

Cultural control of the brown planthopper

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Cultural control methods are needed to help reduce the brown planthopper population because resistant varieties and pesticides alone are inadequate.

Simultaneous rice cropping, if practiced over a wide area and rotated with secondary crops, would break the life cycle of the insect pest. Immediate destruction of rice stubbles and ratoons of a harvested rice crop would help keep down the population of the pest; it would also eliminate the source of infection by the grassy stunt virus and the ragged stunt virus. Raising a field's water level or draining it for a few days would help destroy the insect population. Plant spacing should allow some sunlight to reach the basal portion of the plant. Reduced fertilizer use might not be in line with the agronomic requirement of the crop. In certain cases, early planting or simultaneous cropping of early maturing rice would keep the crop well clear of attack. Simultaneous cropping with proper rotation is most promising in the long run, but it needs continuous supervision. Legislation would probably be necessary to make it effective.

AFTER YEARS OF SUCCESSFULLY CONTROLLING the brown planthopper (BPH) *Nilaparvata lugens* (Stål) by using resistant varieties and insecticides, we now find that those methods alone are no longer adequate (pers. comm. with E. A. Heinrichs, The International Rice Research Institute, P.O. Box 933, Manila, Philippines). IR26 and other rice cultivars with the same gene for resistance to the BPH were infested and reported hopperburned in two widely separated small areas in the Philippines (Anonymous 1975). In the Solomon Islands all resistant selections, including IR26, "broke down" (Stapley 1975). New BPH biotypes capable of attacking IR26 have been identified (IRRI 1975).

Indiscriminate and faulty application of insecticides kills effective biological control agents of the pest (Kulshreshtha et al 1974; Nishida 1975; Fernando 1975). Development of resistance to various insecticides has been reported (IRRI 1970; Fernando 1975; Muriya 1976).

Other methods that will help keep down the insect population while reducing the frequency of pesticide applications that may have unwanted side effects

should be explored (Ripper 1956 ; Akesson and Yates 1964; Newsom 1967; Cope 1971; Pimentel et al 1971; Georghiou 1972).

Cultural control is perhaps as old as agriculture itself. It may be defined as the modification of certain farm operations to make the environment unfavorable for the development and multiplication of insect pests but favorable for crop production. Certain techniques, such as modification of planting, growing, cultivating, or harvesting, aim at preventing insect damage rather than at destroying existing insects (National Academy of Sciences 1971). Plant spacing, the cropping system, and fertilizer management may prevent buildup of certain pest populations. Other methods of cultural control, such as flooding the fields or plowing under the stubble after harvest, aim at destroying certain pest populations. They can reduce the number of larvae and pupae of the rice stem borer *Tryporyza innotata* (Walker) (Coot 1925). Digging of rice stubble to control *T. incertulas* was done in Japan from 1880 until around 1940 (Orita 1935; Ishikura and Nakatsuka 1955). On the other hand, keeping plots flooded or saturated favors buildup of the BPH (Dyck 1973). Thus, a thorough knowledge of the ecobiology of the BPH, other pests, and the crop plant is needed before cultural control techniques are introduced. The techniques should be compatible with other control methods and with the needs of the crop. They must be economical to be readily adopted by farmers.

Unlike insecticidal control, cultural control may not give spectacular and immediate results; however, it is the first line of defense against pest attack, and its methods are dependable, economical, ecologically sound, and non-polluting (NAS 1971; Clark et al 1970). The potential of some cultural control methods already used to combat certain pest complexes should be fully exploited, especially against typical epidemic-type insect pests, such as the BPH, that have high rates of population growth, high tolerance for crowding, high degrees of aggregation, and high dispersal ability (Kuno 1973; Kisimoto 1976).

Experimental data on cultural control of the BPH are relatively scarce in the tropics. One reason might be that the insect was generally a minor pest of rice until recently. In Japan cultural control of the BPH is not practiced (pers. comm. with R. Kisimoto, Central Agricultural Experiment Station, Konosu, Saitama 365, Japan). Epidemics of the insect, which are mainly caused by long-distance migration from mainland China, are effectively prevented by applying insecticides in late July and August (Kisimoto 1971, 1976).

The following cultural control practices are deduced from information on the ecobiology of the insect pest and the suspected causes of recent outbreaks.

