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PERSONAL AUTHORS - LITSINGER, J. A.
LUMABAN, M. D.
BANDONG, J. P.
PANTUA, P. C.
BARRION, A. T.
APOSTOL, R. F.
RUHENDI

CORPORATE AUTHORS - IRRI

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A METHODOLOGY FOR DETERMINING INSECT CONTROL RECOMMENDATIONS

J.A. Litsinger, M.D. Lumaban, J.P. Bandong, P.C. Pantua, A.T. Barrion, R.F. Apostol, and Ruhendi

The International Rice Research Institute
P.O. Box 933, Manila, Philippines

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ABSTRACT

Generation of insect-control technology starts in laboratory, greenhouse, and field trials at commodity-oriented experiment stations. A second phase, applied research, adapts the technology to specific areas (environments) within a country. During this phase, insect control technology is specified to farm level cropping patterns and is integrated into other production practices. The methodology of applied research includes the subprocesses of description, design, testing, and evaluation. Description includes evaluation of farmers' present insect control practices, determination of their resource level (cash, power, labor) for applying appropriate insect control technology, understanding constraints and managerial limitations to their adoption of improved technology, quantification of yield losses, and identification of key pests. Appropriate technology is selected (design phase) based on the results of description and is verified through cropping pattern trials on farmers' fields (testing phase) over several years. The results are analyzed (evaluation phase) in relation to the farmers' current production system. If the improved technology is economically attractive, a decision may be made for extension services to embark on a multilocational testing program. Technical problems encountered during the transfer of information to the farmer are fed back through the system and may lead to controlled experiments in an attempt to solve them.

[1]By J. A. Litsinger, entomologist; M. D. Lumaban, J. P. Bandong, P. C. Pantua, and A. T. Barrion, research assistants; R. F. Apostol, research aide, Entomology Department, Cropping Systems Program, International Rice Research Institute, Los Baños, Laguna, Philippines; and Ruhendi, IRRI research scholar, Cropping Systems Program, Central Research Institute for Agriculture, Bogor, Indonesia.

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A METHODOLOGY FOR DETERMINING INSECT CONTROL RECOMMENDATIONS

The phrase coined to highlight recent advances in agricultural technology based on high-yielding cereal varieties was *green revolution*. Although those advances greatly enhanced the potential for food production on Asian farms, the realization of higher yields and profits, particularly for small-scale farmers, has been slower than expected.

The mere adoption of high-yielding varieties does not insure farmers of the full potential yields and profits possible in a given environment. To attain the full benefit from high-yielding varieties, farmers need to properly manage them. That involves correct use of crop production practices, collectively termed *component technology*.

Often the component technology has been dictated as a *package of practices* in nationwide production programs in Asia. The failure of farmers to adopt the complete package of practices and the discrepancies between yields obtained at experiment stations and those in farmers' fields have been termed *yield gap* (IRRI 1979). Constraints associated with the yield gap can be categorized as biophysical and socioeconomic.

The yield gap and its contributing constraints has stimulated researchers to reevaluate the process of technology development for small-scale farmers in Asia. The outcome is embodied in a cropping systems approach (Zandstra 1977).

The cropping systems approach involves local testing and verification of crop production technology in the farm setting by a multidisciplinary team of researchers. The end product is a package of practices adapted to the production program's biophysical and socioeconomic environment.

Insect pest control is one of the most challenging aspects of crop production, but one that farmers find difficult to master (Litsinger et al 1978b). Insect control technology can involve costly inputs of insecticides, labor, and insecticide application equipment. Misuse of insecticides results in loss of profit, poses health hazards to farmers and others, and may cause insect pest resurgence (Chelliah and Heinrichs 1978, Kenmore 1979). The proper execution of insect control technology involves a broad knowledge base, which encompasses insect identification and population assessment techniques as well as decisions on the appropriate control procedures. A wide array of choices of insecticides, dosages, [illegible]ing, and application methods, as well as nonchemical control methods such as host-plant resistance and biological and cultural control, are involved.

The relatively recent concept of integrated insect pest control has evolved within entomology as a means of coping with the complex array of control procedures and insuring more stable solutions to insect pest problems (Brader 1979). The cropping systems approach offers further insights such as how to integrate, adapt, and specify insect control technology into a local farm setting (Litsinger and Moody 1976, Litsinger 1977, Litsinger et al 1977).

Insect control technology should be specified based on cropping patterns, environment, site, yield potential, and farmers' resource levels and managerial capabilities. A method for achieving this includes:

- quantifying yield losses partitioned among crop growth stages,
- determining the key pests responsible for yield losses,
- understanding farmers' current pest control practices, and their potential to adopt new technology,
- selecting appropriate insect control technology,
- testing the technology on farmers' fields on crops grown in cropping patterns under optimal management of other production variables, and
- evaluating the costs and returns of the technology.

The product of this site-conditioned research will form the basic component of integrated pest management systems to be implemented by farmers with the guidance of extension and pest management technicians.

SITE-SPECIFIC DETERMINANTS OF INSECT CONTROL TECHNOLOGY

For each crop, national insect control recommendations cover the entire spectrum of pest problems within a country. Normally these recommendations consist of lists of insect pests and corresponding effective insecticides, resistant varieties, or some cultural control methods. Information on timing of insecticide applications is usually lacking and often, it would be more economical to control several pests with one chemical than with several different chemicals as recommendations sometimes state.

Cropping systems research offers a way of specifying recommendations for each area, considering local variations in pest species abundance, environmental interactions with insect control technology, and local farmer practices, traditions, and capabilities. As a result of testing insect control technology at the local level over several years, the recommendations can be simplified to include appropriate prophylactic and corrective insecticide applications. Cropping systems research provides thorough economic analyses of alternative insect control recommendations, makes them highly efficient, and thus helps the extension technician as well as the farmer.

Specifying technology to cropping patterns

In cropping systems research, insect control technology is evaluated for each crop at the time it is grown in a pattern on farmers' fields. The cropping pattern becomes the basic unit of study. This is a departure from the way research is conducted at experiment stations.

One advantage of studying insect control in the context of cropping patterns is that the level of control is set only for those pests abundant during the time the crop is grown. Many insect pests are highly seasonal in nature. A difference of several weeks to a month in the planting date can mean the difference between an insect's being damaging or not. If an insect regularly occurs at a site in high numbers at a particular planting date, it may be inexpensively controlled with a prophylactic insecticide application. For a highly seasonal pest it would be unwise to specify a prophylactic treatment nationwide.

We site three examples in the Philippines:

1. The rice seedling maggot *Atherigona oryzae*, which was highly damaging to maize seedlings at the Tanauan, Batangas, dryland research site only during August and September plantings. May, June, October, and November plantings, however, escaped damage. This was confirmed over several years.

   The recommended control for rice seedling maggot is 0.5 kg a.i. carbofuran granules/ha, about US$15/ha. It was recommended for maize planted in August and September (second maize crop of the pattern *green maize-field maize-cowpea*, which is established in May). For May-planted maize crop and for maize planted after rice (October or November), only carbaryl seed treatment (US$0.50/ha) was recommended for ants.

2. In double-cropped rainfed wetland rice in Iloilo, the first crop, established in May or June, virtually escapes insect damage because it is grown after a 3 to 4 month rice-free dry season (Litsinger et al 1978a). The second crop, planted in October, suffers a 1 t/ha yield loss due to stem borers and rice caseworm.

3. Pod borers attack mung bean after rice in Pangasinan. Mung bean planting dates vary in the cropping patterns: dry-seeded rice-mung bean (November); green maize-transplanted rice-mung bean (December); and dry-seeded rice-transplanted rice-mung bean (January).

   Two years of trials have confirmed distinct shifts in the dominance among pod borer species attacking mung bean -- *Maruca testulalis* in November plantings, *Heliothis armigera* in December plantings, and *Etiella zinckenella* in January plantings (Table 1). *Heliothis* is more serious than *Maruca* or *Etiella* and if uncontrolled can result in complete crop loss.

Specifying technology to geographical areas

The distribution of insect pests within a country is often uneven. Some pests may occur in some regions and not in others. We cite five examples from the Philippines:

1. *Etiella zinckenella*, which is catastrophic on soybean after rice in Iloilo but is not even recorded on soybean in Batangas (Litsinger et al 1979).

2. *Thrips palmi* on grain legumes has become important in Laguna but is not even recorded in Iloilo province.

3. The white stem borer *Tryporyza innotata* is the dominant rice stem borer in rainfed wetland rice areas of Iloilo but is rarely recorded in Laguna and Pangasinan provinces.

4. Whorl maggot *Hydrellia sasakii* regularly occurs in low numbers on rice in Iloilo and is not a pest, but is a major rice pest in Laguna and Pangasinan provinces.

5. The flea beetle *Medythia suturalis* is a major dry-season pest of grain legumes in Pangasinan (Litsinger et al 1978c). The adults feed on the young seedlings,causing seedling death or stunted plants. This insect is, however, only of minor importance in Laguna and Iloilo provinces.

Specifying technology to environmental parameters

Environmental factors, particularly rainfall pattern, soil type, soil nutrients, landform, and water status, have direct or indirect effects on the incidence of pests and natural enemy species as well as on insecticide performance. Many of these factors are also determinants of cropping pattern performance. Thus, the Cropping Systems Program at IRRI has specified patterns for particular environmental subunits within an area (Tables 2 and 3).

Rainfall pattern and irrigation are perhaps the most dominant of the environmental factors affecting pests, natural enemies, and insect control. Dryland rice typically has fewer insect pest problems than wetland rice. Such pests as brown planthopper and the virus diseases vectored by green leafhopper pose no threat to dryland rice (Litsinger et al 1978a). The long rice-free periods and low relative humidity are reasons cited for the general lack of insect pest problems. 1976-78 tests in Batangas did not reveal any significant yield losses attributed to insect pests (Table 4). Rice root aphid and rice mealybug

Table 1. Effect of planting data on mung bean pod borers and their control with different levels of insecticide.[a] Pangasinan, 1977-78.

Insecticide protection	Defoliation (%) *Heliothis* 45 DE			Million pods/ha		
	Nov	Dec	Jan	Nov[b]	Dec[c]	Jan[d]
High level[e/]	3 a	5 a	5 a	1.71 a	2.42 a	1.04 a
Recommended level[f/]	4 ab	64 b	12 ab	1.68 a	0.90 b	0.85 a
Untreated	13 b	81 c	25 a	0.66 b	0.05 c	0.14 b

[a]Av of 4 fields per planting date. DE = days after crop emergence. In a column, means followed by a common letter are not significantly different at the 5% level. [b]*Maruca testulalis*. [c]*Heliothis armigera*. [d]*Etiella zinckenella*. [e]0.5 kg a.i. monocrotophos/ha at 2, 12, and 25 DE. 1 kg a.i. endosulfan/ha at 35 and 45 DE. [f]0.25 kg a.i. monocrotophos/ha at 2 and 12 DE. 0.75 kg a.i. endosulfan/ha at 35 and 45 DE.

are pests in other dryland areas of the Philippines (e.g. Bukidnon province) characterized by light well-drained soils. The heavy clay soils of Batangas have greater water-holding capacity to allow for brief periods of standing water in the fields after heavy rains, and those insects cannot become established.

