INTEGRATED MANAGEMENT OF PADDY WEEDS IN THAILAND

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ABSTRACT

Paddy weed problems in Thailand vary according to the method of cultivation, including planting. Upland rice, dry-seeded rice, deepwater rice, wet-seeded and transplanted rice all have their characteristic weed associations. Transplanted rice shows the least weed infestation, while upland rice has the worst. Dry-seeded rice and wet-seeded rice are in an intermediate position. Weed control is needed for all types of rice cultivation in order to increase rice production. Integrated weed control includes proper methods of planting, pure rice seed, appropriate cultivars, good land preparation and water management, crop rotation, appropriate timing of planting, and a combination of hand weeding and chemical control. The economics of weed control are also important in Thailand. No one single method of weed control method can succeed: a combination of different methods is needed to give good weed control at minimum cost.

INTRODUCTION

Weeds are a major problem in rice production in Thailand. The level of infestation varies according to the method of planting (transplanting, direct seeding with dry or wet seed), locality etc. Losses due to weeds have been estimated at 37-79% (Menakanit 1991). Considerable progress in weed control has been achieved with various measures such as ensuring the purity of rice seed, proper selection of cultivar and seeding rate, proper planting method, good land preparation and water management, hand weeding and chemical weed control, and crop rotation (De Datta 1981), used together in a system of integrated weed management. Further development of this technology is continuing, the aim being more effective weed management that is better suited to the needs of Thai farmers.

METHOD OF PLANTING RICE

In Thailand, there are several types of rice cultivation, such as upland rice, dry-seeded rice, deepwater rice, transplanted rice, and wet-seeded rice or pre-germinated direct-seeded rice. The level of weed infestation varies with different methods of planting. Upland rice has the worst weed infestation and transplanted rice has the least, with dry- seeded rice and wet-seeded rice in between (Kittipong 1983). Partly for this reason, transplanting of rice was more common than other methods of planting in the period 1985-1989 (Anon 1991) (Table 1).

Methods of planting have been developed to minimize weed infestation. This is easily seen in the case of upland rice. In newly deforested areas there are practically no weeds during the first year, but during the second and third years heavy weed infestation occurs. There are no barriers to the spread of weeds from adjacent cleared areas, and the full sunlight on the exposed soil induces the germination of weed seeds. The upland farmer solves his weed problems by moving on to a new place every few years. Dry-seeded rice also has serious weed infestation, so transplanting was introduced to minimize weed problems. Although transplanting does reduce weeds, it involves high production costs in

Key words: Paddy weeds, method of control, integrated control, economic, Thailand

Table 1. Methods of rice planting used in Thailand, 1985-1989

Season	Planted area (million ha)			
	1985/86	1986/87	1987/88	1988/89
Wet season				
Dry-seeded rice	1.55	1.62	2.08	1.47
Transplanted rice	8.15	8.05	6.74	7.57
Wet-seeded rice	0.62	0.60	0.65	0.81
Dry season	0.65	0.58	0.72	0.91

Source: Department of Agricultural Extension, 1991

terms of nursery beds for seedlings, and the labor cost of gathering seedlings by hand and transplanting them. Wet-seeded rice or pre-germinated direct-seeded rice has been developed in order to reduce costs (Kanchanomai 1981). Direct-seeded rice does have weed problems, whether wet or dry seed is used, but these can be minimized by adopting recommended technology. After direct seeding has been used for a few years, it is recommended that farmers change temporarily to transplanting, which is particularly effective in controlling *Echinochloa crus-galli* and *Leptochloa chinensis* in the central plain of Thailand (Vongsaroj 1987).

PURITY OF RICE SEEDS

Contamination of rice seed with weed seeds promotes weed growth. This is particularly likely when weed seeds are the same size as rice, as in the case of wild rice, or when seeds are difficult to separate out, as in the case of *Echinochloa crus-galli* (Vongsaroj 1987). Introduction of the seed of new weed species into paddy fields can follow the importation of used tractors and other equipment such as mobile threshers or combine harvesters from abroad (Mayudee, personal communication). Raising flocks of ducks in paddy fields is another way in which weeds are dispersed, as has been the case with *Echinochjoa crus-galli* in Samut Songkram province in western Thailand. Irrigation is another cause of weed dispersal. *Leptochloa chinensis* is often found growing on the edge of irrigation canals, into which the seeds fall to be carried by irrigation water into paddy fields.

