

INTEGRATED MANAGEMENT OF PADDY AND AQUATIC WEEDS IN INDONESIA

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ABSTRACT

Rice is the staple food of Indonesia, and plays a major role in both political stability and economic growth. The government of Indonesia has worked consistently to finally reach rice self-sufficiency in 1984. This achievement was made possible by technical improvements, as well as by infrastructural development such as the construction of reservoirs and irrigation networks. The presence of weeds in rice fields reduces rice yield, and their presence in irrigation networks endangers the water supply. This paper describes the techniques which have been developed in Indonesia for weed control and the management of macrophyte vegetation.

INTRODUCTION

After Indonesia achieved self-sufficiency in rice in 1984, it was faced almost immediately with the ecological consequences of that intensification.

The rice brown planthopper, which had cost Indonesia nearly one billion dollars in the 1970s and caused the country to remain the world's largest rice importer, exploded in 1986 throughout North Sumatera, Central Java, and parts of East Java, and began to threaten West Java. Insecticide subsidies were already exceeding US\$128 million per year, and yet no control of brown planthoppers by chemicals had been achieved.

Instead of simply pouring on more chemicals, or frantically multiplying rice varieties of uncertain agronomic potential or unproven profitability which happened to have one more gene for brown planthopper resistance, the government of Indonesia adopted the Indonesian National Policy of Integrated Pest Management. This contained three important points:

- On explicit ecological grounds, 57 trade formulations of insecticides were banned from use on rice. It was ordered that resistant varieties of rice be grown in affected areas.
- The number of official field pest observers assigned to rural extension centers was increased from less than 1300 to more than 2900.

- These and other extension staff and farmers were to be trained in IPM.

An early move was the elimination of 85% of the insecticide subsidy in gradual steps over two years. Since the implementation of this policy, rice production has increased by more than 12%, while the use of formulated pesticides has fallen by more than 50% (Kenmore 1991)

The problem now is to maintain self-sufficiency in rice by intensifying the production system, including the development of appropriate weed management. The intensification program is felt to be particularly important, because a significant area of good rice-growing land has been converted to other uses, such as urban development and industrial use.

Most rice in Indonesia is grown under wetland conditions. The contribution of upland rice is only 6% of national rice production, and average yields are very low. The main constraints, as identified by Manwan *et al.* (1989) and Scholz (1983), are poor soil fertility, diseases such as *Cercospora* and *Helminthosporium*, various insect pests, and the heavy competition exerted by weeds.

The high productivity of the wetland rice systems has been made possible by good infrastructure, including well-maintained irrigation networks, plus an adequate supply of fertilizer, improved seeds and other inputs.

Aspects of rice cultivation which are related to weed management include soil preparation, fertilizers, methods of planting, density (seeding

rate), selection of rice variety, water management and crop rotation.

Soil preparation is an important component of weed management, since it provides weed-free conditions at planting if it is carried out properly. Failure to achieve this will make the problem of weeds much more difficult to solve. The time lag between finishing soil preparation and planting is crucial: the shorter the time lag, the better for the rice crop.

The application of fertilizer tends to enhance the competitive ability of weeds. Although yields of rice are higher at higher levels of fertilizer under weed-free conditions, the presence of weeds may mean a reduction of yield under high fertilizer levels. Fertilizer applications may thus help create serious weed management problems.

Competition tends to be greater in wet-seeded rice than in transplanted rice, while a higher seed rate tends to reduce weed populations. The rice variety "Cipunegara" has a strong rooting system, and even if it receives no weeding at all it is able to compete well.

BIOECOLOGY OF PADDY AND AQUATIC WEEDS

Paddy weeds are associated with wetland rice cultivation, including irrigated and rainfed systems, rice grown in tidal swamps, and deepwater rice.

Common Paddy Weeds in Indonesia

Out of 265 species of rice weeds in Indonesia, 127 species are weeds of wetland rice, and 90 weeds of upland rice, while 48 weed species are common to both types of production system (Soerjani *et al.* 1987).

The most commonly reported weeds in paddy fields are shown in Table 1.