CROP ROTATION

In the humid tropics the BPH is active throughout the year and its population density depends on, among others, the availability of food plants (Pathak 1968, 1969). So far, rice is the only suitable host (Nasu 1964; Kisimoto 1976; Okada 1976). On alternate hosts, the insect can survive but does not multiply

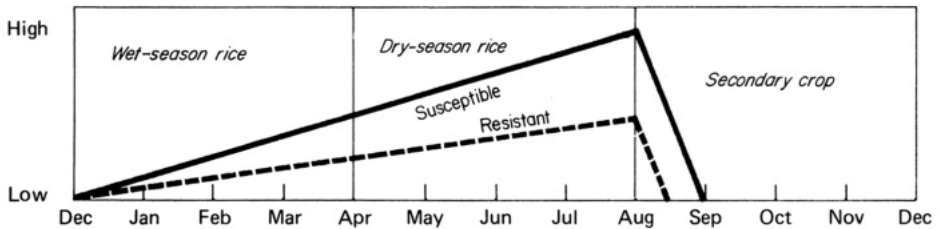
well (Mochida and Dyck 1976). Consequently, during a fallow period or one when rice is not grown, the insect population will be much reduced.

Various cropping systems exist in various rice centers, depending on the availability of water and on custom. In well-irrigated areas, rice is planted twice or even thrice a year and staggered planting with short idle intervals is usual. Such a cropping system appears to stimulate the buildup of the BPH population and to result in serious outbreaks (IRRI 1972; Chatterji 1975; Dyck 1974b; Fernando 1975; Kalode 1974; Kulshreshtha et al 1974; Mochida et al 1975; Mochida 1976; Otake and Hokyo 1976). A recent outbreak of the rice dwarf virus in Japan was also attributed to mixed rice cropping, which increased the abundance and varied the pattern of occurrence of the virus vector, the green leafhopper *Nephotettix cincticeps* (Uhler) (Nakasuji 1974).

Rotating rice with other annual crops or fallowing between two rice seasons will break the life cycle of the pest. The annual crops for rotation should be nonhosts for the insect—soybeans, mung beans, and sweet potatoes. Otherwise they may increase the pest problem. In the Solomon Islands a fallow period appeared to reduce the BPH population to a very low level (Anonymous 1975).

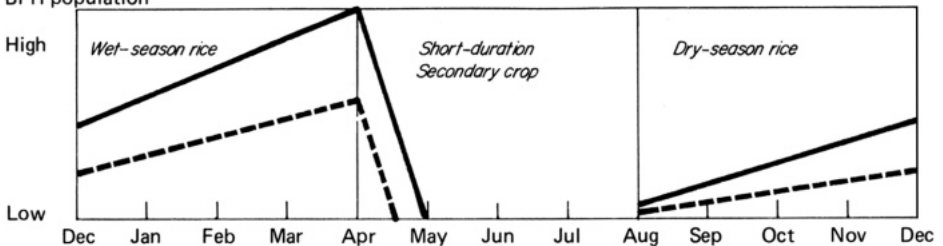
Figures 1 to 4 illustrate cropping systems of well-irrigated areas of parts of West and Central Java and East Java. Rice in the wet season may be immediately followed by rice in the dry season (Fig. 1). Or rice in the dry season may be immediately followed by rice in the wet season (Fig. 2). In this system

BPH population



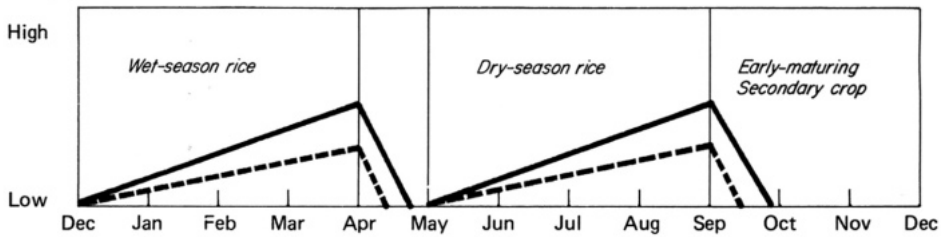
1. Cropping system type 1 for well-irrigated areas (staggered planting).