SELECTION OF RICE CULTIVARS

There are 53 recommended rice cultivars used in Thailand, 27 of which are native varieties and 26 of which are hybrid types (Boonduang and Autchin 1991). These have different abilities to compete with weeds. Native types, especially those with droopy leaves and tall stems, tend to compete with weeds more successfully than the hybrids (Vongsaroj *et al.* 1976; Vongsaroj *et al.* 1977). RD 5 is a hybrid but is as tall as the native cultivars, and competes better with weeds than shorter hybrids (Vongsaroj *et al.* 1977) (Table 2). Replacement of the traditional tall rice cultivars by modern short-statured ones has increased problems of annual grass weeds in tropical Asia (De Datta 1981).

LAND PREPARATION

Land preparation is the first step in growing rice. In the past, plowing was carried out using draft animals, and was done when the soil was saturated and the majority of weeds had germinated. The weed seedlings were killed when ploughing uprooted them and covered them in soil. Now that machines are being used, plowing can be carried out under dry conditions. Newly shed weed seeds lying on the soil surface are buried deep in the soil, while buried seeds from the previous season are brought up to the surface to germinate. This causes severe infestation, especially in upland rice and dry-seeded rice. Soil should be harrowed after the first plowing, when weeds have reached the seedling stage. This will kill the majority of *Echinochloa colona* seeds, for example, since these germinate at 0-1.5 cm soil depth

Table 2. Dry weight of weeds found 50 days after transplanting of various cultivars

Cultivar	Height (cm)	Dry weight (g/sq.m)		
		Bangkhen (1976)	Bangkhen (1977)	Rungsit (1977)
Hybrid				
RD 1	115	34.43	39.46	36.54
RD 3	100	35.67	32.34	35.22
RD 5	146	12.37	21.23	33.26
RD 7	108	37.61	19.64	30.24
RD 9	110	30.29	14.23	27.54
Native				
Khaodokmali	138	19.01	13.65	18.64
Puangnak 16	139	18.07	16.42	26.32
Nangmol S 4	140	10.06	12.39	14.21
Leungpratew 123	150	12.28	14.56	16.23
Kaokaew	140	16.63	17.23	16.45
L.S.D. (0.05)		6.05	4.32	7.24

Source: Vongsaroj *et al.* 1976, Vongsaroj *et al.* 1977

Table 3. Germination percentage of *Echinochloa colona* (L.) Link at various depths below the soil surface under field conditions

Depth of seeds (cm)	Site	
	Phukaotong	Bangban
0 - 0.50	31	32
0.6 - 1.00	27	28
1.10 - 1.50	26	25
1.60 - 2.00	7	7
2.10 - 2.50	3	4
2.60 - 3.00	2	1
3.10 - 3.50	3	2
3.60 - 4.00	1	1

Source: Vongsaroj and Notaya 1991

(Vongsaroj and Notaya 1991) (Table 3). Yingviwatanapong (1986) found that plowing paddy fields with a three-disc plow to a depth of 3.0-12.5 cm reduced the occurrence of *Eleocharis dulcis* by 49.32% in deepwater rice. In the case of heavy infestation of wild rice in Prachin Buri province in eastern Thailand in 1974, burning the rice straw after harvest gave good control (Vongsaroj 1976). Control methods must lower the viability of weed seeds, or alternatively stimulate germination so that control can easily be achieved (Vongsaroj 1976). Puckridge *et al.* (1988) found that broadcasting pre-germinated rice seeds onto puddled soil reduced the wild rice population because the germination of wild rice seeds was inhibited in saturated soil. For wet-seeded rice, a single plowing followed by puddling and leveling of the soil surface minimized weeds because the water level over the whole field could be kept at a specific depth unsuited to weed germination (Vongsaroj *et al.* 1987).

