph2 gene) in Central Thailand 1991.

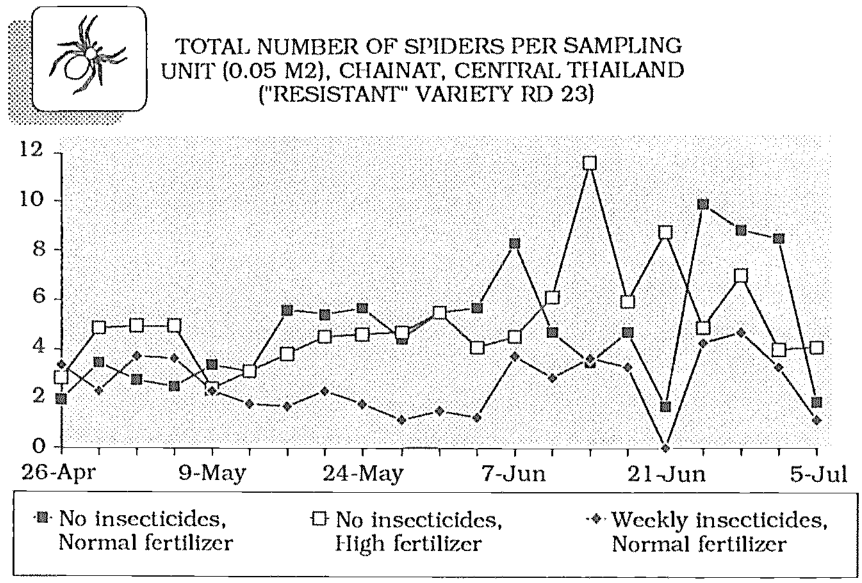


Figure 34. ***Mechanism of accelerated evolution - loss of natural biological control as insecticides kill spiders and permit virulent individuals to reproduce.***

BANGKOK POST, July 19, 1991

Ministry to give farmers' bug-resistant paddy seeds

THE Ministry of Agriculture and Cooperatives will soon distribute to farmers new paddy seedlings which are resistant to brown plant hoppers.

Agriculture Minister Anat Arbhabhirama said the Agriculture Department had cultivated 60 tons of new paddy seedlings, called Suphan Buri 90, and would provide it for farmers so they could cultivate it in the coming main crop.

This followed Cabinet approval of a 677.6-million-baht budget for the ministry to start a six-year plan this year to get rid of brown plant hoppers.

Three million rai of rice fields in the central plains and other areas were damaged by brown plant hoppers last year, resulting in a sharp drop in the country's paddy yields.

Agriculture Department Director-General Thanongchit Wongsiri said Suphan Buri 90 was more resistant to brown plant hoppers than Suphan Buri 60, but similar to RD 23 (another kind of paddy seedlings).

He said the quality of the new paddy seedlings was the best available and would meet market requirements.

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