In 1990, the consumption of herbicides in Indonesia, while very low compared to Japanese herbicide consumption, reached a value of nearly US\$ 23 million and is still increasing (MP 1991). Although a greater range of herbicides is available than ever before, is important that in weed management, a holistic approach to the overall agricultural production system be developed. This involves understanding how rice weeds interact in the paddy ecosystem. Weeds are competing with each other besides competing for the same resources with rice. Their growth and population dynamics may be ma-

nipulated to the benefit of the rice crop.

Weed Germination

The interaction between weeds has been studied by Pons (1985), who measured the germination of various weeds at various water depths and when covered by *Salvinia molesta*, the floating water fern. He showed that submerging weed seeds in 12 cm of water combined with a surface layer of *Salvinia molesta* prevented the germination of many weed seeds (Table 2).

Submergence alone was enough to reduce the germination percentage of some weeds, including *F. littoralis* and *C. iria*. *M. vaginalis* and *C. difformis* were not affected by the water depth.

Competition

The effect of competition on rice exerted by weeds is the cause of the yield reductions commonly cited in the literature. It is easily understood that a hectare of land can support only so much vegetation, whether it be rice or weeds. The soil does not differentiate between rice and weeds (Moody 1991),

Table 1. Common paddy weeds in Indonesia

Species
Broadleaf weeds
<i>Monochoria vaginalis</i> (Burm.f.) Persl.
<i>Marsilea crenata</i> Persl.
<i>Limnocharis flava</i> (L.) Buch.
<i>Spenochlea zeylanica</i> Goertn.
<i>Ludwigia octovalvis</i> (Jacq.) Roven
<i>Salvinia molesta</i> D.S. Mitchell
Grasses
<i>Paspalum distichum</i> L.
<i>Echinochloa crus-galli</i> (L.) Beauv.
<i>Echinochloa colona</i> (L.) Link.
<i>Leersia hexandra</i> Sw.
<i>Leptochloa chinensis</i> (L.) Nees.
Sedges
<i>Cyperus difformis</i> L.
<i>Cyperus iria</i> L.
<i>Scirpus juncooides</i> Roxb.
<i>Fimbristylis littoralis</i> Gaudich

Source: Bangun and Wiroatmodjo 1986; Gurning and Fagi 1986; Soerjani *et al.* 1987

Table 2. No. of weed seedlings emerging in three lowland rice fields in West Java. (Combined surface area 1360 cm², three depths of irrigation water).

Species	Level of Significance	Depth of irrigation water (cm)			
		0	2.5	12	12 + <i>Salvina</i> ¹
Alluvial soil					
<i>Fimbristylis littoralis</i>	*	794	390	170	0
<i>Cyperus difformis</i>	NS	143	155	78	0
<i>C. iria</i>	*	28	41	3	0
<i>Scirpus lateralis</i>	*	21	49	3	1
Latosol					
<i>F. littoralis</i>	*	50	7	0	0
<i>M. vaginalis</i>	NS	55	42	38	0

1) : Water surface completely covered with floating *Salvinia molesta*

* : Significant at 5% level

NS: Not significant

Source: Pons 1985

as was demonstrated by Pons and Kruif (1985) in their work at BIOTROP in Indonesia (Table 3).

Table 3 shows that *E. crus-galli* at a rate of 4 plants/pot reduced both the number of tillers and the dry weight of the rice plants. *C. iria* had a similar effect, but the presence of 4 plants/pot of *F. littoralis*, *S. juncooides* and *E. congesta* did not affect the growth of rice. In this experiment, it was noticed that weeds were also greatly affected by the presence of the rice plants.

A further study by Pons and Kruif (1985) demonstrated that in fact the reduction in the biomass of *E. crus-galli* in competition with rice was greater than any reduction in the biomass of the rice plant (IR-26). Why then do weeds persist, and constitute a constant threat to rice yields?

The success of weeds in colonizing paddy fields seems to be related to their reproductive capacity. The reproductive output of annual weeds is particularly important, since the seed represents the only link to the area between generations. Annual weed species seems to be so plastic that a relatively stable output can be maintained.