TIME OF PLANTING

Most rice cultivars can be grown throughout the year in Thailand. Weed infestation during the wet season consists of different species associations compared to the dry season. For example, *Echinochloa crus-galli* is most common during the dry season, *Sphenoclea zeylanica* in the wet season. A high percentage of weeds germinate in the wet season, and only *Eclipta alba* germinates in the dry season, between February and June (Vongsaroj *et al.* 1973) (Table 4). Sowing rice in June instead of May reduces infestation by wild rice (Puckridge *et al.*

1988).

RATE OF PLANTING

Planting rate has an important role in weed control. Thai farmers normally apply seed in very dense stands to help the rice compete with weeds. In dry-seeded rice, a high seed rate of 125-162.50 kg/ha was found very effective in suppressing weeds (Supatanakul *et al.* 1977) (Table 5). For wet-seeded rice, a rate of 100 kg/ha was found to be suitable (Kanchanomai 1981). In transplanted rice, spacing hills 25x25 cm with 1,3,6,9,12 or 15 plants/hill gave a dry weight of *Marsilea crenata* of 197.60, 188.40, 108.00, 111.20, 120.80 or 114.80 g/sq. m, respectively (Supatanakul and Khomvilai 1986). The yield was highest at 1 and 3 plants per hill, probably because the number of filled grains/panicle was also the highest. Transplanting at a spacing of 8x8 cm with one plant per hill minimized infestation by *Chara zeylanica* in the northeast of Thailand (Vongsaroj *et al.* 1977).

WATER MANAGEMENT

Water is widely recognized as an effective means of suppressing weeds, because many weeds such as *Cyperus difformis* cannot germinate under

Table 4. Weed seed germination (%) during the year

Weed species	Germination %											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Aeshynomene aspera	53	44	46	39	46	18	46	63	57	45	51	40
Melochia corchorifolia	1	1	1	1	2	13	2	1	1	1	0	0
Eclipta alba	9	28	36	37	50	22	9	1	0	0	1	3
Jussiaea linifolia	8	35	80	76	73	27	74	74	59	71	57	0
Pentapetes phoenicia	6	0	0	8	4	3	3	4	1	3	1	0
Sesbania roxburghii	6	5	5	9	10	18	12	9	7	12	5	4
Echinochloa colona	11	32	24	16	44	31	18	9	9	1	0	7
Leptochloa chinensis	7	12	18	18	43	12	12	9	1	0	0	0

Source: Vongsaroj *et al.* 1973

Table 5. Dry weight of weeds and yield of rice at various rates of seeding

Rate of seeding (kg/ha)	Dry weight of weeds (g/sq.m)		Yield of rice (mt/ha)	
	Pimai	Ratchaburi	Pimai	Ratchaburi
50.00	48.25 a	85.00 a	1.17 a	1.02 a
62.50	39.75 a	84.25 a	1.17 a	0.98 a
75.00	39.25 a	70.25 a	1.23 a	1.06 a
87.50	35.00 a	65.75 ab	1.28 a	1.19 a
100.00	25.50 ab	63.25 ab	1.43 ab	1.32 a
112.50	26.00 ab	65.50 ab	1.62 b	1.28 a
125.00	20.00 b	50.75 b	1.56 b	1.39 ab
137.50	20.00 b	39.20 b	1.65 b	1.54 b
150.00	17.50 b	40.00 b	1.62 b	1.68 b
162.50	15.00 b	35.75 b	1.63 b	1.68 b

Means within the columns followed by the same letter are not significantly different at a 5% level by Duncan's multiple range test.