BPH population



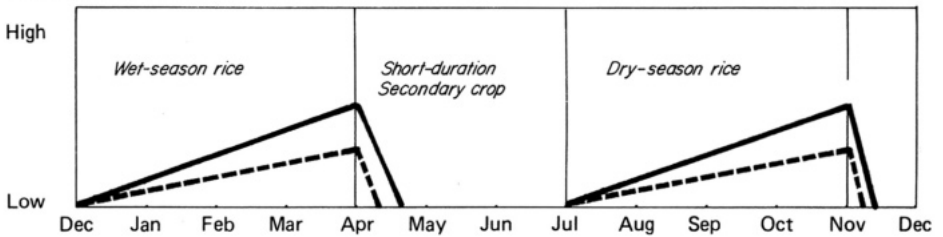
2. Cropping system type 2 for well-irrigated areas (staggered planting).

BPH population



3. Cropping system suggested to reduce buildup of the brown planthopper population when wet-season rice is followed by dry-season rice.

BPH population



4. Cropping system suggested to reduce the buildup of the brown planthopper population when dry-season rice is followed by wet-season rice.

the BPH is able to develop continuously. If a field is fallowed for at least 1 month, e.g. April (Fig. 3) or November (Fig. 4) its following rice crop may have relatively fewer pests.

Integration of this cultural control with resistant varieties (IR26, IR28, IR30) should further reduce pest buildup (Oka 1975; Mochida et al 1976; Samino 1976). A short-duration secondary crop should be chosen to fit the cropping system. To be effective, simultaneous planting should be encouraged and carried out over an entire community (Dyck 1974a; Oka 1976; Mochida et al 1976). But efforts to regulate the planting time in Laguna province, Philippines, were difficult to enforce (Calora 1974).

With simultaneous rice cropping and rotation with other crops in Dolok Masihul, North Sumatra, in the 1975-76 rice season, the average BPH population on the susceptible varieties Pelita and C4-43 was below 20/hill; in Pasar Miring (North Sumatra) it was 77/hill with continuous and staggered rice cropping (Purba 1976). The average BPH population on IR26, however, was low in both places. Similar observations were made in some Java areas by Otake and Hokyo (1976).

Simultaneous cropping with resistant varieties is gradually being introduced to farmers in rice areas of Indonesia (Oka 1976; Soenardi 1976). Simultaneous planting of resistant varieties from different genetic sources would be strategically sound (Otake and Hokyo 1976). It would minimize selection pressure

on the BPH and thus reduce the chance for development of new biotypes.

In the Solomon Islands, control of the BPH is attempted through such agronomic practices as fallowing and strip-cropping with grasses, to favor parasites of the egg (MacQuillan 1974; Stapley 1975).

Crop rotation controls certain pests and provides a number of other benefits, but its potential is limited by crop-production economics (Pimentel et al 1965).

SANITATION

It has been suggested that weedy fields increase the BPH population (Cendaña and Calora 1964; Fernando 1975). Experiments at the International Rice Research Institute (IRRI) show that near rice crop maturity, the planthopper tends to be more abundant in weedy than in weeded plots, probably because the dense vegetation of weedy fields provides an environment suitable for the insect (IRRI 1973). After harvest the insect usually transfers to weeds and grasses but does not hibernate (Alam 1964; Pathak 1969).

Since the survival of the BPH population in the next rice season may depend on alternate host plants, it is important to determine whether certain weeds and grasses serve as alternate hosts on which the insect can breed and feed during both the rice season and the off-season. Definitions of planthopper "host plants" differ. Mochida and Okada (1971) compiled more than 90 plant species other than *Oryza sativa* L. that belong to various families and are believed to serve as host and oviposition plants for the BPH in Japan. They doubt, however, that all are satisfactory host plants for the insect. They consider a real host plant as one on which the insect could develop for at least one generation in the field. Oka (unpubl.) caged 34 species of weeds and grasses individually and infected each with 200 BPH adults. The survival rate on all plants was very low, and by the third week after infestation nearly all the insects were dead. Although they produced a few nymphs on all the test plants, all nymphs were dead 15 days after infestation (Table 1).

Knowing the real alternate hosts for any insect pest is important in sanitation programs. Sanitation aims to remove all breeding or hibernating sites and sources of food of the insect. In Okayama, Japan, epidemics of the rice dwarf virus transmitted by the green leafhopper were almost completely subdued within 2 years by winter plowing to control weeds such as *Alopecurus aequalis* Sobol, an alternate host for the green leafhopper (Nakasuji and Kiritani 1976).

