

Weed Management in Deepwater Rice

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INTRODUCTION

Weeds are a major problem limiting the growth and yield of deepwater rice. The land is generally dry at seeding, become moist with the rain and is finally flooded. The variable land conditions from upland to lowland conditions and to flooded conditions (Figure 1) are suited to all types of weeds. Deepwater rice is thus infested with upland, lowland and aquatic weed types. The infestation levels tend to be higher than other types of rice cultivation. One single method of weed control is enough hence the integration of weed control methods and weed management is needed. Smith and Raynold (1966) defined weed management as a weed population management system that uses all suitable methods in a compatible manner to reduce weed populations and maintain them at a level below that causing economic injury. Plucknett, *et al.*, (1997) explained weed management a part of total vegetation management; namely use of various combinations of cultural, manual mechanical, chemical, biological

and ecological methods in attempt to create an environment that is detrimental to weeds and favorable to the crops. Weed management must conform to the needs of farmers ; which means being simple (easy to use), effective (reduces weeds and increases crop yield), deficient (involves

Table 1. *Ischaemum rugosum* population on yield of deepwater rice at Prachin Buri, Thailand. (Supatanakul and Khomvilai, 1985).

<i>Ischaemum</i> Population/sq.m	Yield of rice		Yield loss (%)
	kg/ha*	(%)	
0	1840.81	100.00	0.0
2	1704.31	92.58	7.42
4	1525.38	82.86	17.14
8	1320.90	71.72	38.28
16	1251.31	67.98	32.02
32	1100.19	59.77	40.23
64	677.00	36.78	43.22

*Highly statistical significant

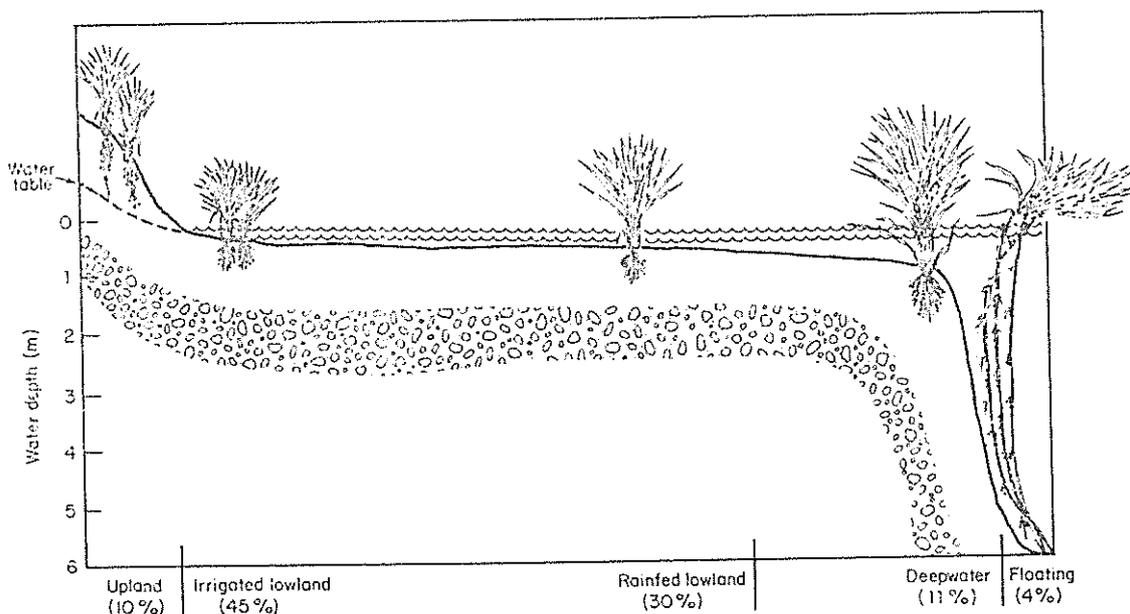


Figure 1. The world 's rice land classified by water regime and predominant rice type (De Datta, 1981)

(1) Botany and Weed Science Division. Department of Agriculture

Table 2. Weeds in deepwater rice (adapted from : WARDA, 1981; Kittipong, 1985, Vongsaraj, 1982, Nantasomsaran, *et al.*, 1983 and Saw Ler Wah, 1994).