Bunded rice fields of the wetlands allow for soil puddling. In these areas soil insects such as white grub, termites, root aphids, and mealybugs cannot survive. In dryland rice environments, such rice pests as whorl maggot and caseworm do not occur. These insects require standing water during the vegetative stage.

Another consequence of flooding is the apparent absence of important earwig predators in the wetland rice environments. As a result, the Asian corn borer *Ostrinia furnacalis* is a serious pest in areas where earwigs do not occur. However, in Batangas, soil-inhabiting earwigs are the major reason why the corn borer is not a pest despite the continuous availability of maize from May to January (IRRI 1977). However, not all unflooded habitats are suitable for the earwigs and in Bukidnon the corn borer is a major pest. Factors responsible for the high earwig populations in Batangas are still unknown.

Puddling also affects the performance of granular insecticides on grain legumes planted in soils that are alternately flooded and unflooded. Carbofuran granules applied in seed furrows are more effective on continuously dry soils than on dry soils that had been previously flooded (Table 5). The reason for carbofuran's relatively poor performance against early-season grain legume pests on puddled soils is unknown, but it is perhaps related to differences in soil texture.

Heavy rainfall quickly washes insecticide off the foliage, and during the rainy season insecticides applied as sprays are less efficient than granular formulations. Thus, granular systemic insecticides are recommended for whorl maggot control for wet-season rice. During the dry season, however, sprays are effective against grain legume pests.

Rainfed wetland rice is prone to periods of drought and flooding. It has been demonstrated that diazinon granules, which are highly effective in irrigated rice where paddy water levels can be controlled, are ineffective against whorl maggot and rice caseworm (Table 6). Diazinon is not a systemic insecticide and depends on the capillary movement of water up the culm behind the leaf sheath to achieve control. With a low paddy water level this upward movement cannot occur. Typhoon rains may also wash the granules out of the rice fields. This is another reason for recommending soil incorporation of carbofuran granules for rainfed wetland rice. Root-zone application of a granular systemic insecticide is effective during periods of drought or flooding.

Another reason for recommending granular systemic insecticides for rainfed wetland rice is that water for sprayers may not be always readily available to dryland farmers, unlike in irrigated areas where water can be taken directly from the field or near-by canals (Litsinger et al 1978b).

The choice of crop variety is also determined by environmental factors. Many modern high-yielding rice varieties are resistant to some insect pests; but in other crops such resistant varieties are not available. The farmer, however, often has a choice in terms of crop maturity for crops such as rice (105-180 days), maize (75-130 days), and cowpea (75-200 days). Early-maturing varieties that escape insect pest buildup because they remain in the field for shorter periods have been developed. Early-maturing rice varieties escape brown planthopper and stem borer buildup to a great extent, and thus require less insecticide protection. Likewise, 75-day maize varieties can escape the third generation borer. Determinant cowpea varieties are less exposed to pod borers than indeterminant varieties. The longer a crop is in the field, the more insecticide applications required.

Specifying technology to cultural practices

Rice can be established in many ways.

- transplanted either from a wet or dry bed using 2- (*dapog*) or 3-week-old seedlings,
- direct seeded into dry or wet soil either broadcast, sown in rows, or dibbled in hills, and
- ratooned.

Each method allows for a variety of methods of applying insecticide, such as seed treatment, seedling soak, seedling dip, sprays, broadcast granules, soil incorporation of granules, or placement of granules in rows or hills. For any one cultural practice there is an optimal method.

The recommended dosage of granular systemic insecticide is 0.5 kg a.i./ha, placed in dry furrows, for dry-seeded rice and 1 kg a.i./ha, incorporated into the soil, for transplanted or pregerminated wet-seeded rice.

Soil incorporation of systemic granules is a simple technique of placing the insecticide in the root zone. The minimum effective dosage depends on the degree of puddling. For loose, well-prepared, and free-of-plant debris soil, a 0.5 kg a.i./ha dosage is effective. In rainfed wetland areas, if the soil is

Table 2. Historical development of cropping patterns designed for Iloilo, 1975-79.

Crop year	Cropping pattern[a]		Environment[b]
1975-76		cowpea	Wetland
		mung bean	"
	DSR-WSR	maize	"
	WSR-WSR/TPR –	sorghum	"
	TPR/WSR	soybean	"
		peanut	"
		sweet potato	"
		melon	"
	TPR-TPR-TPR		"
	DSR-TPR-TPR		"
		sorghum	"
		soybean	"
	Green maize-TPR/WSR –	mung bean	"
		maize	"
		peanut	"
	Green maize + dryland rice –	soybean-sweet potato	Dryland
		sorghum	"
	Maize-soybean –	sweet potato	"
		sorghum	"
1976-77	WSR-TPR/WSR	– mung bean	Plateau/Side slope/Plain
	TPR	– melon	"
	DSR-TPR/WSR –	cowpea	Plateau/Plain
		mung bean	"
	TPR	– sorghum	"
		mung bean	Plateau/Side slope
	TPR –	cowpea	"
		sweet potato	"
	Green maize-TPR	– cowpea	"
	TPR	– maize	Side slope/Plain
	TPR	– peanut	Plateau
	DSR-TPR-TPR		"
	Green maize-TPR	– sorghum	"
	WSR-TPR/WSR-TPR/WSR		Plain
	WSR-TPR	– melon	"
	Green maize + DSR	– soybean-sweet potato	"
	TPR	– maize + peanut	"
	TPR	– maize + mung bean	"

Continued on next page

Table 2. continued

1977-78	WSR-TPR/WSR -	mung bean	Plateau/Side slope/Plain/Bottom land
		cowpea	"
	DSR-WSR -	mung bean	Plateau/Side slope/Plain
		cowpea	"
	TPR/WSR -	mung bean	"
		cowpea	"
		sorghum	"
		sweet potato	"
		peanut	"
		soybean	"
	Green maize-WSR/TPR -	mung bean	"
		cowpea	"
1978-79	TPR-ratoon -	mung bean	Plateau/Side slope/Plain/Bottom land
		cowpea	"
	WSR	- mung bean	Plateau/Side slope/Plain
	Green maize-TPR/WSR -	mung bean	"
		cowpea	"
		peanut	"
	WSR-TPR -	mung bean	Plateau/Plain/Bottom land
		cowpea	"
	WSR-WSR -	mung bean	Plain/Side slope/Bottom land
		cowpea	"
	TPR	- mung bean	Plateau/Side slope
	TPR	- cowpea	"
	WSR	- mung bean	"
	DSR-WSR -	mung bean	Plateau/Plain
		cowpea	"
	WSR-WSR -	mung bean	"
		cowpea	"
	DSR-TPR	- peanut	Plateau
	WSR-ratoon	- peanut	"
	WSR	- peanut	"
	DSR-WSR -	mung bean	Plain
		cowpea	"
	TPR	peanut	"
1979-1980	TPR/WSR-ratoon -	mung bean	Plateau (heavy soil)/Side slope
		cowpea	"
	WSR-TPR/WSR -	mung bean	Plateau/Plain
		cowpea	"
	DSR-TPR -	mung bean	Plateau (light soil)
		cowpea	"
	WSR-WSR -	mung bean	Plain/Bottom land
		cowpea	"

[a]TPR = transplanted rice, DSR = dry-seeded rice, WSR = pregerminated wet-seeded rice. [b]Change in environmental description in 1976-77 (IRRI 1977).

allowed to dry and is not well prepared, or many weeds or rice stubbles are present, a 1 kg a.i./ha dosage is recommended.

Rice should remain in the seedbed for 2-3 weeks before transplanting. Methods of intensifying the number of crops per year by transplanting older seedlings are, however, being evaluated. A crop transplanted at the maximum tillering stage will require less insecticide protection against early-season pests such as whorl maggot, caseworm, and stem borer. These pests can be effectively controlled in the seedbed with a great savings on insecticide.

The method of establishing grain legumes after rice has a profound effect on preflowering insect pests of mung bean and cowpea. If grain legumes are established in standing rice stubbles, pests such as bean fly (*Ophiomyia phaseoli*), leafhopper (*Amrasca biguttula*), thrips (*Thrips palmi*), aphid (*Aphis craccivora*), and leaf miner (*Stomopteryx subsecivella*) are substantially reduced during the first 2-3 weeks of crop growth (Ruhendi and Litsinger 1977) (Table 7). The height and density of the rice stubbles, which are influenced by the variety of rice, tiller density (spacing), and cutting height at harvest, are important in achieving the degree of pest suppression (Table 8).

Table 3. Historical development of cropping patterns designed for Pangasinan, 1975-79.

Crop year	Cropping pattern[a]	Environment[b]
1975-76	DSR-TPR - cowpea	Wetland
	DSR-TPR - mung bean	"
	DSR-TPR - maize + peanut	"
	DSR-TPR - maize + soybean	"
	DSR-TPR - maize + mung bean	"
	TPR - cowpea	"
	TPR - mung bean	"
	TPR - sorghum	"
	TPR - soybean	"
	TPR - sweet potato	"
	TPR - maize + mung bean	"
	TPR - maize + peanut	"
	TPR-soybean-cowpea	"
	TPR-maize-cowpea	"
	TPR-TPR-sweet potato	"
1976-77	DSR/WSR-TPR - mung bean	Wetland
	DSR/WSR-TPR - cowpea	"
	DSR/WSR-TPR - sorghum	"
	DSR-TPR/WSR-Mung bean	"
	TPR/WSR - peanut	"
	TPR/WSR - sweet potato	"
	TPR/WSR - mung bean	"
	TPR/WSR - cowpea	"
	TPR/WSR - soybean	"
	Green maize-TPR/WSR - mung bean	"
	Green maize-TPR/WSR - cowpea	"
	Green maize-TPR/WSR - soybean	"
	Green maize-TPR/WSR - sorghum	"
	Green maize-TPR/WSR - peanut	"
	Green maize-TPR/WSR - sweet potato	"
	Green maize-TPR/WSR - bush sitao	"
	WSR-sorghum- ratoon	"
	TPR/WSR-TPR-WSR	"
1977-78	DSR/WSR-TPR - mung bean	Deep/Shallow water table
	DSR/WSR-TPR - sorghum	"
	DSR/WSR-TPR - cowpea	"
	DSR/WSR-TPR - bush sitao	"
	DSR/WSR-TPR - peanut	"
	Green maize-TPR - mung bean	Deep water table
	Green maize-TPR - sorghum	"
	Green maize-TPR - cowpea	"
	TPR-TPR-TPR	Shallow water table (free-flowing wells)
1978-79	DSR/WSR-TPR/WSR - cowpea	Shallow or deep water table - rainfed or partially irrigated
	DSR/WSR-TPR/WSR - mung bean	"
	Green maize-TPR/WSR - mung bean	Deep water table - partially irrigated
	Green maize-TPR/WSR - cowpea	"
1979-80	DSR-TPR - mung bean	Shallow water table - rainfed Shallow water table - partially irrigated Deep water table - partially irrigated
	Green maize-TPR - mung bean	"
	DSR - mung bean	Deep water table - rainfed

[a]TPR = transplanted rice, DSR = dry-seeded rice, WST = pregerminated wet-seeded rice. [b]Change in environmental description in 1976-77 (IRRI 1977).