Floral Composition of Weed Communities

It is generally accepted that the presence and abundance of weed species are affected by agronomical practices and other ecological features prevailing in the area. Currently, infestation by *E.*

crus-galli is increasing rapidly in Indonesia. The traditional method of hand weeding cannot eliminate this weed properly, because farmers have great difficulty in distinguishing it from young rice plants. In addition, high-yielding rice varieties usually have short stature, so are less able to compete against this fast-growing weed.

In West Java it has also been reported that populations of *Cyperus iria* and *Ludwigia* sp. have been increasing, so that both species have become a threat to rice production (Burhan, personal communication).

Infestation by submerged weeds such as *Hydrilla verticillata* (L.f.) Royle has been increasing in areas where integrated fish-rice culture is practiced. These weeds occupy the ditches which have been constructed in rice fields to serve as fish sanctuaries.

Aquatic Weeds

The term 'aquatic weeds' refers here to weeds which exist in an aquatic environment other than paddy fields, including water reservoirs (man-made or natural), irrigation channels, rivers and streams (but not marine or mangrove environments).

There have been several reports on the inventory of aquatic macrophyte weeds found in various water systems in Indonesia (Table 4). Pancho and Soerjani (1978) reported 112 taxa, representing 69 genera and 43 families, of aquatic macrophyte

Table 3. Plant height, tiller number, and dry weight of rice (2 plants/pot) and weeds (4 plants/pot) grown in pots

Weed species	Plant height (cm)		No. rice tillers	Dry weight (g/plot)	
	Rice	Weed		Rice	Weed
Rice (R)	99		26	24.9	
R + <i>Echinochloa crus-galli</i>	90*	115	17*	14.3*	21.1*
<i>Echinochloa crus-galli</i>	-	112	-	-	30.5
R + <i>Cyperus iria</i> L.	88*	107	19*	15.5*	18.7*
<i>Cyperus iria</i> L.	-	100	-	-	30.0
R + <i>Cyperus difformis</i> L.	93*	88	20*	18.4*	6.8*
<i>Cyperus difformis</i> L.	-	104	-	-	12.0
R + <i>Cyperus pilosus</i> Vahl.	96	88	22*	20.6	6.6*
<i>Cyperus pilosus</i> Vahl.	-	93	-	-	17.4
R + <i>Fimbristylis littoralis</i> Gaudich	98	68	23	21.7	4.4*
<i>Fimbristylis littoralis</i> Gaudich	-	72	-	-	7.2
R + <i>Scirpus juncooides</i>	98	70	24	23.1	1.7*
<i>Scirpus juncooides</i>	-	79	-	-	5.0
R + <i>Eleocharis congesta</i> D. Don	95	39	24	24.1	1.2*
<i>Eleocharis congesta</i> D. Don	-	44	-	-	2.0

* : significant at a 5% level

Source: Pons 1985

weeds in the Southeast Asian region. Of these taxa, 94 were found in Indonesia. The ten most important of these aquatic weeds are presented in Table 5.

Recent reports have indicated further weed species that are becoming troublesome in Indonesia, including *Phragmites karka* (Sastroutomo and Utomo 1985), *Polygonum barbatum* (Hisbi 1991), *Hanguana malayana* (Sastroutomo and Utomo 1985), *Ipomoea fistulosa*, *I. aquatica* (BIOTROP 1973) and *M. pigra* (Tjitrosemito and Uji 1992).

Waterhyacinth (*Eichhornia crassipes*) is the most troublesome aquatic weed. It has infested a number of lakes and reservoirs in Java, Sumatera, and recently also in Irian Jaya.

P. karka has invaded the Rawa Danau lake which supplies water to the Cilegon Steel Factory. The advance of this weed was stimulated by the fertilizer applied to paddy fields around the lake, and by the heavy deposits of silt washing into the lake following forest clearance (Sastroutomo and Utomo 1985).

P. barbatum has formed a thick cover over water reservoirs in South Kalimantan, and has reduced the storage capacity of the reservoir to the extent that the production of electricity generated from the reservoir is threatened.