Weed species	Type of weeds	Country presented	Time of Infestation
<i>Echinochloa colona</i> (L.) Link	G	Ba,Th	BF
<i>Echinochloa crus-galli</i> (L.) Beauv.	G	Ba,Th	BF
<i>Echinochloa stagnina</i> (Retz.) Beauv.	G	Th	AF
<i>Echinochloa picta</i> (Koen) Mich	G	Th	AF
<i>Echinochloa lelievrei</i> (Chevel.) Berhurt	G	Ba,Th	BF, AF
<i>Ischaemum rugosum</i> Salisb.	G	Th	BF, AF
<i>I. barbatum</i> Retz.	G	Th	BF, AF
<i>Oryza rufipogon</i> Griff.	G	Mal	BF, AF
<i>Oryza bathii</i> A. Chev.	G	Mal	BF, AF
<i>Oryza glaberrima</i> Steud	G	Mal	BF, AF
<i>Oryza longistaminata</i> Chev.	G	Mal	BF, AF
<i>Oryza stapffi</i> Roshev.	G	BA	BF, AF
<i>Oryza sativa</i> var, Fatva Prain	G	Th	BF, AF
<i>Setaria geniculata</i> (Lank.) P. Beauv.	G	Th	BF, AF
<i>Paspalum cambogiense</i> Balansa	G	Th	BF, AF
<i>Leersia hexandra</i> Sw.	G	BA, Th	BF, AF
<i>Hymenache paeudointerrupta</i> (Muell)	G	Th	BF, AF
<i>Leptochloa chinensis</i> (L.) Nees	G	Th	BF, AF
<i>Panicum repens</i> Linn.	G	Th	BF
<i>Hygroryza aristata</i> (Reta.) Nees	G	BA	BF, AF
<i>Vossia cuspidata</i> (Roxb.) W. Grisff	G	BA	BF, AF
<i>Eleusine indica</i> (L.) Gaertn.	G	BA	BF
<i>Brachiaria</i> sp.	G	Mal	BF
<i>Paspalum scorbiculatum</i> L.	G	Mal	BF, AF
<i>Sacciolepis cymbiandra</i> Stapf.	G	Mal	BF
<i>Chamaeraphis gracilis</i> Hack	G	Ba	BF
<i>Aeshynomene sensitiva</i> Sw.	B		BF, AF
<i>Aeshynomene indica</i> L.	B		BF, AF
<i>Sesbania sesban</i> (L.) Merr.	B	Mal	BF, AF
<i>Achyranthes aspera</i> L.	B	Mal	BF
<i>Alternanthera sessilis</i> (L.) R. Br. ex Roth	B	Mal	BF, AF
<i>Melochia corchorifolia</i> L.	B	Mal, Th	BF
<i>Corchorus fascicularis</i> Lam	B	Mal	BF
<i>Ipomoea aqatica</i> Forsk	B	Ba, Mal, Th	BF, AF
<i>Ipomoea gracilis</i> R. Br.	D	Th	BF
<i>Nepuntia oleracea</i> Lour	B	Mal	AF
<i>Nymphaea lotus</i> L.	B	Mal	AF
<i>Nymgea nouchali</i> Burm. F.	B	Th	AF
<i>Nymphoides indica</i> (L.) Kuntze	B	Mal, Th	AF
<i>Cyperonia</i> sp.	B	Mal	AF
<i>Utricularia stellaria</i> L.	B	Mal	AF
<i>Utricularia aurea</i> Lour	B	Th	AF
<i>Borreria filifolia</i> (S & Th.) K. Schum	B	Mal	BF
<i>Polygonum mildbredii</i>	B	Mal	AF
<i>Eichhornia crassipes</i> (Mart.)	B	I, Ba	AF
<i>Nymphaea stellata</i> Willd.	B	I,	AF
<i>Nelumbo nucifera</i> Gaertn.	B	I,Th	AF
<i>Hydrilla verticillata</i> Presl	B	I,	AF
<i>Limnophylla heterophylla</i> Roxb	B	Th	AF
<i>Typha</i> sp.	B	I,Th	AF

Table 2. (continue)