Iloilo and Pangasinan farmers continually thin their maize fields during crop growth and use the plants as cattle feed. This is customarily practiced by farmers in areas of highly intensive agriculture where idle land for grazing is scarce. Maize grown at the onset of the rainy season is a good source of fodder at a time it is scarce. Because the crop is harvested every few days, insecticide residues pose a health hazard to the draft animals, and farmers will not adopt postemergence applications of insecticide on maize. Therefore, in those areas, it would be futile to conduct trials that would lead to recommendations on the use of insecticides on maize.

However, in Mindanao where farm size is 6-12 ha and rainfall occurs throughout the year, farmers should be more receptive to the use of insecticides on maize because they do not need to thin their maize fields for cattle feed during crop growth.

Specifying technology to the inherent yield potential of a crop

In many regions of a country the potential yield of a variety is less than optimal because of soil-related factors such as salinity, pH, nutrient excesses or deficiencies, or low inherent fertility. Some regions may be more prone to weather-related factors such as frequent typhoons, excessive cloud cover, or drought. The cause is not important. The point is, there is a direct relationship between potential yield and the optimal level of inputs for a particular crop. If rice has only a 2 t/ha potential, insecticide for a 5 t/ha crop should not be recommended.

Farmers growing a crop under high-risk conditions will not commit their inputs until they see how the crop is performing. Insecticide recommendations should consider this.

Specifying technology to farmers

The farmer is the ultimate consumer of any new rice technology. If a technology is to be successfully delivered to him, there is need to understand him better and to develop recommendations based on his capabilities.

Present practices. An understanding of farmers' current pest control practices allows an estimate of their capability in dealing with pest problems and recommendations can be scaled accordingly.

Table 4. Yield loss due to insects on upland rice (Dagge). Batangas, 1976-78.

Year	Fields (no.)	Yield (t/ha)		
		Treated[a]	Untreated	Difference
1976	6	3.1	3.0	0.1 ns
1977	4	2.8	2.6	0.2 ns
1978	6	2.7	2.9	- 0.2 ns

[a]0.5 kg a.i. Furadan granules/ha in seed furrows followed by biweekly sprays of 1 kg a.i. Azodrin/ha until harvest.

Table 5. Comparison of granular and sprayable insecticides against preflowering mung bean pests after flooded rice.[a] Pangasinan, 1977-78.

Insecticide	Dosage (kg a.i./ha)	Timing	Insecticide cost (US$/ha)	Bean fly				Flea beetle defoliation (%) 21 DE	Yield (t/ha)
				Larvae + pupae (no./25 plants)		Infested plants (%)			
				12 DE	21 DE	12 DE	21 DE		
Carbofuran 3 G	0.5	Basal	15.3	1.5 a	1.5 a	19 a	30 b	9 b	1.10 a
Carbofuran 3 G	1.0	Basal	30.6	1.0 a	1.2 a	18 a	24 b	7 ab	1.14 a
Monocrotophos 16.8 EC	0.25	2 and 12 DE	15.0	0.7 a	1.0 a	8 a	10 a	3 a	1.16 a
Untreated	-	-	-	5.2 b	4.2 b	40 b	57 c	13 bc	0.75 b

[a]Av of 4 fields. In a column, means followed by a common letter are not significantly different at the 5% level. DE = days after emergence.

A study of farmers' practices in three areas in the Philippines revealed that farmers recognized only a portion of the pests causing crop losses (Litsinger et al 1978b). All farmers used insecticides but because they did not recognize many of the key pests they did not effectively time their applications. Most farmers used sprayable formulations but did not apply insecticide at lethal dosage levels. Consequently their degree of control was entirely inadequate, even if properly timed. As a result, granular formulations are recommended for rice. This represents only a slight change in farmers' current practice, because applying granulars is no more difficult than applying granular fertilizers, a practice farmers understand. If insecticide use is to be effective, a great deal of emphasis on farmer education on proper usage is needed.

On the other hand, farmers perform many cultural control practices that they learn from experience over many years of farming. For example, Batangas farmers do not plant maize in August or September because of the seedling maggot. Pangasinan farmers delay planting mung bean until December because of the flea beetle. Rainfed wetland farmers sow grain legumes into rice stubbles, and have succeeded in avoiding many insect problems. It was found, however, that farmers did not know why these practices had been developed except that by doing them, they achieved higher yields.

The farmers studied understood the general concept of host-plant resistance and knew some varieties were resistant to insect pests. However, they did not know which specific pests could be controlled by plant resistance. In addition they had little knowledge of the role of natural enemies in pest suppression.

Resource level. It is important to know the amount of cash farmers spend for insecticide. This knowledge will serve as guide in determining the amount of insecticide to be adopted.

Rice yields were low in the two rainfed wetland sites in Iloilo and Pangasinan in 1975, when IRRI cropping systems trials started. However, by changing the rice variety and modifying the management practices, the yield potentials have greatly increased, which now justifies increased expenditures for insecticide (Gines et al 1977, Magbanua et al 1977). As a rule of thumb an insecticide application is not recommended unless it results in a two- to threefold return. The true challenge is to develop recommendations that require little cash resource or credit.

If sprayable insecticides are recommended there is need to know if farmers have access to sprayers. Fortunately, in the Philippines this has not been a constraint.

Table 6. Comparison of diazinon and carbofuran granules for whorl maggot and caseworm control[a] on IR36. Pangasinan, Philippines, 1977-78.

Insecticide	Whorl maggot (grade[b]) 30 DT	Caseworm (% defoliation) 25 DT	Yield (t/ha)
Carbofuran[c]	1 a	3 a	4.43 a
Diazinon[d]	7 b	11 b	3.99 b
Untreated	8 c	15 c	3.86 b

[a]Av of 7 fields; DT = days after transplanting. Means in a column followed by a common letter are not significantly different at the 5% level. [b]1-9 scale: 1 = negligible damage, 9 = severe damage. [c]1.0 kg a.i./ha soil-incorporated. [d]1.5 kg a.i./ha broadcast 3 DT.

Table 7. Effect of rice stubble on the incidence of preflowering insect pests of cowpea.[a] Iloilo, 1977-78.

Variety	Rice stubble	Bean fly 10 DE: Larvae + pupae (no./20 plants)	Bean fly 10 DE: Infested plants (%)	Aphid rating[b] (grade) 30 DE	Insects (no.)/20 plants 30 DE: Leafhopper	Insects (no.)/20 plants 30 DE: Leaf miner
EG2	Yes	1 a	9 a	2 a	1 a	2 a
	No	24 b	68 b	5 b	18 b	8 b
Camaros	Yes	1 a	6 a	2 a	0.3 a	1 a
	No	16 b	59 b	6 b	15 b	21 b

[a]Av of 4 fields. Untreated with insecticide. DE = days after emergence. Means in a column followed by a common letter are not significantly different at the 5% level. [b]1-9 scale: 1 = no aphids, 3 = adults only, 5 = several colonies, 7 = many distinct colonies, 9 = many colonies, coalesced and indistinct.

Table 8. Effect of rice stubble management and tillage system on the incidence of preflowering insect pests of cowpea established after flooded rice.[a] IRRI, 1978.

Rice stubble	Tillage system	Pest incidence (no./15 plants)[b]			Yield (kg/ha)	
		Bean fly (larvae + pupae) 13 DE	Thrips 20 DE	Leafhopper 20 DE	With preflowering insecticide[c]	Without preflowering insecticide
None	Plowed and harrowed twice	17 a	83 a	36 b	687 bc	316 e
Mulch	Plowed and harrowed twice	15 a	8 a	13 c	571 cd	354 e
2 cm high	Furrows plowed between rice rows	15 a	82 a	83 a	480 d	532 d
2 cm high	Dibbling in rows	12 b	9 b	53 ab	775 b	575 cd
15 cm high	Furrows plowed between rice rows	9 bc	6 b	13 c	815 b	621 c
15 cm high	Dibbling in rows	8 bc	15 b	9 cd	944 a	799 b
30 cm high	Furrows plowed between rice rows	6 c	1 b	6 cd	626 c	360 e
30 cm high	Dibbling in rows	5 c	1 b	2 d	964 a	525 d

[a]Av of 3 replicates. IR36 transplanted at 25 x 25 cm. Means followed by a common letter are not significantly different at the 5% level. [b]Without insecticide. DE = days after emergence. [c]1% wt/wt carbofuran seed treatment, 0.5 kg a.i. monocrotophos/ha and 1.0 kg a.i. carbaryl/ha sprays. All plots received a similar post-flowering protection 1.0 kg a.i. monocrotophos/ha sprays.

Labor availability and farm size are related in terms of pest control. On farms averaging 1-2 ha, labor is provided mainly by the family. A limitation to more intensive cropping has been scarcity of labor at certain times of the year, which is another reason for keeping the number of insecticide applications to a minimum (Price and Barker 1978).

Traditional beliefs and customs. Farmers practice many traditional methods of insect control ranging from superstition to the use of plant parts to repel pests in the field (Litsinger et al 1978b). However, there is no apparent conflict between their traditional and modern practices. There are no religious beliefs against killing insects and farmers readily use insecticides in the Philippines.

WORKING WITHIN AN INTERDISCIPLINARY TEAM

Cropping systems applied research is a team effort. Interaction between team members insures that insect control practices will be harmonious with other production practices and that they will be economically attractive. At the local level the members must visit each other's trials and discuss results and implications jointly. At the national level at least one annual meeting must be held to discuss research results.

Variety trials

Variety trials for each crop are conducted at each site over the duration of the testing phase. The variety selected for each crop in a cropping pattern should be evaluated for insect pest susceptibility. Input from entomologists and plant pathologists is necessary to insure that the varieties selected for the patterns are not highly susceptible to pests.

It is important that variety trials receive the same insect and disease control levels as currently recommended for the same crops in cropping patterns. Often variety trials are conducted with high levels of insect and disease control. This practice is suitable for experiment stations where determination of yield potential is the main objective. For applied research, however, economic considerations of crop production outweigh considerations of yield potential. If varieties are tested at a site with pest control levels designed to eliminate any pest damage, the variety selected may later cause nonadoption of the cropping pattern because of the high input costs.

Agronomy

Many pests, including the Asian corn borer, are known to respond positively to high nitrogen levels (Medrano 1975). The yield benefit from added nitrogen may be offset by increased insect pest damage and added insecticide cost. For example, use of 90 kg N/ha was less profitable than 60 kg N/ha for green maize because at the 90 kg N rate, an insecticide was needed to offset the increased corn borer populations. At the 60 kg N level no insecticide was needed. Yields were the same for both levels.

Sometimes granular insecticides are applied at the same time as fertilizer. Labor costs can be reduced if the insecticide and fertilizer are mixed and applied together. Collaboration between entomologists and agronomists is necessary to insure that the resultant mixture is compatible.

Seeding methods and tillage practices for establishing grain legumes after rice is another area where disciplines overlap. Standing rice stubbles help suppress early-season grain legume pests. Thus, agronomists were asked to develop minimum tillage systems to retain erect stubbles for establishing mung bean and cowpea after rice.

Economics

The farm record-keeping data and baseline survey results by economists at each site are important benchmarks for determining not only input levels but also insect control tactics that should be tested.