Source: Supatanakul *et al.* 1977

flooded conditions. A water depth in newly transplanted rice of 5-10 cm prevents germination of some species of grasses, broadleaf weeds and sedges (Vongsaroj 1987). Dry seeded rice is sown under dry conditions, but when the field is then flooded, certain weeds at some stages of growth are killed. Nakkaew (1991) found that 100% of *Echinochloa colona* 10 days after emergence was killed when the field was submerged for two weeks at a depth of 30,50 and also 70 cm. 100% of *E. colona* at 20 days after emergence was killed at a water depth of 50 or 70 cm, and at 30 or 40 days after emergence with a water depth of 70 cm. (Nakkaew 1991) (Fig. 1). Thus, if dry seeding is used, farmers need a good stand of rice before they flood the field, so that some weeds will be suppressed by water. Certain weeds still germinate when land is flooded, such as *Monochoria vaginalis*, but rice yields are higher if the field is flooded to a depth of 3-12 cm (Vongsaroj *et al.* 1990) (Table 6). Farmers can use water to minimize weed problems in wet seeded rice by draining out the water 10 days after seeding. The population of *Echinochloa crus-galli* will then be reduced under dry conditions, but replaced by *Echinochloa colona* and *Leptochloa chinensis* which are then killed when the field is flooded again. In irrigated areas, farmers grow wet-seeded rice as an upland crop to induce upland weeds to germinate. When the rice crop reaches the seedling stage, the land is gradually flooded to a depth of 10-20 cm. This technique gives good weed control (Vongsaroj 1987).

HAND WEEDING

Hand weeding is the primary direct weed control method used in Thailand, and is critical at the early stages of rice growth. However, it is labor intensive, and labor costs are rising with the alternative demands for labor both on and off the farm. Thai farmers do hand-weeding whenever they are free from other work. If weeding is delayed until the initiation of panicle primordia, the rice yield will be greatly reduced (Table 6). It is recommended that hand weeding of transplanted rice is carried out for the first time 30-50 days after transplanting. It should be carried out 30-50 days after seeding in the case of upland rice, dry-seeded rice and deepwater rice (Anon 1988).

CHEMICAL CONTROL

Herbicides offer the most practical, effective and economical way of reducing weed competition, crop losses and production losses in rice (De Datta 1981). Many herbicides are recommended by

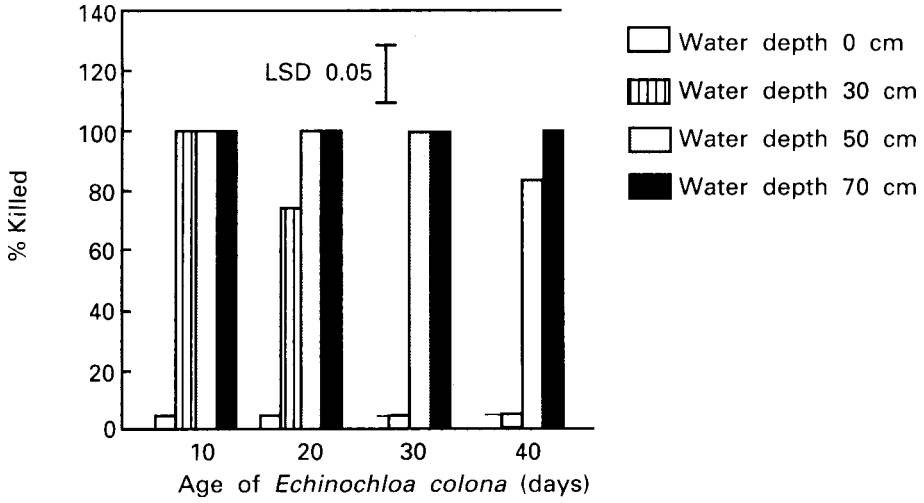

Fig. 1. Percentage of *Echinochloa colona* killed in rice field by flooding

Table 6. Number of panicles and filled grains of rice at various water depths, with and without *Monochoria* infestation.

Depth of water at soil surface (cm)	No. of panicles		Filled grains (g)	
	Without *Monochoria*	With *Monochoria*	Without *Monochoria*	With *Monochoria*
-3	50.33 ab	42.00 a	107.31 b	103.94 b
0	50.00 ab	41.00 a	148.80 a	105.29 b
+3	52.67 ab	40.33 a	148.17 a	112.96 a
+6	55.67 a	42.33 a	154.55 a	121.44 a
+9	48.37 ab	29.00 b	149.37 a	116.32 a
+12	47.67 b	24.67 b	145.55 a	110.19 a

Means within the columns followed by the same letter are not significantly different at 5% level by Duncan's multiple range test