Weed species	Type of weeds	Country presented	Time of Infestation
<i>Lemna</i> sp.	B	I,Th	AF
<i>Vallisneria</i> sp.	B	I,	AF
<i>Mariophyllum</i> sp.	B	Th	AF
<i>Potamogeton</i> sp.	B	I,	AF
<i>Pistia stratiotes</i> L.	B	I,Th	AF
<i>Heliotropium bracteotum</i> R. Br.	B	Th	BF
<i>Sesbania aculeata</i> Poir.	B	Ba	BF, AF
<i>Sesbania puludosa</i> Jacq.	B	Ba	BF, AF
<i>Monochia vaginalis</i> (Burm. f.) Presl	B	Ba, Th	AF
<i>Ottelia alismoides</i> (L.) Pers	B	Th	AF
<i>Najas gramineae</i> Del	B	Th	AF
<i>Ceratophyllum demersum</i> Lim	B	Th	AF
<i>Alisma plantago-aquatica</i> L.		My	AF
<i>Alternanthera philoxeroides</i> (Marl.)	B	My, Th	AF
<i>Cyanotis axillaris</i> (L.) D. Don	B	My, Th	BF, AF
<i>Pistia stratiotes</i> L.	B	Ba, My, Th	AF
<i>Pentapetes phoenicia</i> L.	B	My, Th, BF, AF	
<i>Cyperus rotundus</i> L.	S	I, Ba, Th, BF	
<i>Cyperus iria</i> L.	S	I,Ba, Th	BF
<i>Cyperus difformis</i> L.	S	I, Ba, Th	BF, AF
<i>Eleocharis dulcis</i> Burm. f. Henschel	S	I, Ba, Th	BF, AF
<i>Eleocharis plantaginea</i> (Retz.) Roem.	S	Mal	BF, AF
<i>Scirpus praelongatus</i> Poir	S	Mal	BF, AF
<i>Pycneus</i> sp.	S	Mal	AF
<i>Fimbristylis littoralis</i> Gaud	S	Th	BF
<i>Fimbristylis sracilenta</i> Hanoe	S	Th	BF
<i>Cyperus pulcherrimus</i> Willd. ex Kunth	S	Th	BF
<i>Salvinia</i> sp.	F	I, Th	AF
<i>Chara zeylanica</i> Kl. ex. Willd.	A	I, Th	AF

I = India Ba = Bangladesh Mal = Malaysia Th = Thailand
 My = Myanmar G = Grass B = Broadleaf S = Sedges
 F = Fern A = Algae BF = Before flooding
 AF = After flooding

less effort and time), robust (produces consistent results over time), flexible (adaptable to the entire farm) and motivating (feels good to use it without risk) (Kon, 1993). Prior to achievement of weed management, knowledge of weeds in deepwater rice and the methods of weed control are needed as basic information, as well as of their ecosystem, namely habitat and cultural practices in deepwater rice.

DEEPWATER RICE

Deepwater is mostly direct seeded under dry conditions for 1-3 months when it rains the land become moist and floods with maximum depths from 50 cm to 400 cm. Yields in Thailand averaged around 2.0 t/ha. The luxuriant growth of foliage is

partly nourished by silt and nutrients in flooded water. Farmers seldom apply fertilizer (Catling, 1992). The lengths of different periods depend on rainfall. In some area, the dry period is short because of the early start of rainy season. Farmers generally broadcast dry seeds, but transplanting with tall seedlings is done. Deepwater rice is growing in many countries namely India, Bangladesh, Thailand, Vietnam, Myanmar, Mali, Cambodia, Sri Lanka, Niger, Nigeria, Senegal, Gambia, Sierra Leone, Guinea, Mauritania (Vergara, 1985) (Catling, 1992).

WEEDS

Weeds in deepwater rice are classified as grass (G), broadleaf (B), sedge (S), fern (F), and

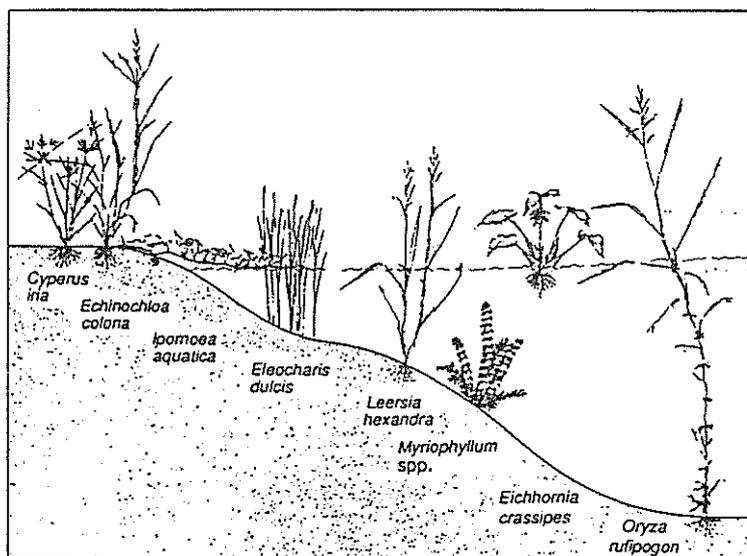


Figure 2. Some typical weeds of deepwater rice according to water depth (Catling, *et al.*, 1992)