Economists also calculate the production costs and net returns of the patterns at test sites and compare those with existing cropping patterns. This gives the entomologists the economic implications of each insect control recommendation in terms of material cost and labor. This analysis should serve as a guide to input levels in recommended treatments.

METHODOLOGY FOR DETERMINING INSECT CONTROL RECOMMENDATIONS FOR PRODUCTION PROGRAMS

A methodology for determining insect control recommendation has been developed. It follows an objective process of arriving at a recommendation for insect control on any crop of interest. It follows the overall cropping systems model of description, design, testing, and preproduction evaluation (IRRI 1977).

Description

Baseline data provided by economists are useful as a quick means of understanding the farmers in a target area. The data should provide information on farmers' insect control practices in terms of resources allocated and managerial capabilities. This information should be supplemented by in-depth farmer interviews to determine what pests farmers recognize, the insect control tactics they use, how well they execute insect control technology, and the kinds and levels of technology they will likely adopt. A sample questionnaire for rice is given in Appendix I.

Results of such an interview exercise are discussed by Litsinger et al (1978b). Evaluation of that information is possible only if biological data are also collected at the site. The information will determine to a large degree the level of insect control technology to test at a site and is valuable for extension services in the production phase. Entomologists working at cropping systems sites should undertake such in-depth surveys which are neither overly time-consuming nor costly.

The next step is to conduct yield loss studies to determine if and how much insect control is needed for the recommended varieties of each crop in the cropping patterns -- even for rice followed by rice. Trials should be repeated several years at each site. We should not only measure total yield loss but also partition the yield loss among the various growth stages where insect pests are likely to be damaging. The following are examples from transplanted rice, grain legumes, and maize in the Philippines.

Transplanted rice. Transplanted rice has four growth stages in terms of insect damage: seedbed (caseworm and armyworm), vegetative stage (whorl maggot, caseworm, and stem borer deadhearts), reproductive stage (stem borer whiteheads and leaf folder), and ripening stage (rice bug). The first six treatments in Figure 1 show how yield losses can be assessed. The cost of the insecticides used in determining yield loss is not relevant to the six treatments because they are not feasible. The most effective available insecticides should be applied at adequate dosages and frequencies to insure that as near as insect-free condition as possible will be achieved. The yield losses measured will be those for an insect-resistant variety.

To quantify yield loss for each of the four growth stages, insecticide protection is successively omitted during each stage, while providing control in the other three. This subtractive approach allows greater powers of interpretation than applying insecticide during each stage, because yield loss is expected to occur during more than one stage.

The trial plots receive the same management as cropping pattern fields except in insect control Because of the relatively large plot size necessary for insect studies (50-100 m^2), treatments are replicated across farms in a randomized complete block design. A minimum of 4 farms (replicates) is suggested, however 6 to 8 farms are best in terms of statistical precision. The treatments for the yield loss assessment and the insect control treatments are pooled and randomly assigned to plots within each field. These trials should be repeated for several years to determine year-to-year variability in pest populations.

Insect pest populations are monitored using recognized sampling procedures (Dyck 1978, Litsinger 1979). The amount of effort expended here is in relation to manpower availability. The purpose is to pinpoint key pests responsible for any yield loss that may occur.

The yield results are analyzed statistically to insure that any numerical differences are real. This allows for more precise interpretation. The method is illustrated by the results of a single-crop transplanted rice in Pangasinan 1976-77 (Fig. 2) and a second-crop transplanted rice in Iloilo 1976-77 (Fig. 3).

A significant yield loss (1.6 t/ha) occurred in Pangasinan due to whorl maggot damage, stem borer deadhearts, and caseworm defoliation. All of the yield loss occurred during the vegetative stage where insecticide protection was omitted No yield loss was recorded during the three other growth stages, although a 3% whitehead damage was measured.

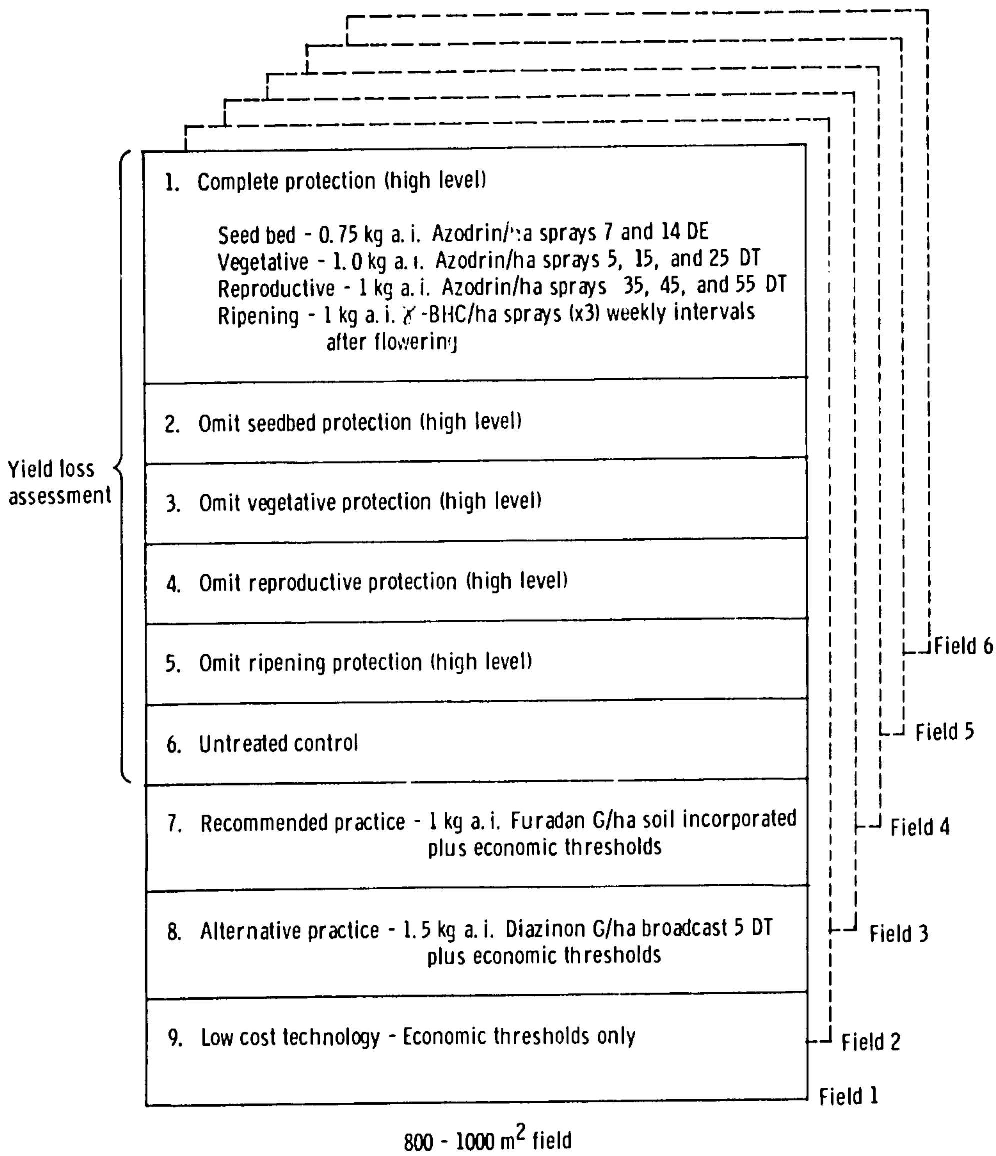

Fig. 1. Experimental design for yield loss assessment and determination of the optimal insect control recommendation for transplanted rice.

Results of the yield loss trials provide information on the correct timing of insecticide applications. In the Pangasinan case only insecticide during the vegetative stage was warranted.

In Iloilo significant yield loss occurred during the vegetative and reproductive stages (Fig. 3). The principal tests were stem borer and caseworm. No yield loss was recorded during the ripening stage even though 5 rice bugs/m^2 were recorded.

Grain Legumes. Only two growth stages -- preflowering and postflowering -- are recognized for mung bean and cowpea and the same general procedure as for rice is followed (Fig. 4). Figures 5 and 6 present results for November- and December-planted mung bean in Pangasinan in 1977-78. The 0.83 t/ha yield loss from untreated plots (0.47 t/ha for preflowering and 0.36 t/ha for postflowering) was caused by bean fly, flea beetle, and *Maruca* pod borer. The December planting was heavily infested by *Heliothis* and yield loss was almost complete.

Maize. Figure 7 shows a possible layout for three growth stages of maize -- seed/seedling, vegetative, and reproductive.

The designs presented in Figures 4 and 7 should be adapted to local insect pest problems but the procedure is the same:

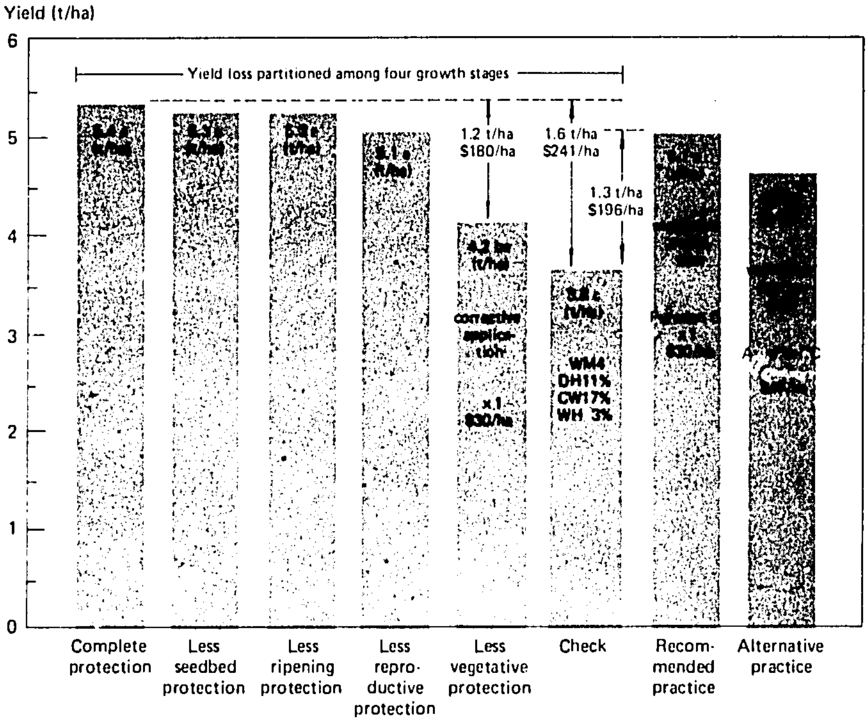

Fig. 2. Yield loss assessment and an economic evaluation of the chemical insect control recommendation for single-crop transplanted rice (IR36), Pangasinan, 1976-77.