A sanitation program to control the BPH should aim mainly at destroying the stubble and ratoon remaining in a harvested rice field, because the insect can survive in great numbers in the off-season (IRRI 1971) and in fallow period on stubble and ratoon, which may serve as a source of inoculum for the grassy stunt virus and the ragged stunt virus. Stubbles should be plowed under immediately after harvest (Anonymous 1974; Oka 1975) and the field prepared for the next planting. Israel (1969) and Kulshreshtha et al (1974) suggest burning stubble and straw after the punja crop. That practice, carried

Table 1. Survival Of adults Of the brown planthopper and production of nymphs on various weeds.

Weed species ^a	1st wk		2nd wk		3rd wk		Total survival	
	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
<i>Brachiaria mutica</i>	0	0	0	12	0	0	0	0
<i>Isachne implexicaulis</i>	0	0	0	277	0	7	0	0
<i>Fimbristylis littoralis</i>	5	0	0	99	0	0	0	0
<i>Eragrotis uniloides</i>	0	0	0	20	0	0	0	0
<i>Cyperus cyperoides</i>	1	0	0	56	0	1	0	0
<i>Cyperus difformis</i>	25	0	0	53	0	0	0	0
<i>Cyperus compressus</i>	2	0	0	16	0	0	0	0
<i>Cyperus kyllinga</i>	0	0	0	110	0	0	0	0
<i>Cyperus iria</i>	15	0	0	36	0	0	0	0
<i>Echinochloa crus galli</i>	6	0	0	223	0	1	0	0
<i>Echinochloa colonum</i>	2	0	0	442	0	0	0	0
<i>Scirpus juncooides</i>	5	0	0	171	0	1	0	0
<i>Axonopus compressus</i>	0	0	0	32	0	0	0	0
<i>Eleusine indica</i>	0	0	0	19	0	0	0	0
<i>Fuirena ciliaris</i>	6	0	0	19	0	0	0	0
<i>Leersia hexandra</i>	1	0	0	27	0	0	0	0
<i>Paspalum vaginatum</i>	0	0	0	48	0	0	0	0
<i>Cynodon dactylon</i>	0	0	0	10	0	0	0	0
<i>Eleocharis pellucida</i>	1	0	0	305	0	0	0	0
<i>Ischaemum rugosum</i>	0	0	0	186	0	0	0	0
<i>Sorghum heolepensis</i>	0	0	0	99	0	0	0	0
<i>Cyperus malacaensis</i>	0	0	0	226	0	0	0	0
<i>Dactyloctenium aegyptium</i>	1	0	1	267	0	0	0	0
<i>Bachiaria muticum</i>	0	0	0	21	0	5	0	0
<i>Sphenoclea ap.</i>	0	0	0	61	0	0	0	0
<i>Eclipta alba</i>	0	0	0	0	0	0	0	0
<i>Hyptis capitata</i>	0	0	0	0	0	0	0	0
<i>Panicum distachium</i>	0	0	0	111	0	0	0	0
<i>Ischaemum timorense</i>	1	0	0	227	0	0	0	0
<i>Digitaria sanguinalis</i>	1	0	0	405	0	0	0	0
<i>Rottboelia exaltata</i>	0	0	0	284	0	0	0	0
<i>Cyperus ferax</i>	0	0	0	247	0	0	0	0
<i>Panicum tryphiron</i>	0	0	0	67	0	0	0	0
<i>Brachiaria sp</i>	0	0	0	84	0	0	0	0

^a Each weed infested with 200 adults.

out in North Sumatra right after harvest (Effendi 1976), helps reduce the pest population. But during wet weather the intensive schedule does not permit drying and, therefore, burning. Burning the stubble may also destroy most of the arthropod populations that play an important role in decomposing plant remains. Burning also eliminates the available nitrogen in the plant remains. Moreover, nutrient loss by leaching is much higher after burning (IRRI 1973).

Weed sanitation in rice fields is, of course, needed, particularly when the rice plant is somewhat older. It makes a microclimate that is less favorable for the insect. However, weeds and grasses from the ditches and fallow fields do not have to be completely removed because they may shelter natural enemies of the BPH. Moreover, weeds are not an ideal habitat of the pest (Otake and Hokyo 1976; I. N. Oka, unpubl.). More research is needed to determine the role of weed grasses in the interaction of the insect pest with its natural enemies.