algae (A) (Table 2) according to the morphology. They can be grouped by their habitat before and after flooding (De Datta, 1981). After rice seeds are sown under dry condition, grasses such as *Oryza rufipogon*, *Echinochloa colona*, *Ischaemum rugosum*, *Cynodon dactylon*, *Brachiaria reptans* are the most abundant. Sedges found in the period included *Cyperus rotundus*, *Eleocharis dulcis*, *Fimbristylis miliacea*. Common broadleaved weeds are *Pentapetes phoenicea*, *Melochia corchorifolia*, *Aeshynomene indica*, *Cyanotis axillaris*, *Sesbania*

sesban, *Ipomoea aquatica*. When the land become wet and flooded, weeds such as *Marsilea crenata*, *Chara zeylanica*, *Nymphaea nouchali* appear (Table 2). The weeds either complete their growth cycle before flooded conditions, such as *Echinochloa colona*, *Cynodon dactylon* are killed by rising water and *Cyperus* spp. are in marginal (Figure 2) for variable periods (Catling *et al.*, 1988). Tall grass like *Echinochloa stagnina*, *Leersia hexandra*, *Ischaemum rugosum*, *I. barbatum*, *Oryza rufipogon* elongate their stem to survive as exergence. Broadleaved weeds like

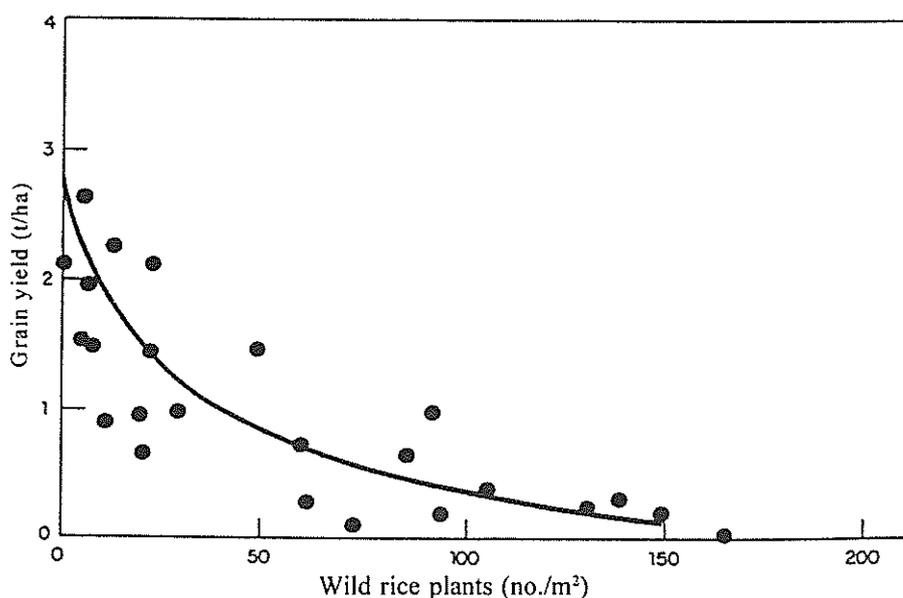


Figure 3. Relationship between wild rice, *O. rufipogon* population and grain yield of Leb Mue Nang 111 deepwater rice in Phitsanulok, Thailand, wet season 1984. Points show individual plots, curve fitted by eyes (Puckridge, *et al.*, 1988)

Table 3. Farmers reporting weed problems, and their weed control methods in provinces growing deepwater rice in Thailand (Niyomvit, 1984)

Province	Farmers interviewed (no.)	Farmers with weed problem (no.)	Methods of control (no.)		
			Chemical	Hand	Both
Pichit	21	21	15	-	5
Nakhon Sawan	25	23	17	4	1
Sing Buri	18	16	14	-	1
Lop Buri	17	16	10	-	2
Ang Thong	56	50	38	1	4
Ayuttahaya	147	140	127	-	1
Prachin Buri	23	16	7	4	-
Total (no.)	307	282	228	9	14
Percent	100	92	74	3	5