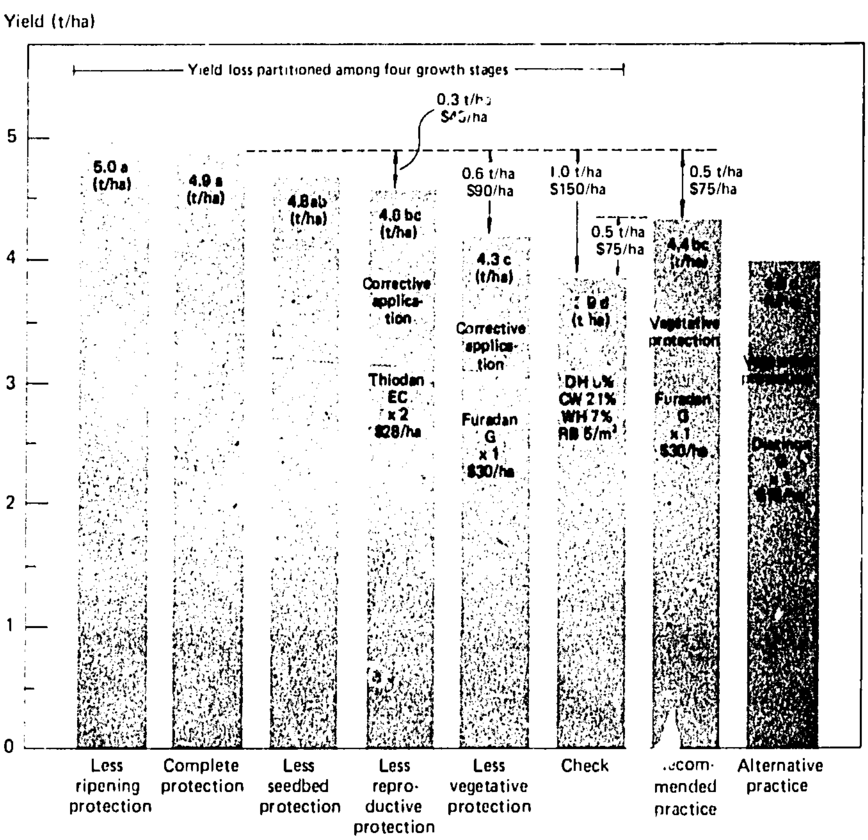

Fig. 3. Yield loss assessment and an economic evaluation of the chemical insect control recommendation for second-crop transplanted rice (IR36), Pangasinan, 1976-77.

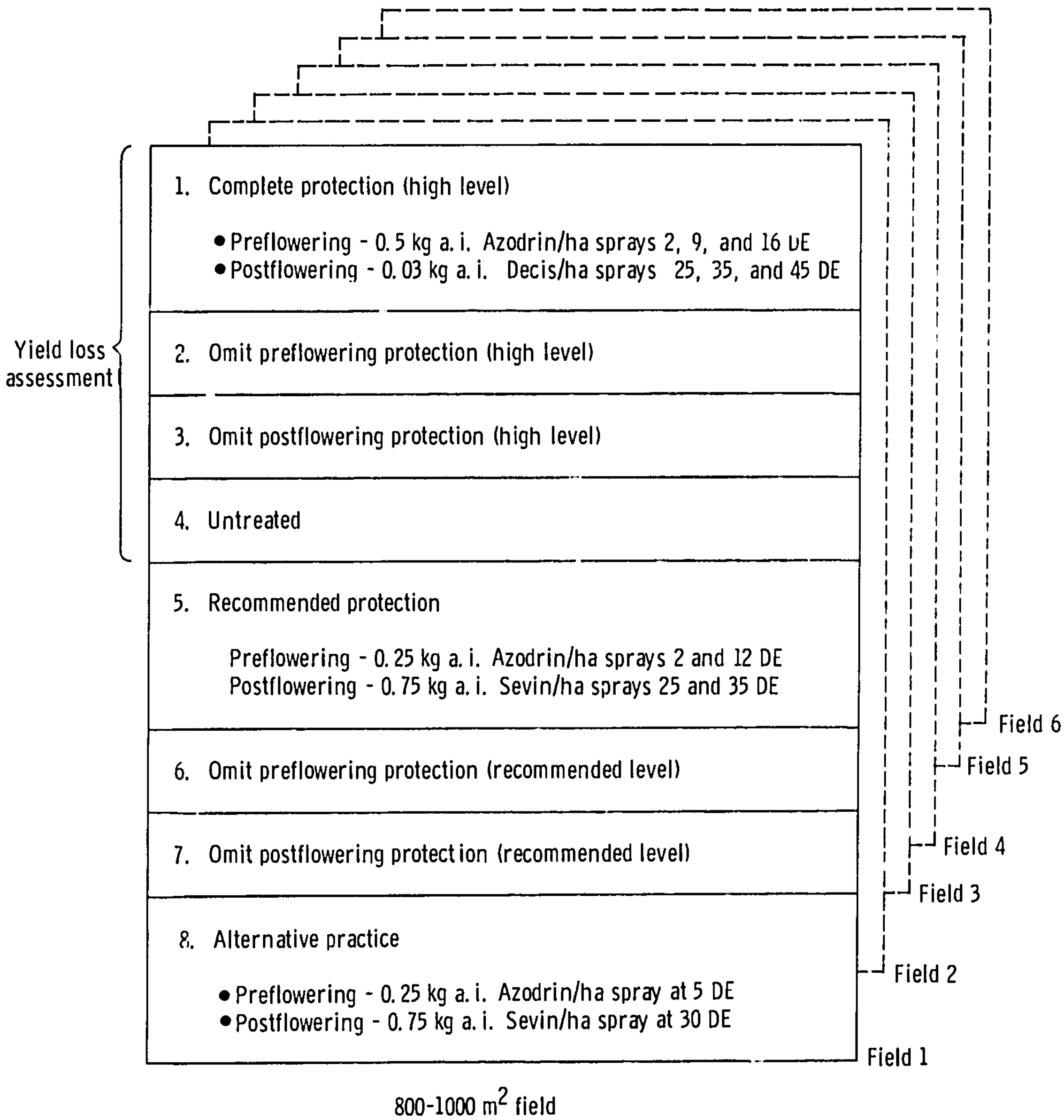

Fig. 4. Experimental design for yield loss assessment and determination of the optimal insect control recommendation for mung bean and cowpea.

1. Choose insecticide regimes that could most effectively minimize pest damage;

2. Assign successive treatments where one growth stage is unprotected while protecting the rest;

3. Have complete control and untreated plots for comparisons;

4. Monitor pest populations to identify the key pests; and

5. Analyze the results statistically.

Design (technology assessment)

Insect control technology is designed on the basis of the information gathered during the descriptive phase. The technology should be aimed at the key pests causing damage during the growth stages where significant yield loss was recorded. The type of insect control methods chosen must be compatible with farmers' resources and management capability and with other management practices.

Time and resources do not allow, nor is there any need for, repetition of basic research trials on farmers' fields. There is little purpose in evaluating insecticides or determining dosage level on farmers' fields unless a unique insect pest is found. Table 9 outlines the types of technologies appropriate for basic research experiment stations and applied research on-farm activities.

It is a good idea to list insecticide costs based on retail prices. Tables 10-12 show those for the Philippines. Another important aspect is the LD_{50}

values (oral and dermal) for each insecticide (Table 13). These criteria help the researcher select one or more insecticides from among the larger listing within national insect control recommendations. The choice should be based on low cost, low human toxicity, and availability within the country.

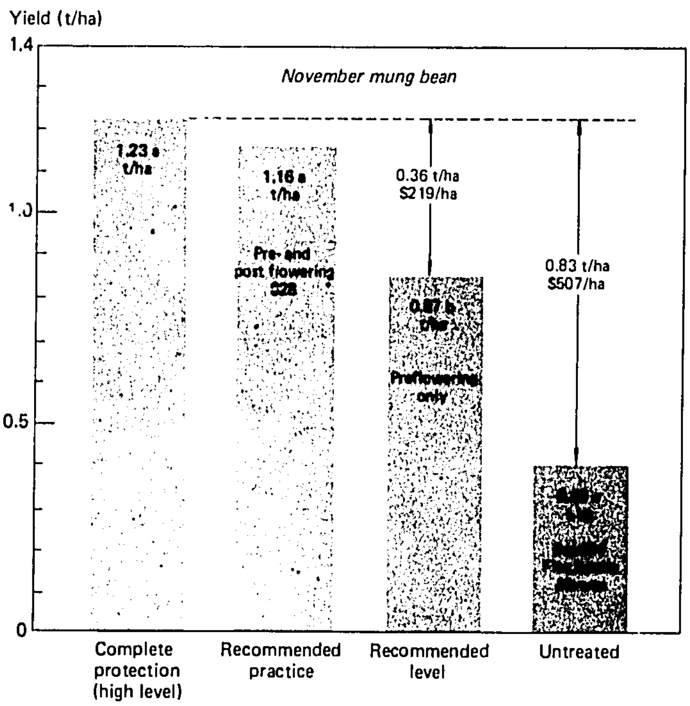

Fig. 5. Yield loss assessment and an economic evaluation of the chemical insect control recommendation for November-planted mung bean, Pangasinan, 1977-78.

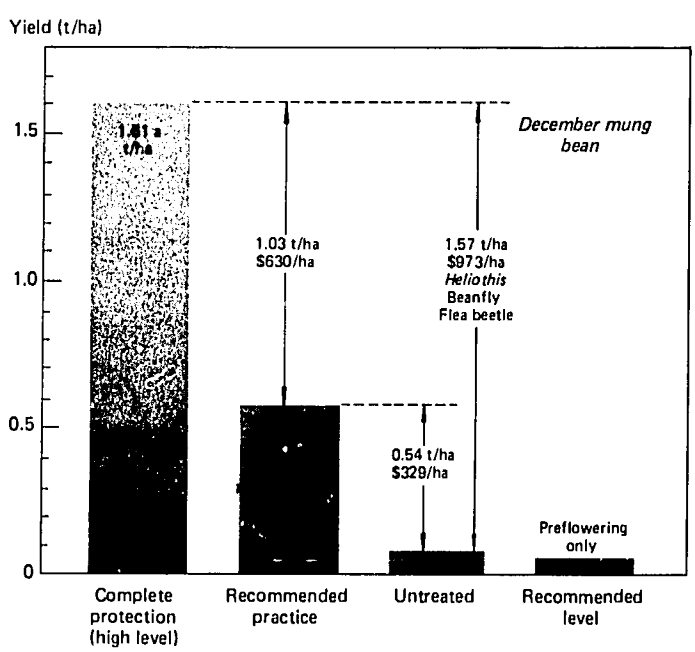

Fig. 6. Yield loss assessment and an economic evaluation of the chemical insect control recommendation for December-planted mung bean, Pangasinan, 1977-78.

Testing (technology verification)

The next step is to test insect control alternatives on cropping patterns to determine the recommendations. This is done in the same trials as the yield loss assessment and is repeated several years at each site (Figs. 1, 4, and 7).

The current recommended practice is always included, along with alternative practices. All treatments -- yield loss assessment and insect control practices -- are randomized within the same field. Treatments are replicated across fields. It is important to obtain information on field-to-field as well as year-to-year variability because the recommendations will be extrapolated over much wider geographic areas.