M. pigra has become a major problem in

swampy areas used for rice in South Sumatera and Kalimantan. This weed has been able to form a very dense community, eliminating the natural *Scleria* vegetation, so that farmers are unable to cultivate their paddy fields. Tjitrosemito and Uji (1992) have identified two different forms of *M. pigra*.

MANAGEMENT OF PADDY AND AQUATIC WEEDS

PADDY WEEDS

Yield Loss Assessment

The yield loss of rice from weed infestation varies according to the weed species and its population, the rice variety selected, and agronomic practices (see Table 6). *P. distichum*, a perennial weed, is extremely difficult to control, while *M. vaginalis* is very competitive and reduced the yield of rice considerably.

The effect of weed control techniques and the rice variety selected on yield losses are shown in Table 7. The Indonesian variety Cipunegara is a better competitor than IR36, since it has a stronger rooting system, and grows rapidly to give better canopy coverage.

Table 4. Inventory of aquatic weeds found in various types of open water in Indonesia

Site	No. of Species	Reference
1. Rawa Pening lake, Central Java	215	Notosoedarmo and Nahamura 1976
2. Selorejo Water Reservoir, East Java	102	BIOTROP 1973
3. Curug Water Reservoir, West Java	54	Soerjani 1974
4. Tempe lake, Sulawesi	45	BIOTROP 1977
5. Singkarak lake, West Sumatera	12	University of Indonesia 1977
6. Maninjau lake, West Sumatera	11	University of Indonesia 1978
7. Toba lake, North Sumatera	9	University of Indonesia 1979
8. Tondano lake, North Sulawesi	34	University of Indonesia 1979
9. Kerinci lake, Jambi	24	University of Indonesia 1979
10. Rawa Danau lake, West Java	17	Sastroutomo and Utomo 1985
11. Saguling & Cirata water reservoir	69	Ramlan and Dhahiyat 1989
12. Sentani lake, Irian Jaya	17	Sukarwo 1991
13. Ir. M. Noor reservoir	10	Hisbi 1991

Table 5. The most important aquatic weed species in Indonesia

No.	Aquatic weed species
1.	<i>Eichhornia crassipes</i> (Mart.) Solms.
2.	<i>Salvinia molesta</i> D.S. Mitchell
3.	<i>Hydrilla verticillata</i> L.
4.	<i>Scirpus grossus</i> L.
5.	<i>Najas indica</i> (Willd.) Cham.
6.	<i>Ceratophyllum demersum</i>
7.	<i>Nelumbo nucifera</i> Gaertn.
8.	<i>Panicum repens</i> L.
9.	<i>Potamogeton malayanus</i>
10.	<i>Mimosa pigra</i> L.

Source: Pancho & Soerjani 1978

Critical Period of Weed Control

It is common knowledge that the critical period for weed control is the first third of the cropping season. For high-yielding varieties of rice, this is the first 30 to 40 days after transplanting (Mercado 1979).

Farmers in Java hand weed their paddy fields twice, at 21 and 42 days after transplanting.

The first and second weeding each requires about 20 - 40 man days/ha. Moody (1991) emphasized that control inputs should be applied only after weeds reach a threshold that causes economic loss to the crop. Unfortunately, not much work has been done in Indonesia on this aspect, but the threshold level could be expected to vary according to labor costs and the price of paddy rice. Bangun (1988) indicated that the economic threshold for controlling *E. crus-galli* could be low, since even at a ratio of one hill of *E. crus-galli* per four hills of rice, the yield reduction in rice was about 20.5%. In addition, *E. crus-galli* can be an alternate host for rice bugs (*Leptocorisa oratorius*), sheath rot (*Acrocyllindricum oryzae*), sheath blight (*Croticium sasakii*) and leaf scald (*Rhynchosporium oryzae*).

Given this potential role of *E. crus-galli* as a transmitter of pests and diseases, its economic threshold will still vary. It would be possible for a zero population of *E. crus-galli* to represent the economic threshold, if the risk of harboring disease is such that the normal yield of paddy rice is threatened.