Cyanotis axillaris, *Melochia corchorifolia*, *Pentapetes phoenicea*, *Sesbania sesban*, *Monochoria vaginalis* and *Scirpus grossus* are adapted to rising water while *Ipomoea aquatica* a root creeping vine, sends out runners along the water surface and either produce seeds or under favorable conditions is perennial. Flooded fields are colonized by a complex of free floating plants, emergents and submerged aquatic plants. Some weeds are adapted to pH 4 and below include *Scirpus grossus*, *Eleocharis dulcis*, emergents and below include *Scirpus grossus*, *Eleocharis dulcis*, *Phragmites karka* and *Cyperus iria* (Grabial, *et al.*, 1986). Wild rice is the most difficult weed in deepwater rice causing a big yield losses (Figure 3). *Ischaemum rugosum* caused yield reductions to 92% when the population was 2/ plants/m² and 37% with 64 plants/m² (Supatanakul, *et al.*, 1985). In 7 provinces of Thailand where deepwater rice are growing, it was found that 282 of 307 farmers had weed problems (Niyomvit, 1984)(Table 3).

METHOD OF WEED CONTROL

1. Prevention

Weed damage can be reduced by growing deepwater using purified seeds/free from weed seeds, especially *Oryza rufipogon*. Wild rice normally has a similar size and shape seed with cultivated rice but sheds seed. To use new seed from a place where there is no wild rice should help minimize wild rice problems (Vongsaroj, 1976). High percentage of germination as well as a high vigor of seed is advantage for competition with

weeds. Another method of prevention is to have a longer period of fallow after harvesting of rice (Vongsaroj, 1976).

2. Land Preparation

Land preparation is a first step of growing rice. In the past, plowing was practiced by animal drawn plough and was done while the soil was wet, after the majority of weed had germinated. Weed seedlings were killed by turning over into the soil. Now tractors are available, and plowing can be done under dry conditions. Weed seeds on the soil surface are buried into the soil, while the previous season's seeds are brought up to surface for germination and cause severe infestation (Vongsaroj, 1976). Increasing the number of plowing can minimize weed problems by plowing at 2 weeks after heavy rain, letting new weed seedlings emerge, then second ploughing, wait until a new

Table 4. Various methods of wild rice control in deepwater rice at Wakema, Myanmar (Saw Ler Wah, 1993).

Treatments	Dry wt. of wild rice	Yield of rice (t/ha)
Two plowings + harrowing	0 a	2.37 a
One plowing + harrowing	0 a	2.11 a
Straw burning	0 a	2.24 a
Paraquat	0 a	1.68 a
Glyphosate	0 a	2.43 a
NA + oxadiazon	3.63 a	2.09 a
Untreated check	51.0 b	1.35 a
Hand weeding	0 a	22.3 a

Value followed by the same letters are not significantly different at 5% level by DMRT.

Table 5. Effect of cultural practice on number of wild rice, *Oryza rufipogon*, and deepwater rice stems, Phitsanulok, Thailand, 1982-86. (Puckridge *et al.*, 1988).

Time	Treatment	Rice stems (no./m)											
		1982		1983		1984		1985		1986			
		Wild rice	KND	Wild rice	KND	Wild rice	KND	Wild rice	KND	Wild rice	KND		
A	1 Broadcast onplowed soil	240 b	150 b	237 b	116 a	109 d	167 ab	61 bc	111 b	109 b	122 d		
	2 Rows at 50 cm, hoeing between rows	-	-	-	-	176 e	187 a	85	86 b	29 a	146 bcd		
	3 Rows at 25 cm, hoeing between rows	-	-	-	-	-	-	65 bc	99 b	23 a	38 cd		
B	4 Broadcast after plowing	117 a	211 a	77 a	86 ab	-	-	-	-	-	-		
	5 Broadcast after shallow tillage	-	-	84 a	57 b	39 c	107 bc	45 b	113 b	25 a	140 bcd		
	6 Rows at 50 cm, hoeing between rows	-	-	-	-	35 bc	154 ab	53 bc	91 b	19 a	181 abc		
	7 Rows at 25 cm, hoeing between rows	-	-	-	-	-	-	39 b	137 b	16 a	183 abc		
C	8 Broadcast after plowing	148 a	194 a	44 a	45 b	-	-	-	-	-	-		
	9 Broadcast after shallow tillage	-	-	64 a	71 b	-	-	-	-	-	-		
	10 Dry seed broadcast on soil puddled after rain	-	-	-	-	12 ab	71 c	1 a	18 b	26 a	198 ab		
	11 Pregerminated seed broadcast on puddled soil after rain	-	-	-	-	8 a	46 c	8 a	126 a	4 a	231 a		