Source: Vongsaroj *et al.* 1990

the Thai Department of Agriculture (Anon 1988) (Table 8), but all are effective only on particular types of weed and must be applied at specific times (Vongsaroj 1987). 2,4-D and butachlor are the most popular chemical herbicides, as reflected in the quantities imported (Anon 1991) (Table 7). For upland rice, bifenox, pendimethalin, oxadiazon and oxyfluorfen are used after seeding, and 2,4-D, propanil, 2,4-D/propanil, propanil/molinate and propanil/thiobencarb are used when weeds reach the 2-4 leaf stage after rice emergence (Vongsaroj 1987). In dry-seeded rice, wet-seeded rice and deepwater rice, bifenox and oxadiazon are used after the rice seed has been sown, and 2,4-D/propanil, propanil/molinate and propanil/thiobencarb when weeds reach the 2-3 leaf stage (Vongsaroj 1987). For transplanted rice, the most common herbicides used are thiobencarb, bifenox, butachlor, CNP, oxadiazon, piperophos/dimethametryn and bensulfuron methyl, applied 5-8 days after transplanting (Table 8). The same chemicals can be used in wet-seeded rice 8-10 days after seeding. The effectiveness of herbicides depends on a number of other factors beside timing of applications, such as land preparation in the case of upland rice and dry seeded rice, and the water level in transplanted rice and wet seeded rice. The type of sprayer is also important. A comparison of stirrup pump, knapsack sprayer, mist blower, micron herbi, microfit herbi and micro twin was made, using 2,4-D/propanil applied at a rate of 2 kg/ha (Table 9). The mist blower was the most toxic to rice. Weed control in terms of dry weight of dead weeds was 5.5, 7.0 and 14.25 g/sq.m from knapsack, stirrup and mist blower, respectively, while the untreated check yielded 55.00 g/sq. m (Lekham 1990) (Table 9).

CROP ROTATION

Continuous rice monoculture leads to an increase in the populations of weeds adapted to wet growing conditions. Breaking the wet land cycle with a dryland crop helps prevent the build-up of particular weed species (Ahmed and Moody 1982). A study was made of the effect on weed growth of growing rice and soybean in rotation. Oxadiazon and oxyfluorfen were used to control weeds in the rice crop (Vongsaroj and Price 1987) (Table 10 Table 11). After the rice had been harvested, soybean was immediately planted in the rice straw without any tillage. Herbicides applied to the rice had a residual effect on the soybean crop, reducing the incidence of broadleaf weeds and their seeds (Table 11 Table 13), giving a higher soybean yield than the untreated check (Vongsaroj and Price 1987) (Table 12). The same results were found in 1989, 1990 and 1991 when soybean was grown after rice treated with thiobencarb and piperophos/dimethametryn. There was a particularly marked increase in soybean yield in the third year (Vongsaroj *et al*. 1991) (Table 14). Crop rotation is being successfully practiced in the north of Thailand, especially in Chiang Mai province, growing soybean after rice.

CONCLUSION

No single method of weed control in paddy fields is fully effective. The integrated use of several methods is needed. Thai farmers generally use integrated weed management, by making use of good land preparation, suitable rates and timing of