WATER MANAGEMENT

The BPH prefers lowland (irrigated) to upland rice. It multiplies near the plant base where the microenvironment is humid and shaded (Pathak 1968; Nishida 1975). Rice fields with standing water have been found to encourage the multiplication of the BPH (Pathak and Dyck 1973; Fernando 1975). Experiments at IRRI with continuously flooded plots developed two large peaks of BPH population. But when the field was kept saturated but not flooded, only one moderate peak developed (IRRI 1972; Dyck 1974a). Stapley (1975) also reported that the BPH problem in the Solomon Islands increased when irrigated rice cultivation replaced dry rice cultivation. In Japan, the insects are numerous in humid lowlands (Suenaga 1963).

Good water management could be a means of controlling the planthopper. Miller and Pagden (1930) reported that several outbreaks of the insect in Malaysia were suppressed by draining the fields for about 2 days. In the Philippines farmers stop irrigating infested fields that are almost mature, and spread the plants apart every few rows to help dry the field (Dyck 1974a). Draining rice fields at the proper time and withholding irrigation water for a while also effectively control the rice water weevil (Pimentel et al 1965).

Excess water also hinders development of the BPH. Esaki and Sameshima (1940) found that the insects eggs perished if kept on leaves at 100% relative humidity. Raising the water level can destroy eggs laid in the leaf sheaths. In Taiwan, Iso (1954) and Grist (1968) reported that the insect was controlled by deep irrigation early in the morning, followed by the addition of a certain amount of kerosene (preferably mixed with pyrethrum) to the water. The plants are shaken to cause the insect to fall into the water. An oil-dropping method with whale oil was used in Japan as early as 1670 to control rice plant-hoppers (Mine 1910). Raising the water level was a common practice in Indonesia to control the BPH (Tjoa 1952). Sand or sawdust containing 0.25 liter kerosene for every 100 sq m was broadcast on the raised water level and the plants were shaken.

In Fiji raising the water level as the plants grow is also suggested to drown eggs and drive the insect from its favored location on the lower stems (Hinckley 1963).

SPACING

Close spacing of rice plants is believed to contribute to the rapid increase of the BPH population (Kalode 1974; Fernando 1975; Kisimoto 1976a). Experiments at IRRI showed that at times of peak insect populations, both tall and short Peta had significantly more BPH per tiller at 10- × 10-cm spacing than at 50- × 50-cm spacing (IRRI 1972; Dyck 1973). Rectangular plantings (25 × 24 cm) and three-row plantings to facilitate use of the horse-drawn paddy weeder (27-39-27 × 18 cm) tended to have more BPH than row plantings

(60 × 9 cm). If the rows ran east to west, the population also tended to grow (Suenaga 1963). With closely spaced plants microenvironments were slightly cooler and more humid. Mochida (1964) reported that 20 macropterous females laid a total of 2,967 eggs in late August and 2,798 in late September. Temperatures were higher in August than in September.

Cooler temperature in the closely spaced plants may not be the main cause of the BPH populations. More important might be the fact that a shaded and humid microenvironment is unfavorable for the development of the natural enemies of the insect (Nishida 1975).

Close planting, particularly when associated with repeated foliar sprays of parathion enhanced the development of the BPH at IRRI in 1976 (pers. comm. with E. A. Heinrichs). That may be because foliar sprays may not reach insects that are "protected" by the thick canopy of the rice crop, but they destroy natural enemies inhabiting the foliage (Nishida 1975). Aerial spraying of phosphamidon and fenitrothion on the thick canopy of rice failed to check a hopper infestation in Kerala, India (Kulshreshtha 1974).

Little sunshine reaches the bases of closely spaced rice plants. Since the BPH is negatively phototactic (Pathak 1968), such a dark habitat is an ideal place for it to congregate and multiply. Suenaga (1963) reported that solar and ultraviolet radiation act abiotically against the BPH and restrain its increase. Spacing that allows some sunshine to reach the basal area of the rice plants for some part of the day may thus be another reason for smaller insect populations. The most appropriate spacing would let enough sunshine penetrate to prevent pest increase, but would provide a suitable habitat in which biological control agents could develop. It would allow insecticide sprays, if necessary, to reach the area where the insects congregate. Kulshreshtha et al (1974) suggested planting the crops in rows 15 to 20 cm apart.

More studies are needed to determine how plant spacing influences the complex interrelationships of environmental factors, the BPH, its natural enemies, and rice production.