KND = Khao Niew Dam, LMN 111 = Leb Mue Nahng 111. Dash (-) means not applicable.

In a column, means followed by a common letter do not significantly differ by Duncan's multiple range test at the 5% level

Table 6. Grain yield of LMN 111 with different treatments to control wild rice, Phitsanulok, Thailand, 1982-86. (Puckridge, *et al.*, 1988).

Time	Treatment	Grain yield (t/ha)				
		1982	1983	1984	1985	1986
A	1 Broadcast on plowed soil	0.11 b	0.36	0.46 b	0.57	0.37 d
	2 Rows at 50 cm hoeing between rows	-	-	1.01 ab	0.50	0.82 cd
	3 Rows at 25 cm hoeing between rows	-	-	-	0.41	0.53 d
B	4 Broadcast after plowing	0.69 a	0.55	-	-	-
	5 Broadcast after shallow tillage	-	0.36	1.26 a	0.69	0.49 d
	6 Rows at 50 cm hoeing between rows	-	-	1.63 a	0.76	1.56abc
	7 Rows at 25 cm hoeing between rows	-	-	-	0.66	1.08 bcd
C	8 Broadcast after plowing	0.87 a	0.64	-	-	-
	9 Broadcast after shallow tillage	-	0.61	-	-	-
	10 Dry seed broadcast on puddled soil	-	-	1.44 a	0	1.62 ab
	11 Pregerminated seed broadcast on puddled soil	-	-	1.64 a	0.63	2.24 a

weed seedlings come up, broadcast rice seeds and harrowing (Vongsaroj, 1976). It was found in Myanmar (Table 4) that two plowings and one plowing plus harrowing minimized wild rice population as well as straw burning (Saw Ler Wah, 1993). Puckridge, *et al.*, (1987) found that delayed tillage in 1986 reduced the number of wild rice plant by 50% but the number remaining still averaged over 100/m² (Table 5). The yield of rice for the third sowing was 7 times that of check (Table 7). In 1983, delayed second tillage markedly reduced the wild rice population to 35% or less of that treatment 1, although wild rice plants still numbered more than 40/m² (Table 5). In 1984 the wild rice plants was reduced by delayed tillage (Table 5), and yield was improved (Table 6). Puckridge, *et al.*, (1987) also found that sowing rice seeds on puddled soil gave the lowest counts of wild rice (Table 5) with rice yields of 1.4 - 1.6 t/ha (Table 6). Yingviwatanapong (1986) found that on plow with 3 discs at 3.0 - 12.5 cm depth reduced the *Eleocharis dulcis* by 49.32%. In case of heavy infestation of specific weed where other method are not effective, burning straw after harvest was proved to reduce wild rice population (Vongsaroj, 1976).

3. Method of planting

Deepwater rice is generally grown by direct

Table 7. Seed rate on weed and yield of rice at Prachin Buri, Thailand (Supatanakul and Khomvilai, 1985).

Seed rate (kg/ha)	Dry weight of weeds (g/sq.m)	Yield of rice (kg/ha)
62.5	27.01	731.25
93.25	17.59	1212.5
125.0	21.51	1205.63
156.25	16.15	1228.13
187.5	16.87	1108.75
218.25	12.72	1405.0
250.0	13.11	1259.30
281.25	7.53	1223.13

* Weeds are : *Ischaemum rugosum* Salisb., *Eleocharis dulcis* (Burm.f.) Henschel, *Aeshynomene aspera* (Linn.), *Ipomoea aquatica* Forsk., *Pentapetes phoenicea* (Linn.), *Melochia corchorifolia* (Linn.) and *Cyanotis axillaris* Roem and Schult.

seed methods. The weeds and crop germinate at the same time, and infestation of weeds is very severe. In some areas where the rain starts very early, the dry period is too short for broadcast rice seeds. When farmers broadcast pre-germinated rice seeds, fewer grass weeds can germinate, broadleaf and sedge need sometime germinate, so weeds will be too small to compete with rice. In Myanmar, transplanting of tall seedlings in popular to overcome wild rice problem (Vongsaroj, 1992).