Weed Control Methods

Control of paddy weeds in Indonesia is mainly carried out manually, or semi-mechanically

Table 6. Effect of weed species and their populations on the yield of rice (IR30)

Population of weeds (no./m ²)	<i>P. distichum</i>		<i>M. vaginalis</i>		<i>M. crenata</i>	
	(mt/ha)	(%)	(mt/ha)	(%)	(mt/ha)	(%)
0	5.8 ^a	100	8.0 ^a	100	7.6 ^a	100
8	4.3 ^{ab}	74	3.1 ^b	39	6.9 ^a	91
16	4.2 ^{ab}	72	3.1 ^b	39	7.3 ^a	96
32	3.3 ^b	57	2.8 ^b	34	6.4 ^a	85

NB. Numbers in one column followed by the same letter do not differ significantly at a 5% level

Source: Bangun 1988

Table 7. Effect of rice variety and weed control practices on rice yield

Treatment	Time of application (DAT)	Weed dry weight (g/m ²)			Rice yield (mt/ha)		
		IR36	CN*	KA	IR36	CN	KA
Control	-	14.4	15.0	12.7	4.2	5.2	4.9
Manual (twice)	21 + 42	0	0	0	5.4	6.2	6.9
2,4-D	14	9.6	9.9	8.9	4.7	6.3	6.0
2,4-D+Manual	14+28	11.9	10.5	9.6	5.9	5.7	6.3

(Note: No statistical analysis given). *CN: Cipunegara; KA: Krueng Aceh.

Source: Bangun 1988

using rotary weeders. However, some farmers are using herbicides to control weeds both for land preparation (in tidal swamp rice systems), and to control weeds after planting.

Manual Weeding

In manual or hand weeding, the weeds are uprooted and piled on dikes or buried in the mud. Weeding is done twice, i.e. at 21 and 42 days after transplanting. A combination of manual and chemical weeding has been tried, but has not been widely adopted by farmers.

Rotary Weeders

Manual weeding is expensive, and rotary weeders are becoming popular because they are faster and require less labor than hand weeding. Rotary weeders are utilized under shallow water

conditions, when weeds are easily uprooted by the teeth of the rotating drum and buried in the mud. In deeper water, the uprooted weeds will float and may be able to regrow. The currently used rotary weeder has usually been modified to have two rotating drums, and can be utilized either by pushing or pulling.

Chemical Control

A wide range of herbicides are currently available on the market for weed control in paddy fields. Compared to hand weeding or rotary weeders, chemical weed control is much more efficient in terms of time, labor and cost. However, the application of chemical herbicides requires that farmers are careful to follow the correct procedures. A slight error in the timing of the application or the rate of herbicide used may result in serious phytotoxicity.

2,4-D can be utilized as a post-emergence

herbicide with good results when it is applied in paddy fields with shallow water. Oxadiazon is easy to apply, simply by dripping the chemical from the bottle, while granules of thiobencarb + 2,4-D can be broadcast as pre-emergence herbicides. In the application of oxadiazon and thiobencarb + 2,4-D, the water level should be kept at around 2.5 - 5 cm. If the herbicides are applied correctly, they give good weed control and the rice yield is reasonable (Table 8).

It is interesting that *Salvinia molesta* and *Azolla pinnata* can both function as cover crops, reducing infestation by weeds. This may be through their effect in reducing the germination of weed seeds without affecting the growth of rice, as shown by Pons (1987).

The application of slow-release formulations of thiobencarb and butachlor is currently being tested. Although they do not give better weed control than existing commercial formulations, they are more compatible with integrated fish-rice culture (Suyud 1992).

Chemical control may also be utilized as an aid in soil preparation, especially in tidal swamp rice systems. Rice production in tidal swamps is basically

a shifting cultivation type of agricultural system. Rice is planted only once a year, and after harvesting the area is left undisturbed until the time of the next rice planting. The growth of vegetation, mainly sedges (*Scleria* spp.), is prolific and forms a thick biomass. Normally farmers will require more than two months to clear it, but with appropriate herbicides the work becomes easier and the yields are higher. Sundaru *et al.* (1978) reported on the use of herbicides for killing the vegetation in tidal swamps before these are planted in rice (Table 9).