When IRRI entomologists first started working in the cropping systems sites, the yield loss assessment by crop growth stage was not included. An untreated control and usually a complete protection plot were always included. Most of the treatments were alternative insect control practices, one compared with the others. As a result it was uncertain if the optimal control level was approximated because of the infinite number of combinations of treatment levels among the various growth stages. Interpretation was difficult. With the yield loss assessment component, the number of alternative insect control treatments had been substantially limited.

There is a practical limit to how many treatments one can compare in a trial. Ten to twelve treatments should be the maximum handled by a research team. However, with sharp focus on a few growth stages, there is no need to test more than 3 alternative practices at a time.

Evaluation

Data interpretation is the most difficult job in applied research. Definite recommendations are needed. The researcher cannot hide behind the phrase "more studies are needed."

This method was developed to allow for strict interpretation of the results. For instance, in the Pangasinan single-crop transplanted rice example, the recommended practice of 1 kg a.i. Furadan/ha as soil-incorporated granules gave as good a control as the complete-protection plots. The treatment cost US$30/ha and yielded 1.3 t/ha or US$795: a 6:1 return on investment. The alternative practice of Azodrin sprays actually cost more (US$45/ha) and did not outperform the recommended practice.

A more difficult evaluation is presented in the Iloilo second-crop rice data (Fig. 3). The recommended practice -- 1 kg a.i. Furadan/ha as soil-incorporated granules (US$30/ha) -- gave only a 2.5-fold return (US$75/ha) and was significantly less (4.4 t/ha) than that in the complete-protection plot (4.9 t/ha). The difference amounted to US$15/ha. But a minimum control for late-season stem borer is 2 sprays of Thiodan, which cost US$28/ha. The return from an additional 2 sprays during the reproductive stage is only 1.5 to 1, which is not a sufficient incentive for farmers. The Furadan granular treatment, therefore, would be the optimal recommendation. Note that diazinon granules, which cost half as much as Furadan granules, did not perform any better than the untreated control.

Any future alternative to 1 kg a.i. Furadan granules/ha should cost less than US$30/ha.

The recommended practice for insect control in November-planted mung bean appears optimal. The returns are 8 to 1 (US$219/ha vs US$28/ha). However, there may be less costly alternatives that should be evaluated in the future.

The recommended practice for the December-planted mung bean clearly shows room for improvement. The difference between the recommended practice and the complete control amounted to US$630/ha. This was due to improper timing of the postflowering sprays 35 and 45 days after emergence (DE) which was corrected by using Sevin sprays 25 and 35 DE.

Tables 14-20 show the historical development of insect control recommendations for the Iloilo and Pangasinan sites for the 5-year testing period for dry-seeded rice (Table 14), first-crop wet-seeded rice (Table 15), single-crop transplanted rice (Table 16), second-crop transplanted rice (Table 17), mung bean and cowpea after rice (Table 18), green maize before rice (Table 19), and sorghum after rice (Table 20). The historical development of economic thresholds for the same period is given in Table 21.

Table 9. Division of roles for entomologists in experiment stations and cropping systems sites.

Pest control tool	Basic research activity (technology generation)	Applied research-production activity (technology specification)
Ecology and pest management	Taxonomy Pest bionomics Economic threshold determination National pest control recommendations	Pest complex determination Population assessments Target farmer (behavior, resource level, and managerial capabilities) Pest control recommendations for each site
Chemical control	Screening (efficacy) Dosage Formulation Method of application Timing and frequency Residues Phytotoxicity Environmental impact assessment Toxicology	Timing and frequency Method of application Minimum dosage
Host plant resistance	Varietal screening Mode of resistance Genetics	Verification of resistance Deselection of susceptible varieties
Cultural control	Seasonal effect Spacing Fertilizer Tillage Trap crop Intercropping Crop residue management Crop rotation Crop maturity (Microlevel studies)	Planting time Synchronous planting Crop residue management Tillage Removal of alternate hosts (Macrolevel studies)
Biocontrol	Taxonomy Natural enemy effectiveness and bionomics Introduction of exotic species Augmentation (mass release) Conservation	Natural enemy complex determination Populations of natural enemies Conservation

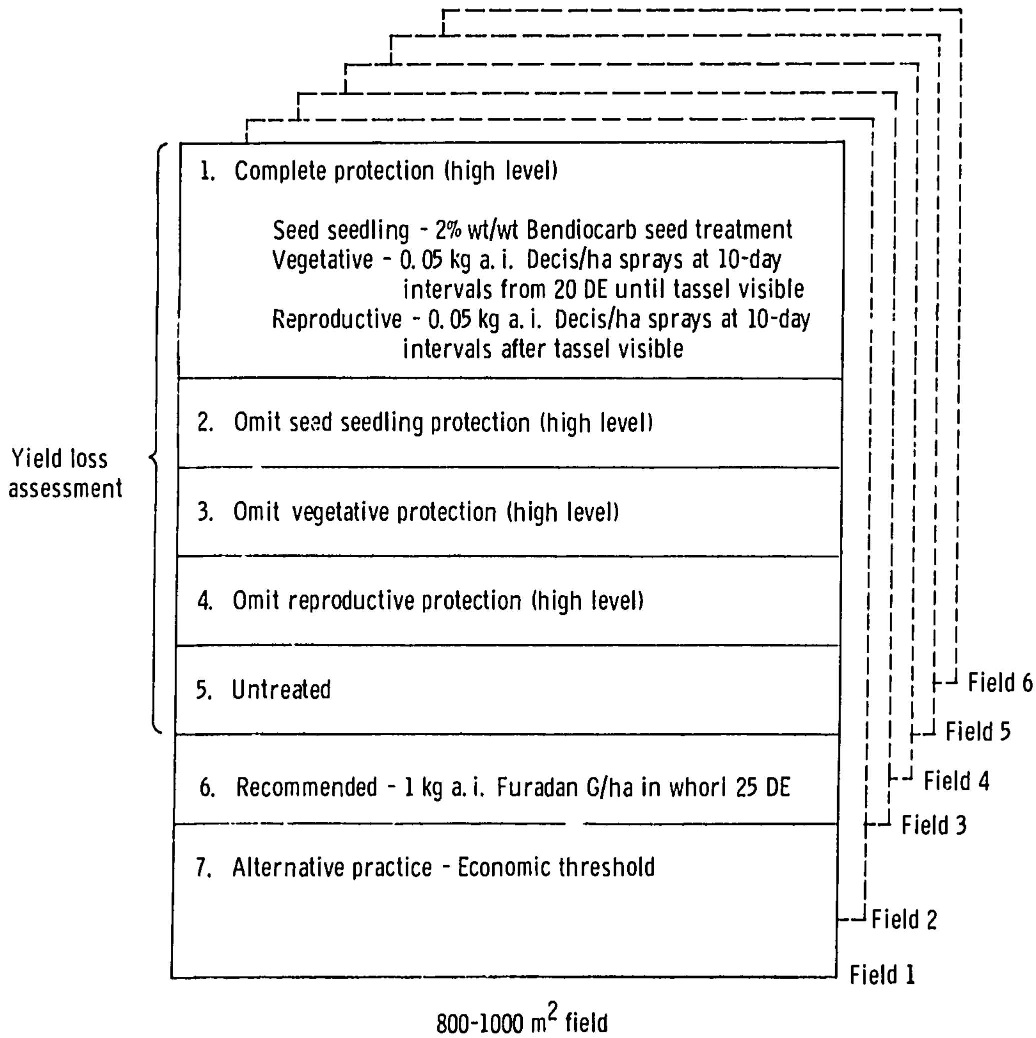

Fig. 7. Experimental design for yield loss assessment and determination of the optimal insect control recommendation for maize.

SUMMARY AND CONCLUSION

A large body of knowledge on crop management has been generated through controlled research in laboratory, greenhouse, and field trials at experimental stations. That knowledge, if properly specified and transferred to farmers, should produce results of a magnitude equal to that from seed-based technology (breeding high-yielding varieties). This component technology is much more complex than seed-based technology and involves the application of an optimal balance of several production variables -- notably fertility, tillage, and pest control -- in local environments and at farmers' levels of resources and management.

To serve the need for transfer of this more complex technology to farmers, the concept of cropping systems research and development was born. Insect control -- because of its complexity, high demand on resources, and location-specific nature -- is highly adapted to the cropping systems approach.

Cropping systems work at the farmers' level remains under research because the on-farm trials are not demonstration plots. It is adaptive research because it is not directly involved with technology generation but focuses on specifying, integrating, verifying, and evaluating existing technology for a specific area. The results of insect control activities in cropping systems lead to extension production and technology transfer programs such as integrated pest control.

A methodology for determining insect control recommendations for introduced cropping patterns was developed to meet the requirements of the Asian Cropping Systems Network of research sites. The method, as summarized in Figure 8, involves:

- quantifying yield losses partitioned among crop growth stages,
- identifying the key pests responsible for yield losses,

Table 10. Ranking by cost of nonpyrethroid sprayable insecticides recommended in the Philippines, 1978.

Insecticide			Cost (₱) for 0.25 kg a.i./ha	Retail price (₱)
Brand name	Common name	Formulation		
Malathion	malathion	57% WC	11	28.00/qt
Sevin	carbaryl	85% WP	16	28.00/500 g
Folidol, Parapest, Meptox	methyl parathion	50% EC	21	42.50/qt
Rogor, Cygon	dimethoate	40% EC	22	36.00/qt
Hopcin, Baycarb, Shellcarb	BPMC	50% EC	25	50.00/qt
Etrofolan, Mipcin, Hytox	MIPC	50% WP	26	26.00/500 g
Tsumacide	MTMC	50% EC	28	28.20/500 g
Dimecron	phosphamidon	50% EC	29	57.00/qt
Thiodan	endosulfan	35% EC	32	45.40/qt
Perthane	Perthane	45% EC	32	49.50/qt
Gusathion A	azinphos-ethyl	40% EC	34	54.00/qt
Lethox, Endyl	carbophenothion	30% EC	38	48.00/qt
Brodan	BPMC + chlorpyrifos	31.5% EC	40	52.00/qt
Cidial, Elsan, Pennant	phenthoate	50% EC	42	77.50/qt
Lebaycid	fenthion	50% EC	42	84.00/qt
Metasystox R	oxydemeton-methyl	25% EC	43	42.50/qt
Basudin	diazinon	20% EC	45	34.50/qt
Hostathion	triazophos	40% EC	53	87.15/qt
Gardona	tetrachlorvinphos	75% WP	54	9.05/50 g
Azodrin 168	monocrotophos	16.8% EC	55	39.00/qt
Orthene	acephate	75% EC	63	95.00/500 g
Eradex, Dursban, Lorsban	chlorpyrifos	15.8% EC	77	48.00/qt
Lannate	methomyl	30% EC	83	64.08/qt
Bayrusil	quinalphos	25% EC	85	75.00/1
Furadan F	carbofuran	12% EC	94	43.00/qt
Actellic	pirimiphos-methyl	25% EC	114	54.00/16 oz

1 qt = 946 cc (ml) = 32 fluid oz = 30 cc. EC = emulsifiable concentrate, WP = wettable powder, SP = soluble powder, a.i. = active ingredient.

Table 11. Ranking by cost of synthetic pyrethroid insecticides available in the Philippines, 1978.