4. Rice cultivar

There are many rice cultivars in deepwater rice, each variety has a different ability to compete with weeds. India is going to release new deepwater rice variety which has branching stems and has a large canopy to compete with weeds very well. Thakur (per. com. 1993).

5. Rice plant density

Weeds affect rice growth mostly at the seedling stage when stand density of rice is determined. A good stand can minimize weed problem. The farmers generally use a very high seed rate at 156.25 kg/ha in Thailand. Seeding of rice seed at 62.5, 156.25 and 781.25 kg/ha, less dry weight of weeds namely *Eleocharis dulcis*, *Aeshynomene aspera*, *Ipomoea aquatica*, *Pentapetes phoenicea*, *Melochia corchorifolia* and *Cynotis axillaris* were obtained (Figure 4) (Supatanakul, et al., 1985) and with *Ischamum rugosum* (Table 1, Figure 5). It was found with the same trend with the work of Yinviwatanapong (1986) that the rice plant number 44, 156, 625 and

2,500 had different population of *Eleocharis* (Figure 6), the higher seed rate, the smaller population of *Eleocharis* was obtained. High seed rate minimizes weed population but yield will be declined, if the seed rate is too high and it was evidence from Supatanakul et al., (1985) that even the dry weight of weeds declined, the yield of rice was lower when the seed rates were over 218.75 kg/ha (Table 7).

6. Time of planting

Delayed seeding after a heavy rain and certain time of dry period will reduce the weed problem. Delaying seeding of rice from May to June, reduced wild rice population (Table 5) (Puckridge, et al., 1988), (Vongsaroj, et al., 1973) studied germination of weed seeds namely *Aeshynomene asper*, *Melochia corchorifolia*, *Eclipta alba*, *Jussiaea linifolia*, *Pentapetes phoenicea*, *Sesbania roxburghii*, *Echinochloa colona* and *Leptochloa chinensis* under room temperature and found that most of the weed germinated early in wet season.

Table 8. Number and dry weight of weeds at 45 days after seeding of field crops. (Vongsaroj et al., 1993)

Treatments ^{1/}	Number of weeds ^{2/} /0.5 sq.m					Dry weight of weeds ^{2/} g/0.5 sq.m				
	1	2	3	4	5	1	2	3	4	5
S+M	4.5 a	7.8 ab	1.5 a	16.5 a	2.0 a	3.7 a	7.1 a	0.3 a	18.8 a	2.0 b
S+M+R										
(O DASF)S+M+R	5.0 a	20.3 a	1.3 a	10.3 ab	1.8 a	3.5 a	4.1 abc	0.3 a	9.2 bc	4.9 a
(20 DASF)	3.8 a	7.3 b	1.5 a	10.0 abc	1.8 a	3.3 a	2.6 bc	0.3 a	15.3 ab	1.5 b
S+M+oxa	0 b	6.8 ab	0.3 a	6.3 bcd	0 c	1.6 a	2.3 c	0.1 a	3.1 cd	0 b
S+M+R (0 DASF)										
+oxa	0 b	3.3 b	0.8 a	5.0 bcd	0 c	2.8 a	1.3 c	0.2 a	1.6 d	0 b
S+M+R (20 DASF)										
+oxa	0 b	4.5 b	0.8 a	3.8 bcd	0.5 bc	0.4 b	1.6 c	0.1 a	2.7 cd	0.7 b
S+M+fenoxaprop	0.5 b	14.0 ab	1.3 a	10.8 ab	0.5 bc	0.9 b	3.8 abc	0.9 a	14.1 ab	0.2 b
S+M+R (O DASF)										
+fenoxaprop	1.0 b	21.0 a	1.3 a	7.3 bcd	1.3 ab	0.7 b	6.4 ab	0.5 a	5.9 cd	1.4 b
S+M+R (20 DASF)										
+fenoxaprop	0 b	17.5 ab	1.0 a	5.0 bcd	1.8 a	0.8 b	3.6 abc	0.3 a	7.0 cd	1.3 b
S+M+HW	1.25 b	5.2 ab	1.0 a	2.8 d	0.5 bc	0.7 b	1.0 c	0.4 a	1.9 d	0.2 b
S+M+R (O DASF)										
+HW	1.56 b	3.5 a	2.0 a	3.0 d	0.5 bc	0.6 b	0.8 c	0.8 a	2.5 cd	0.7 b
S+M+R (20 DASF)										
+HW	1.50 b	5.0 ab	2.3 a	3.3 cd	0.5 bc	0.6 b	1.3 c	0.4 a	2.3 cd	0.7 b