Table 7. Importation of rice herbicides (mt) into Thailand in 1990

Herbicide		1982	1983	1984	1985	1986	1987	1988	1989
2,4-D (Na salt)	Ai	498	1743	1657	1403	744	1150	858	1207
	F	575	2050	1949	1741	875	1353	1353	2601
2,4-D (Premix)	Ai	–	–	–	–	–	–	–	18
	F	–	–	–	–	–	–	–	26
2,4-D (1BE)	Ai	414	71	137	169	79	123	616	26
	F	575	98	191	246	118	179	815	36
2,4-D (BE)	Ai	–	–	–	–	–	–	–	256
	F	–	–	–	–	–	–	–	261
Bensulfuron	Ai	–	–	–	–	–	–	–	11
	F	–	–	–	–	–	–	–	18
Butachlor	Ai	24	57	175	199	115	120	192	190
	F	489	1037	3357	3550	2976	1976	6194	3243
CNP	Ai	–	–	–	–	–	–	–	1
	F	–	–	–	–	–	–	–	1
EPTC	Ai	–	–	–	–	–	–	–	57
	F	–	–	–	–	–	–	–	52
Fenoxaprop	Ai	–	–	–	–	–	–	–	5
- ethyl	F	–	–	–	–	–	–	–	68
Fluroxypyr	Ai	–	–	–	–	–	–	–	2
	F	–	–	–	–	–	–	–	8
Metsulfuron	Ai	–	–	–	–	–	–	–	1
- methyl	F	–	–	–	–	–	–	–	4
Molinate +	Ai	–	–	–	–	–	–	–	128
propanil	F	–	–	–	–	–	–	–	193
Oxadiazon	Ai	–	–	–	–	–	–	–	27
	F	–	–	–	–	–	–	–	29
Propanil	Ai	–	–	–	–	–	–	–	2845
	F	–	–	–	–	–	–	–	10,137
Piperophos +	Ai	–	–	–	–	–	–	–	16
dimethametryn	F	–	–	–	–	–	–	–	16
Pretilachlor	Ai	–	–	–	14	32	38	51	84
	F	–	–	–	46	106	125	170	279
Propanil	Ai	15	15	15	24	28	82	94	101
	F	41	42	70	66	79	225	262	172
Propaniol +	Ai	–	–	–	–	–	–	–	1
2,4-D	F	–	–	–	–	–	–	–	4
Quinclorac	Ai	–	–	–	–	–	–	–	4
	F	–	–	–	–	–	–	–	2
Thiobencarb	Ai	–	–	–	–	–	–	–	216
	F	–	–	–	–	–	–	–	233

Ai = Active ingredient, F = formulation product, P = pendimethalin

Source: Department of Agriculture, Thailand, 1990

planting, well-timed hand weeding, effective water management, plus chemical herbicides if necessary. Crop rotation is now being introduced to farmers outside Chiang Mai province. Besides the effectiveness of weed control, farmers must consider the profits from growing rice. Maximum profits can be obtained by achieving an adequate level of weed control at minimum cost. A study has been made of the profits from herbicide usage since 1976. Supatanakul *et al.* (1976) found that thiobencarb, oxadiazon and hand weeding gave higher profits than bifenox, 2,4-D, propanil or 2,4-D + propanil in dry seeded rice. In wet seeded rice, 2,4-D gave a higher profit than thiobencarb, butachlor, oxadiazon or hand weeding (Sangtong *et al.* 1976). Vongsaroj and Price (1991) found in rice-soybean rotations in 1986 that oxyfluorfen gave the highest yield and, despite its fairly high price, produced the highest

Table 8. Herbicides recommended for use in paddy fields

Upland rice and dry-seeded rice (deepwater rice)	Transplanted rice	Wet-seeded rice
Oxadiazon	Butachlor	Thiobencarb
Oxadiazon + 2,4-D	Oxadiazon	Butachlor
Oxadiazon + butachlor	Bifenox	Oxadiazon
Butachlor + bifenox	Thiobencarb	Pretilachlor
2,4-D	Pretilachlor	Piperophos/2,4-D
Propanil	Piperophos/2,4-D	Bifenox
Propanil + 2,4-D	Piperophos/dimethametryn	2,4-D
Propanil/thiobencarb	Bensulfuron methyl	Propanil
Propanil/molinate	2,4-D	Propanil + 2,4-D
	Propanil	Pronapil/thiobencarb
	Propanil + 2,4-D	Propanil/molinate
	Propanil/thiobencarb	
	Piperophos/dimethametryn	
	Oxadiazon + 2,4-D	
	Butachlor + 2,4-D	
	Thiobencarb + bifenox	
	Thiobencarb + butachlor	
	Bifenox + butachlor	
	Propanil/molinate	

Source: Botany and Weed Science Division, Department of Agriculture, Thailand, 1988

Table 9. Efficiency of 2,4-D/propanil applied with various types of sprayer

Type of sprayer	Toxicity[1/] to rice	Dry weight of weeds (g/sq.m)	Yield of rice (mt/ha)
Stirrup	2.1	7.00	4.07
Knapsack	2.3	5.50	3.94
Mist blower	3.2	14.25	3.99
Micron herbi	2.7	22.75	4.00
Microfit herbi	2.8	20.25	3.89
Microfit twin	3.0	12.00	4.01
Untreated check	0.0	55.00	3.09
L.S.D. (0.05)		4.21	0.56

Toxicity to rice: 1 = slight toxicity; 5 = rice completely killed

Source: Lekham *et al.* 1990

revenue (Table 15). 2,4-D gave a lower yield than either oxadiazon and oxyfluorfen but its lower price gave a better gross margin than oxadiazon (Table 15). In 1987, the price of rice increased from 3000 baht/mt to 3500 baht/mt. Oxyfluorfen again gave the highest yield and gross margin, followed by oxadiazon and 2,4-D, in that order.