Insecticide			Cost (₱) for 0.01 kg a.i. /ha	Retail price (₱)
Brand name	Common name	Formu-lation		
Kafil	permethrin	10% EC	21	50/8 oz
Sumicidin	phenvalerate	3% EC	28	80/qt
Ripcord	cypermethrin	2.5 EC	42	101/qt
Decis	decamethrin	2.5 EC	116	290/qt

Table 12. Ranking by cost of granular insecticides available in the Philippines, 1978.

Insecticide			Cost (₱) for 0.5 kg a.i. /ha	Retail price (₱)
Brand name	Common name	Formu-lation		
Lindane	γ-BHC	6 G	33	70/16 kg
Diazinon	diazinon	10 G	45	45/10 kg
Furadan	carbofuran	3 G	112	112/16.7 kg

Table 13. Mammalian toxicity of recommended insecticides.

Insecticide	LD 50 of technical	
	Oral	Dermal
Folidol, Parapest, Meptox (m-parathion)	10	110
Furadan (carbofuran)	11	10,200
Gusathion A (azinphos-ethyl)	12	220
Dimecron (phosphamidon)	15	125
Lannate (methomyl)	17	1,000
Azodrin (monocrotophos)	20	350
Lethox, Endyl (carbophenothion)	32	3,100
Metasystox R (oxydemeton-methyl)	65	100
Bayrusil (quinalphos)	66	340
Thiodan (endosulfan)	70	350
Hostathion (triazophos)	80	11,000
Lindane, Agrocide (gamma BHC)	88	1,000
Eradex, Dursban (chlorpyrifos)	100	2,000
Decis (decamethrin)	130	2,000
Etrofolan, Mipcin, Hytox (MIPC)	180	500
Lebaycid (fenthion)	225	330
Rogor, Cygon (dimethoate)	250	150
Ripcord (cypermethrin)	251	
Diazinon, Basudin (diazinon)	300	
Sevin (carbaryl)	300	500
Hopcin, Baycarb, Shellcarb (BPMC)	400	340
Elsan, Cidial, Pennant (phenthoate)	439	5,000
Sumicidin (phenvalerate)	450	2,500
Tsumacide (MTMC)	600	1,000
Malathion	880	4,000
Orthene (acephate)	890	2,000
Actellic (pirimiphos methyl)	2,050	2,000
Kafil (permethrin)	4,000	4,000
Perthane	8,000	

Table 14. Historical development of economically optimal insect control recommendations for dry-seeded rice (IR36) in two rainfed wetland environments, 1975-79.

Year	Iloilo	Pangasinan
1975	ET	ET
1976	ET	ET
1977	1 kg a.i. Furadan G/ha in seed furrow plus ET	1 kg a.i. Furadan G/ha in seed furrow plus ET
1978	0.5 kg a.i. Furadan G/ha in seed furrow plus ET	0.5 kg a.i. Furadan G/ha in seed furrow plus ET
1979	0.5 kg a.i. Furadan G/ha in seed furrow plus ET	0.5 kg a.i. Furadan G/ha in seed furrow plus ET

ET = economic threshold (see Table 21), G = granule.

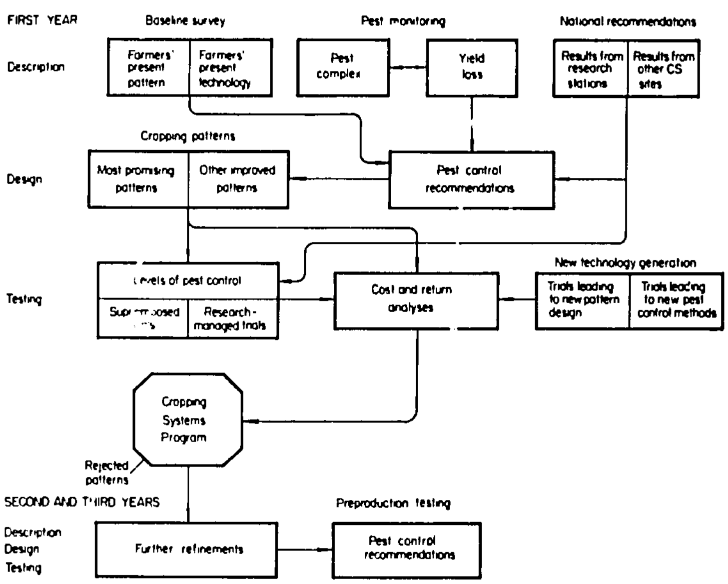

Fig. 8. Scheme of the 3-year process of adapting national insect control recommendations for cropping patterns at cropping systems sites.

- understanding farmers' current pest control practices, and their potential to adopt new technology,
- selecting appropriate insect control technology,
- testing the technology on farmers' fields on crops grown in cropping patterns under optimal management of other production variables, and
- evaluating the costs and returns of the technology.

The method will allow optimal insect control recommendations to be made in 2 or 3 years, it is highly objective in that it allows strict interpretation of the data, it is not costly to perform, and it can be carried out by researchers with minimal experiences.

Table 15. Historical development of economically optimal insect control recommendations for first-crop, wet-seeded rice in two rainfed wetland environments, 1975-79.

Year	Iloilo	Pangasinan
1975	2 kg a.i. Furadan G/ ha broadcast 3 DT; 0.75 kg a.i. Azodrin /ha sprays 25, 35, 45 DE plus ET	2 kg a.i. Furadan G/ ha broadcast 3 DT; 0.75 kg a.i. Azodrin /ha sprays 25, 35, 45 DE plus ET
1976	2 kg a.i. Furadan G/ ha soil-incorporated; 0.75 kg a.i. Azodrin /ha sprays 25, 35, 45 DE plus ET	2 kg a.i. Furadan G/ ha soil incorporated; 0.75 kg a.i. Azodrin /ha sprays 25, 35, 45 DE plus ET
1977	ET	1.5 kg a.i. Furadan G/ha soil incorporated; 0.75 kg a.i. Azodrin/ha sprays 35 and 45 DE plus ET
1978	ET	1 kg a.i. Furadan G/ ha soil incorporated plus ET
1979	ET	1 kg a.i. Furadan G/ ha soil incorporated plus ET

ET = economic threshold (see Table 21), DE = days after emergence, G = granule.

Table 16. Historical development of economically optimal insect control recommendations for single-crop transplanted rice in two rainfed wetland environments, 1975-79.

Year	Iloilo	Pangasinan
1975	2 kg a.i. Furadan G/ha broadcast 3 DT; 0.75 kg a.i. Azodrin/ha sprays at 35, 45, and 55 DT plus ET	2 kg a.i. Furadan G/ ha broadcast 3 DT; 0.75 kg a.i. Azodrin /ha sprays 35, 45 and 55 DT plus ET
1976	2 kg a.i. Furadan G/ha soil incorporated; 0.75 kg a.i. Azodrin/ ha sprays at 35, 45, and 55 DT plus ET	2 kg a.i. Furadan G/ ha soil incorporated; 0.75 kg a.i. Azodrin /ha sprays 35, 45, and 55 DT plus ET
1977	1.5 kg a.i. Furadan G/ ha soil incorporated plus ET	1.5 kg a.i. Furadan G/ha soil incorporated plus ET
1978	1.0 kg a.i. Furadan G/ ha soil incorporated plus ET	1.0 kg a.i. Furadan G/ha soil incorporated plus ET
1979	1.0 kg a.i. Furadan G/ ha soil incorporated plus ET	1.0 kg a.i. Furadan G/ha soil incorporated; 0.75 kg a.i. Thiodan sprays 35 and 45 DT plus ET

ET = economic threshold (see Table 21), DT = days after transplanting, G = granule.

Table 17. Historical development of economically optimal insect control recommendations for second-crop transplanted rice in two rainfed wetland environments, 1975-79.

Year	Iloilo	Pangasinan
1975	2 kg a.i. Furadan G/ ha broadcast 3 DT, 0.75 kg a.i. Azodrin/ha, sprays 35, 45, 55 DT plus ET	2 kg a.i. Furadan G /ha broadcast 3 DT, 0.75 kg a i. Azodrin /ha, sprays 35, 45, 55 DT plus ET
1976	2 kg a.i. Furadan G/ ha soil-incorporated, 0.75 kg a.i. Azodrin/ ha sprays 35, 45, 55 DT plus ET	2 kg a.i. Furadan G /ha soil-incorporated, 0.75 kg a.i. Azodrin/ha sprays 35, 45, 55 DT plus ET

continued on next page

Table 17. continued

Year	Iloilo	Pangasinan
1977	1.5 kg a.i. Furadan G/ha soil-incorporated plus ET	1.5 kg a.i. Furadan /ha soil-incorporated plus ET
1978	1 kg a.i. Furadan G/ ha soil-incorporated plus ET	1 kg a.i. Furadan/ ha soil-incorporated, 0.75 kg a.i. Thiodan, 35 and 45 DT
1979	1 kg a.i. Furadan G/ ha soil-incorporated plus ET	1 kg a.i. Furadan G/ ha soil-incorporated plus ET

ET= economic threshold (see Table 21), DT = days after emergence, G = granules.

Table 18. Historical development of economically optimal insect control recommendations for mung bean and cowpea after rice in two rainfed wetland environments, 1975-79.

Year	Iloilo	Pangasinan
1975	1.0 kg a.i. Furadan G/ ha basal	1 kg a.i. Furadan G/ ha basal
1976	0.25 kg a.i. Azodrin/ ha sprays 5 and 15 DE	0.25 kg a.i. Azodrin/ ha sprays 5 and 15 DE
1977	0.25 kg a.i. Thiodan/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha sprays 35 DE	0.25 kg a.i. Thiodan/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha sprays 35 DE
1978	*High tillage*	*High tillage*
	0.25 kg a.i. Azodrin/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha 25 and 35 DE	0.25 kg a.i. Azodrin/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha 25 DE; 0.75 kg a.i. Azodrin/ha 40 DE
	Zero, minimum tillage	*Zero, minimum tillage*
	0.25 kg a.i. Azodrin/ ha sprays 7 DE; 0.75 kg a.i. Sevin/ha 25 and 35 DE	0.25 kg a.i. Azodrin/ ha sprays 7 DE; 0.75 kg a.i. Sevin/ha 25 DE; 0.75 kg a.i. Azodrin/ha 40 DE
1979	0.25 kg a.i. Azodrin/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha 25 and 35 DE	0.25 kg a.i. Azodrin/ ha sprays 2 and 12 DE; 0.75 kg a.i. Sevin/ha 25 and 35 DE

Table 19. Historical development of economically optimal insect control recommendations for green maize before rice in two rainfed wetland rice environments, 1975-79.

Year	Iloilo	Pangasinan
1975	0.5 kg a.i. Furadan G /ha basal; 1.0 kg a.i. Furadan G/ha in the whorl 35 DE	0.5 kg a.i. Furadan G/ha basal; 1.0 kg a.i. Furadan G/ha in the whorl 35 DE
1976	0.5 kg a.i. Furadan G /ha basal; 1.0 kg a.i. Furadan G/ha in the whorl 25 DE	0.5 kg a.i. Furadan G/ha basal; 1.0 kg a.i. Furadan G/ha in the whorl 25 DE
1977	ET	ET
1978	2% wt/wt Sevin seed treatment plus ET	2% wt/wt Sevin seed treatment plus ET
1979	2% wt/wt Sevin seed treatment plus ET	2% wt/wt Sevin seed treatment plus ET

ET = economic threshold (see Table 21), DE = days after emergence, G = granule.