Since 1970, there has been a gradual reduction in the type of pesticide research which investigates new active ingredients. This may reflect public concern about the environment. People are trying to find a better combination of existing active ingredients, rather than searching for new ones, and there is also a growing interest in biological control.

Biological Control

Research on the floating fern *Salvinia molesta* showed that it was able to reduce the germination of some weed seeds (Pons 1985) and

Table 8. The effect of weed control on weed growth and rice yield at Singamerta, (Indonesia, wet season 1983/84)

Weed control	Rate (kg/ha product)	Time of application (DAT)	Percent of weed cover* at 45/DAT	Yield of rice (mt/ha)**)
Rotary weeder (twice)	-	21.42	50	3.9 a
Double rotary weeder (twice)	-	21.42	10	3.7 a
Hand weeding (twice)	-	4	5	4.2 a
<i>Salvinia</i> cover	40%	4	45	4.0 a
<i>Azolla</i> cover	40%	10	60	4.2 a
Herbicides,				
Rilof H 500 EC	1.5	14	60	3.6 a
DMA-6	2.0	14	30	3.5 a
Ronstar 12L	3.0	4	55	3.8 a
Saturn D6G	30.0	4	40	4.0 a
Control	-	-	100	2.7 b

*) No statistical analysis

***) Numbers followed by the same letter do not differ significantly at a 5% level

NB. Rilof H 500 EC - Piperofos isopropyl ester
 DMA-6 - 2,4-D
 Ronstar 12L - Oxadiazon
 Saturn D6G - Thiobencarb + 2,4-D IPE

Source: Bangun 1988

also reduce the growth of weeds (Table 8), while at the same time it did not reduce the yield of rice. *S. molesta* can be regarded as a biological control agent of paddy weeds, at least in transplanted rice. This situation complicates the control of *S. molesta* in open water, where it is usually considered a weed.

AQUATIC WEEDS

The control of aquatic weeds in lakes or reservoirs is carried out by government agencies, such as the Department of Public Works or the State Electricity Agency. In tertiary irrigation canals, weed control is done by farmers. The main method of control is manual. Only occasionally are machinery and herbicides used.

Control is unfortunately discontinuous, so that infestation with aquatic weeds such as waterhyacinth occurs repeatedly, through the re-growth of the remaining weeds. Continuous funding is required to keep waterhyacinth from blocking the flow of water to the turbines and generators (Tjitrosoedirdjo and Widjaja 1991).

Biological Control

The biological control of aquatic weeds in Indonesia began in 1975, when BIOTROP imported the waterhyacinth weevil, *Neochetina eichhorniae*, from the University of Florida. This followed a recommendation made at the Southeast Asian Workshop on Aquatic Weeds, held in Malang in 1974, that

Indonesia should investigate the use of biocontrol agents (Soerjani and Tjitrosemito 1976).

An investigation into the role of natural enemies of aquatic weeds in Indonesia was subsequently carried out. The use of insects, pathogens and fish as biological control agents was actively studied (Mangundihardjo *et al.* 1977; Kasno *et al.* 1979; Kasno and Saraswati 1979; Hadi and Setyawati 1976). *Nymphula responsalis* Wlk (Lepidoptera: Pyralidae) was found to be the most common natural enemy of water fern in Java, while water lettuce is attacked by *P. hennia* Swinhoe (Lepidoptera: Noctuidae, reidentified as *Epipsammia pectinicornis*).

Field observations in Java and Sulawesi have shown that *Haltica cyanea* (Weber) and *Haltica* sp. (Coleoptera: Chrysomelidae) and *Nanophyes nigrutilus* Boh (Coleoptera: Curculionidae) all feed on water primrose, and may be potential biocontrol agents. Other work on the biological control of aquatic weeds was reported by Tjitrosoedirdjo and Widjaja (1991) in their paper presented at the most recent national symposium on Aquatic Weed Management.