In the future, integrated management in Thailand will be emphasized at every step of rice production, from seeding to harvesting. Biological control of weeds will be an important topic of research. A new approach will be the use of toxic allelopathic substances from noxious weeds, to control weeds in paddy fields. Improved methods of

Table 10. Dry weight of weeds in rice (g/0.5 sq.m), 50 days after seeding

Treatment	Grasses	Broadleaf weeds	Sedges	Ferns
2,4-D	39.09	0.53	1.63	5.33
Oxadiazon	0.00	0.25	0.61	0.02
Oxyfluorfen	11.26	2.91	16.16	1.08
Untreated check	33.10	5.29	40.08	2.64
L.S.D. (0.05)	6.41	0.77	12.65	1.26

Source: Vongsaroj and Price 1987

Table 11. Major weed species found in untreated fields with rice/soybean rotation

Weeds in rice	
Grasses	*Echinochloa crus-galli* (L.) Beauv.
	Leptochloa chinensis (L.) Nees
Broadleaf weeds	*Spenoclea zeylanica* Gaertn.
	Monochoria vaginalis (Burm.f.) Presl
Sedges	*Cyperus difformis* L.
	Scirpus juncoides Roxb.
Ferns	*Marsilea crenata* Presl
Weeds in soybean	
Grasses	Volunteer rice
	Echinochloa colona (L.) Link
	Echinochloa crus-galli (L.) Beauv.
	Eragrostis interupta (Lam.) Doell.
	Leptochloa chinensis (L.) Nees
Broadleaf weeds	*Bergia ammaniodes* Roxb.
	Jussiaea linifolia Vahl
	Heliotropium indicum L.
	Sphaerantus africanus L.
Sedges	*Cyperus pulcherrimus* Willd. ex Kunth
Ferns	*Marsilia crenata* Presl

Source: Vongsaroj and Price 1987

Table 12. Yield of soybean (mt/ha) in response to herbicides applied to the preceding rice crop and to the current soybean crop

Soybean treatment	Rice treatment				Mean
	2,4-D	Oxadiazon	Oxyfluorfen	Untreated check	
Fluazifop-butyl	911	1134	1148	949	1011
Fomesafen	908	929	904	784	861
Fluazifop + formesafen	1016	1246	1256	1186	1157
Hand weeding	1053	1174	1217	1186	1157
Untreated check	718	884	848	591	760
L.S.D. (0.05)	For soybean herbicide (SH); mean = 54.34				
	For SH x rice herbicide, mean =108.69				

Source: Vongsaroj and Price 1987

Table 13. Dry weight of weeds in soybean in response to herbicides applied to the preceding rice crop, and to the soybean crop 55 days after seeding