Table 20. Historical development of economically optimal insect control recommendations for sorghum after rice in two rainfed wetland rice environments, 1975-79.

Year	Iloilo	Pangasinan
1975	0.5 kg a.i. Furadan G/ha basal plus ET	0.5 kg a.i. Furadan G/ha basal plus ET
1976	0.5 kg a.i. Furadan G/ha basal plus ET	0.5 kg a.i. Furadan G/ha basal plus ET
1977	ET	ET
1978	ET	ET
1979	ET	ET

ET = economic threshold (see Table 21), G = granule.

Table 21. Historical development of the use of economic thresholds in wetland rice, sorghum, and maize in Iloilo and Pangasinan, 1975-79.

Crop	Pest	Year	Economic threshold	Control
Wetland rice (IR28 1975-76 IR36 1977-79)	Whorl maggot	1975-79	None	Prophylactic if a constant pest
	Caseworm	1975-78	15% defoliation	0.75 kg a.i. Azodrin/ha (1975-78); 0.75 kg a.i. Sevin/ha (1978)
		1979	10% damaged hills or plants before maximum tillering	0.75 kg a.i. Sevin/ha
	Stem borer dead-hearts, whiteheads	1975-79	10% deadhearts to maximum tillering; 3% deadhearts from maximum tillering to panicle initiation	0.75 kg a.i. Azodrin/ha (1975-77); 0.75 kg a.i. Thiodan/ha (1978-79)
	Armyworm	1975-77	10% defoliation	0.75 kg a.i. Azodrin/ha
		1978	15% defoliation	1.0 kg a.i. Sevin/ha spot treat
		1979	15% defoliation before heading; 10% defoliation after heading	1.25 kg a.i. Sevin/ha (1979); spot treat, apply in late afternoon
	Leaf folder	1975-77	10% damaged leaves	0.75 kg a.i. Azodrin/ha
		1978-79	15% damaged leaves	0.75 kg a.i. Sevin/ha, spot treat
	Brown planthopper	1975-79	2-4 hoppers/tiller	0.75 kg a.i. MIPC/ha, BPMC/ha, Perthane/ha (1975-77); 0.75 kg a.i. Perthane/ha (1978-79);
	Rice bug	1975-78	$4/m^2$	0.75 kg a.i. Azodrin/ha (1975-77); 0.75 kg a.i. Sevin/ha (1978)
		1979	$6/m^2$	0.75 kg a.i. γ-BHC/ha spray
Sorghum (Cosor 3) / Maize (DMR2 local)	Armyworm	1975-77	10% defoliation	0.75 kg a.i. Azodrin/ha
		1978-79	15% defoliation	1.0 kg a.i. Sevin/ha spot treat (1978); 1.25 kg a.i. Sevin/ha spot treat in late afternoon (1979)
Sorghum (Cosor 3)	*Heliothis*	1975-79	1 larva/2 grain heads	0.75 kg a.i. Azodrin/ha (1975-76); 1.0 kg a.i. Sevin/ha (1977-79)

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APPENDIX I

QUESTIONNAIRE

Name of interviewer ______________________

Note to interviewer: Make sure you are interviewing a farmer. If the farmer has just arrived in the place, choose another farmer for your subject.

Date of survey ______________ Barrio ______________

1. Name of farmer ______________________ 2. Years of farming in barrio ______________

3. Land ownership and relation to the landlord:

   Share tenant ______________ Owner ______________

   Leaseholder ______________ Others ______________

   Who buys insecticides?

   Farmer ______________% Landlord ______________%

   What share of rice harvest is divided between farmer ________% and landlord ________%

4. Total area you plant to rice ________ ha (area of farm)

5. Total number of plots[a] planted rice ______________

   Number contiguous ______________ Number separated ______________

   (Draw map on back of form)

6. Where do you g a sprayer?

   a. Own ______________% d. Hire to spray ______________%

   b. Borrow (from whom) ______________% e. Don't use ______________%

   c. Rent ______________%

   (May be more than one answer. If so approximate the percentage of occasions)

7. How big is the pesticide sprayer you use (capacity)? ______________

8. When you spray your fields, how many times do you refill using your sprayer?

Plot (no.)	Area (m^2)	Number of refills	(Calculate) Spray volume
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______

[a] A plot is a contiguous unit of land planted at the same time and always receives the same management (= field).

9. Did you spray insecticide to each of the plots last wet or dry season? Yes _____ No _____. If yes, recall and list the insecticides used and the growth stages they were applied.

Plot (no.)	Insecticide	Formulation %	Growth stage DT	Number of tablespoons or bags used	(Calculate) Dosage/application
		LAST WET SEASON			
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
		LAST DRY SEASON			
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______

10. What insecticides have you used on rice in the past? List the chemicals and formulations if different from the above?

Insecticide	Reason for changing
1. ______	______
2. ______	______
3. ______	______
4. ______	______
5. ______	______

11. Farmer's perception and assessment of pest problems.

I	II		III
From your experience as a farmer in this barrio, list and describe as many different types of plant damage symptoms on rice as you have seen caused by insects, diseases, rats, birds, or other similar pests (not weeds or nutrient difficiencies)	List as many names of rice pests as you know that occur in your fields (Be as specific as possible). Rank the importance of each to you (1, 2, 3, ...)		How can you control each of the pests you list (Be specific, i.e. name of insecticide or resistant variety, etc.)
Seedbed	*Pest*	*Rank (1, 2, ...)*	
1. ______	A. ______	______	______
2. ______	B. ______	______	______

3. ________ C. ________ ________ ________

4. ________ D. ________ ________ ________

5. ________ E. ________ ________ ________

6. ________ F. ________ ________ ________

Tillering

7. ________ G. ________ ________ ________

8. ________ H. ________ ________ ________

9. ________ I. ________ ________ ________

10. ________ J. ________ ________ ________

11. ________ K. ________ ________ ________

12. ________ L. ________ ________ ________

Booting-panicle initiation

13. ________ M. ________ ________ ________

14. ________ N. ________ ________ ________

15. ________ O. ________ ________ ________

16. ________ P. ________ ________ ________

17. ________ Q. ________ ________ ________

18. ________ R. ________ ________ ________

Ripening

19. ________ S. ________ ________ ________

20. ________ T. ________ ________ ________

21. ________ U. ________ ________ ________

22. ________ V. ________ ________ ________

23. ________ W. ________ ________ ________

24. ________ X. ________ ________ ________

12. Which insecticide formulation do you prefer?

		Why?	Why not?
Granular	________	________	________
Wettable powder	________	________	________
Liquid	________	________	________

13. What methods have you actually used to contro.. insects in your experience on rice?

Name the pests and elaborate on farmer's comments.

			Insects/Comments
a. *Mechanical physical*			
1. Handpicking	Yes ______	No ______	______
2. Cutting rice seedlings	Yes ______	No ______	______
3. Using traps	Yes ______	No ______	______
4. Others	Yes ______	No ______	______
b. *Cultural*			
Removing infested plants	Yes ______	No ______	______
Using old/young seedlings	Yes ______	No ______	______
Adjusting time of planting	Yes ______	No ______	______
Synchronizing planting with neighbors	Yes ______	No ______	______
Plant spacing (what spacing)	Yes ______	No ______	______
Crop rotation (what pattern)	Yes ______	No ______	______
Using fertilizer, high/low (circle answer)	Yes ______	No ______	______
Flooding/draining field (circle answer)	Yes ______	No ______	______
Removing/leaving weeds (circle answer)	Yes ______	No ______	______
Using plant parts such as branches or leaves in fields	Yes ______	No ______	______
Naming plants and describing methods	______		
Using trap crop (which one)	Yes ______	No ______	______
Planting crops on bunds (which ones)	Yes ______	No ______	______
c. *Traditional*			
Talking to spirits	Yes ______	No ______	______
Placing food in field	Yes ______	No ______	______
Unlucky planting dates (which ones)	Yes ______	No ______	______
Trial plantings	Yes ______	No ______	______
Reciting prayers	Yes ______	No ______	______
Others	______		
Using kerosene	Yes ______	No ______	______
- oil	Yes ______	No ______	______
- salt	Yes ______	No ______	______

- ash Yes ______ No ______ ________________
- sand Yes ______ No ______ ________________
- soap Yes ______ No ______ ________________

Using other homemade mixtures (describe) ________________

____

14. *Biological*

List which natural enemies of insect pests are acting in your fields to control them.

________________ ________________

________________ ________________

________________ ________________

How do you encourage them? Explain.

____

____

15. *Plant resistance*

	Variety	Insects
What varieties have you grown in the past and present? What insects are controlled by each?	________	________
	________	________
	________	________

16. Does farmer know each of these pests (if not mentioned above)? (Describe through the use of photographs, actual specimens or local name).

	Knows but says not a pest (✓)	Does not know (✓)	Comments
a. Whorl maggot	________	________	________
b. Caseworm	________	________	________
c. Leaf folder	________	________	________
d. Brown planthopper	________	________	________
e. Green leafhopper	________	________	________
f. Rice bug	________	________	________
g. Stem borer deadheart	________	________	________
h. Stem borer whitehead	________	________	________
i. Grasshopper	________	________	________
j. Armyworm-cutworm	________	________	________
k. Mole cricket	________	________	________

17. How do you know when it is time to apply insecticide to rice? Do you decide yourself/or do others tell you? ______________________

For each insect:

(Refer to answer in question 11)	Calendar (✓)	Observe pest (✓)	Observe damage (✓)
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________
________	________	________	________

18. Are you applying sufficient insecticide to control pests? Yes ______ No ______. If not, why? (If there is more than one answer rank 1, 2, 3 . . . .).

	Yes	No	Rank
Lack of money (credit)	______	______	______
Water problem in refilling sprayer	______	______	______
Lack of sprayer	______	______	______
Lack of labor	______	______	______
Lack of knowledge to use properly	______	______	______
Pesticides not effective	______	______	______
Others	______	______	______

19. Last year where did you get money to purchase insecticides? (If more than one answer rank 1, 2, 3 . . .).

a. Own cash on hand ______________________

b. Personal savings ______________________

c. Credit (what agency) ______________________

d. Borrowed from neighbor/relative ______________________

e. Others ______________________

20. Do you make effort to control insect pests at the same time as your neighbors? Yes ________ No ________.

If yes, why? ______________________

If no, why? ______________________

21. Who applies insecticide on your rice fields? ______________________

22. When applying insecticide, if you were to apply only one half of the amount you normally apply in your sprayer/field, what result would you expect?

No control ______________ No difference ______________

Kill only one half the number ______________________

Others ______________________

23. How do insecticides actually kill the insect? (Let farmer give answer before mentioning these points). (If more than one answer, rank 1, 2, 3 . . .).

a. Vapor fumigant ____________________

b. Insect eats chemical (stomach poison) ____________________

c. Insect comes into contact while moving on sprayed plant ____________________

d. Repellant ____________________

e. Insecticide hits insect contact ____________________

Farmer's first comment ____________________

____

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