FERTILIZER MANAGEMENT

While some insect species responded negatively to increased nitrogen fertilization of crops, the populations of many others—certain aphid species and spider mites (Pimentel 1965)—significantly increased with nitrogen level. The rice stem borer *Chilo suppressalis* Walker (Ishii 1964) and gall midge *Orseolia oryzae* (Wood-Mason) (Narayanan et al 1973) were significantly more plentiful in fields receiving high rates of nitrogen.

The BPH population was also largest on plots treated with a combination of 27.3 kg N, and 13.6 and 27.3 kg P₂O₅ (Abraham 1957). Females reared on plants receiving high nitrogen levels showed increased fecundity (Kalode 1971, 1976). IRRI experiments demonstrated that nitrogen fertilizer contributed to the population increase of the pest (Dyck 1973). Evidence from various countries suggests that high rates of nitrogenous fertilizers have caused in-

creased BPH infestations (Dyck and Hsieh 1972; Chatterji 1975; Fernando 1975; Kulshreshtha et al 1974; Velusamy et al 1975; Samino 1976). But it is not clear why the high fertilizer levels are associated with greater numbers of planthoppers (Mochida and Dyck 1976). Nishida (1975) suggested that they contribute to the thickness of the canopy.

High rates of nitrogenous fertilizers may result in more protein and amino acid synthesis by the rice plant. The proteins and amino acids are among the essential requirements for growth and development of immature insects and are often needed by adults for the reproductive process (House 1965; Bursell 1970).

Although reducing the amount of applied nitrogen may lower BPH populations, large amounts are essential for high rice yields. It is, therefore, not realistic to recommend less fertilizer use even if pest problems are exaggerated (Pathak 1971; Dyck 1974a).

Integrating the use of fertilizer-responsive BPH-resistant varieties with other control methods should achieve both high rice production and BPH control.

TIME OF PLANTING AND SHORT-DURATION RICE

Manipulation of planting time (early or late) can provide effective control of some pests. For example, epidemics of the Hessian fly *Mayetiola destructor* (Say) on winter wheat are avoided by late fall sowing (Metcalf and Flint 1951). Late planting of rice minimizes infestation by the white rice stem borer *Tryporyza innotata* (Walker) (Goot 1948).

At Cuttack, India, Israel (1969) reported that crops planted by the end of July suffered little from leafhoppers and planthoppers, but crops planted later were severely attacked. Gradual buildup of the BPH population from the beginning of the rice season could cause severe damage to late-planted rice. Early planting also implies simultaneous planting over wide areas, early in the season.

In Sri Lanka the susceptible short-duration (110-day) varieties Bg 34-8 and Bg 94-2, planted in April or up to about 10 May, escaped serious planthopper damage. But 130-day varieties like IR26 were destroyed when planted in the same period. Only two generations of the insect occur on short-duration varieties, while three full generations occur on long-duration cultivars (Fernando 1975). In areas with staggered planting patterns, the short-duration varieties may be damaged because the BPH population is continuously high (Mochida et al 1976). Therefore, their use should be integrated with such other control measures as simultaneous planting.

CONCLUSION

Little experimental work has been carried out on cultural control of the BPH. In view of the ecobiology of the pest and rice crop, and tentative suggestions

of causes for recent outbreaks, the following cultural control methods are suggested :

1. Simultaneous planting and cropping of rice over large areas;
2. Rotating rice with nonhost crops, or fallowing between two rice crops;
3. Selective elimination of suitable hosts and habitats (sanitation);
4. Plant spacing to allow some sunlight to reach the basal portion of the rice plants;
5. Proper water management, i.e. raising the water level, or draining the field for a few days;
6. Early planting of short-season rice; and
7. Integration of methods 1-6 with resistant varieties and the judicious use of pesticides.

The most promising cultural method for planthopper control is synchronized rice cropping and rotation with other crops. Such an approach also makes other pest complexes easier to monitor.

If cultural control of pests is to be more widely accepted, several sociological and political constraints must be overcome.

1. Farmers have to be convinced of the advantages of the method.
2. The regulation of irrigation water may have to be modified so that water becomes available to groups of farmers situated in a large area.
3. Large numbers of farmers have to be organized.
4. There must be close cooperation among researchers, extension people, and local authorities to guide and supervise the program. It may even be necessary to have legislation to enforce the simultaneous planting of rice and proper rotation.

The ideas suggested here should be tested in experiments to allow us to arrive at a sound cultural method or methods that can be recommended as a component of an integrated program to control the BPH.

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