Treatment	Dry weight of weeds (g/sq.m)				
	Grasses	Broadleaf weeds	Sedges	Ferns	Total
2,4-D (on rice)					
Fluazifoy-butyl	24.50	7.31	9.53	1.03	42.37
Fomesafen	58.38	3.19	2.26	1.54	65.37
Fluazifop + formesafen	17.44	3.55	1.23	0.87	23.09
Hand weeding	2.48	0.06	0.08	0.54	3.16
Untreated check	79.35	6.74	3.96	0.82	90.87
Oxadiazon (on rice)					
Fluazifop-butyl	9.80	3.28	0.00	0.53	13.16
Fomesafen	33.93	1.18	0.39	0.86	36.36
Fluazifop + formesafen	15.61	0.55	0	1.53	17.69
Hand weeding	2.26	0.02	0	0.52	2.80
Untreated check	75.85	4.05	0	1.50	81.40
Oxyfluorfen (on rice)					
Fluazifop-butyl	5.91	9.91	0.27	0.59	16.69
Fomesafen	39.86	3.57	0.05	0.55	44.07
Fluazifop + formesafen	13.23	0.33	0.03	0.63	14.22
Hand weeding	2.01	0.07	0.06	0.24	2.38
Untreated check	44.11	8.10	0.37	1.19	53.77
Untreated check (on rice)					
Fluazifop-butyl	16.47	11.41	8.18	1.01	37.07
Fomesafen	63.24	3.81	0.69	1.10	68.15
Fluazifop + formesafen	15.87	4.47	0.17	0.82	21.33
Hand weeding	6.35	0.18	0	0.59	7.12
Untreated check	62.37	15.73	5.67	1.06	84.83
L.S.D. (0.05)	9.20	2.11	4.81	0.37	

Source: Vongsaroj and Price 1987

planting will also be developed. The ideal method should be an integration of various methods of planting, beginning with sowing of upland or dry-seeded rice, then flooding it when it reaches the seeding stage, as with transplanted rice or wet-seeded rice.

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Table 14. Yield of soybean grown after rice from 1989-1991

Rice Treatment	Yield of soybean (mt/ha)					
	1989		1990		1991	
	Untreated check	Hand weeding	Untreated check	Hand weeding	Untreated check	Hand weeding
Thiobencarb	0.78 b	0.92 b	1.22 a	1.23 b	1.06 a	1.22 a
Piperophos/ Dimethametryn	1.16 a	1.12 a	1.35 a	1.27 b	1.20 a	1.19 a
Untreated check	0.56 c	0.93 b	0.40 c	1.34 a	0.86 b	1.14 a

Means whithin the columns followed by the same letter are not significantly different at 5% by Duncan's multiple range test.

Source: Vongsaroj *et al.* 1991

Table 15. Budget of weed control treatment for rice using herbicides, 1986 and 1987

Unit: US$

	2,4-D 0.75 kg/ha	Oxadiazon 0.75 kg/ha	Oxyfluorfen 0.20 kg/ha	Untreated check
1986				
Revenue				
Gross yield (mt/ha)	3.85	3.94	4.01	2.80
Crop value ($/mt)	120	120	120	120
Total value ($)	462.36	472.80	481.20	336.00
Variable costs				
1. *Labor for herbicide applications*				
Man-days/ha (days)	0.50	0.50	0.50	–
Man-days ($)	3.04	3.04	3.04	–
Total cost ($)	1.52	1.52	1.52	–
2. Herbicide cost ($)	4.17	23.04	19.04	–
3. Other variable costs ($)	279.71	279.71	279.71	279.71
Gross margins	177.01	168.53	180.91	56.29
1987				
Revenue				
Gross yield (mt/ha)	3.93	4.18	4.25	2.61
Crop value ($)	140	140	140	140
Total revenue	550.20	585.20	595.00	365.40
Variable costs the same as 1986				
Gross margin	264.81	280.02	294.71	85.69

Source: Vongsaroj and Price 1991

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DISCUSSION

Dr. Prasan was asked to comment on the problem of red rice in eastern Thailand. He was asked how serious it is, and what countermeasures are being taken. Dr. Prasan replied that red rice is not only a serious problem in the east of the country, but also in the south, and that it is advancing northwards. He felt that red rice problems could be minimized by growing wet seeded rice, or by proper land preparation which creates puddled conditions in which red rice cannot germinate. In addition, planting rice relatively late in the season minimizes the population of red rice.

Dr. Smith was interested in the point made in Dr. Prasan's paper that hybrid rice varieties are much less competitive with weeds than traditional native ones. He asked about their relative use of nitrogen. Dr. Prasan answered that this had not been measured, but that in general native varieties are less responsive to N, and tend to lodge if they receive a high N rate. Since in any case, farmers in the northeast of Thailand cannot usually afford a high rate of fertilizer, he recommended that native varieties should be used. Under low rates of nitrogen fertilizer there is not much difference between native and hybrid varieties in terms of yield, and native varieties compete better with weeds.