Aquatic Weed Management

The conceptual management of aquatic weeds has been well developed by Soerjani (1979). Management is aimed at optimizing the utilization of water resources by keeping the population of aquatic weeds, below the economic threshold level. Below

Table 9. The use of herbicides as an aid in soil preparation for rice grown in tidal swamps, Palembang, (Indonesia, wet season 1977/1978)

Treatment	Application Rate (ℓ/ha) formulation	Time of application (DBT)	Rice yield (mt/ha)
1. Paraquat (ℓ/ha)	3.0	7	1.8 ab
2. Paraquat 2x (ℓ/ha)	1.5 + 1.5	14 + 7	1.7 ab
3. Paracol + weeds cut by hand	3.0	14	1.3 ab
4. Paraquat 2x	3.0	14 + 7	2.3 a
5. Paracol + weeds cut by hand	3.0	14 + 7	2.0 ab
6. Traditional system ¹	-	50 + 30 + 15 + 1	1.3 ab
7. Dalapon ² + Paracol	7.0 + 3.0	14 + 7	0.8 b

NB. Numbers followed by the same letter do not differ significantly at a 5% level.

1 Weeds cut manually and incorporated into soil.

2 Dalapon rate in kg/ha

Source: Sundaru *et al.* 1978

this level, they do not have any significant detrimental effect on human beings and their economic activities.

Establishing the economic threshold involves the thorough biological study of aquatic macrophytes in the system, and a determination of their precise function in that system. As primary producers, macrophytes function as a food source for aquatic biophages and provide breeding sites for fishes, birds and insects. Aquatic weeds are also able to absorb pollutants. While they have a useful function, if they are present in too great an abundance the nuisance they cause is considered to outweigh their value. The excessive growth of aquatic macrophytes will hinder the optimum utilization of water reservoirs.

There are various ways of reducing the population of aquatic weeds, including preventive, physical, biological, and chemical methods. Each has its own advantages and disadvantages. Physical methods, for example, are labor-demanding but the biomass they provide when the weeds are removed may generate other activities such as mushroom culture or the production of biogas, paper, pulp, fertilizer, handicrafts or livestock feed. They may even be processed for human consumption.

FUTURE OUTLOOK

After achieving self-sufficiency in rice production, the Indonesian government is now facing problems of how to sustain this success and develop a new strategy to cope with the ever-changing global situation.

As the human population grows, the Indonesian requirement for rice will also continue to grow. Damardjati *et al.* (1987) estimated that 37.5 million ton of milled rice will be needed by the year 2000. An annual growth rate in rice yield of 1.3% between 1986 and 2000 would require the expansion of riceland by about one million additional hectares, obtained by either by double cropping through irrigation or by opening new land for cultivation. Development of markets and irrigation infrastructure, as well as the transmigration program, will be necessary components in the effort to meet growing rice requirements.

The implementation of a national IPM policy since 1986 has not only overcome the problem of the brown planthopper, but has also generated a strong interest in studying the ecological basis of our agroecosystems. This involves analysis of the biodiversity of rice agroecosystems, including their flora, fauna and microorganisms.

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DISCUSSION

Dr. Soekisman was asked about the Presidential Decree to ban herbicides. He explained that the decree to ban herbicides was not intended for rice but for plantation crops such as oilpalm and rubber, for which herbicide use is increasing. There was also discussion about the use of *Salvinia* in paddy fields to control other weeds. Dr. Baki commented that in Malaysia, as in Indonesia, it is difficult to find people to collect and distribute *Salvinia*. Dr. Waterhouse noted that according to the data given, *Azolla* had increased production more than the *Salvinia*, and suggested that it might be better to eliminate *Salvinia molesta* as a weed and concentrate on *Azolla*. He pointed out that *Salvinia* seems to have been introduced to the Philippines from Australia by Filipino farmers, who had seen it in Queensland and had thought it to be a very robust type of *Azolla*. Dr. Soekisman commented that *Azolla* is seen as a good green manure by farmers in Vietnam. Dr. Moody pointed out that when *Salvinia* was introduced into the Philippines, an insect had been introduced to control it and had eventually been successful. However, there had been considerable reluctance among both government officials and scientists to import the insect, because of worries about its effect on non-target species. He suggested that this resistance to importing species for biological control is a basic problem in the classical approach which needs to be addressed. Dr. Baki commented on the difficulty of getting funds for coordinated biocontrol activity, and emphasized the value of regional cooperation and sharing of information.