^{1/} S = sesame, M = mungbean, R = rice and DASF = days after sesame and mungbean sowing

^{2/} 1. *Leptochloa chinensis* (L.) Nees 4. *Ipomoea aquatica* Forsk.

2. *Cyanotis axillaris* (L.) D. Don 5. *Ipomoea gracillis* R. Br.

3. *Euphorbia hirta* L.

DASF = Broadcasting rice seed, days after seeding field crops, oxa = oxadiazon

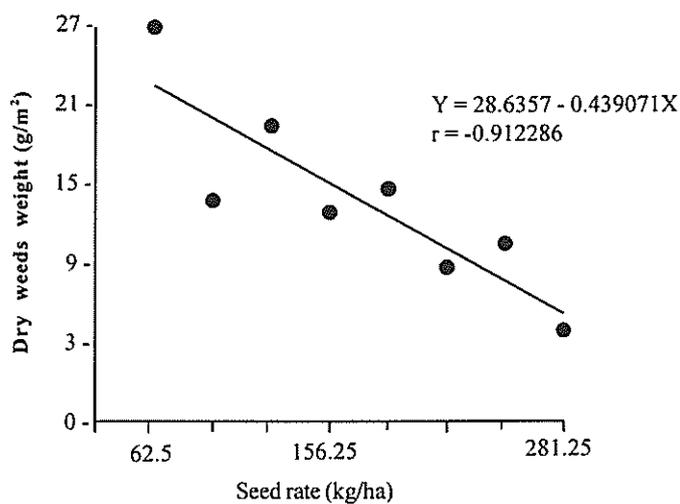


Figure 4. Correlation between dry weeds weight and rice seed rates (Supatanakul, *et al.* 1985).

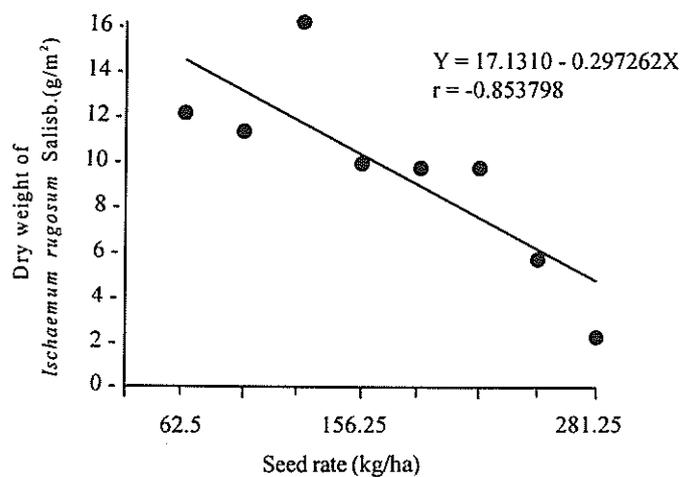


Figure 5. Correlation between dry weight of *Ischaemum rugosum* Salisb. and seed rates (Supatanakul and Khomvilai, 1985).

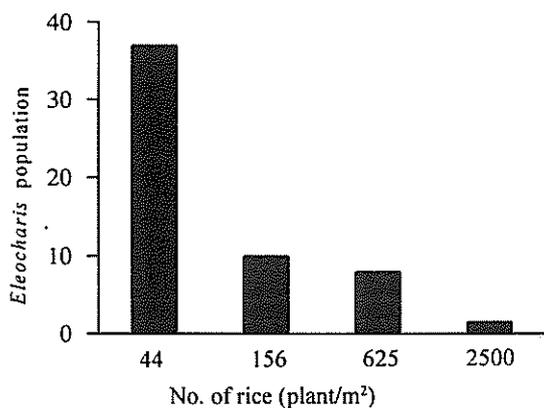


Figure 6. Effect of number of deepwater rice on *Eleocharis* population (Yingviwatanapong 1986).

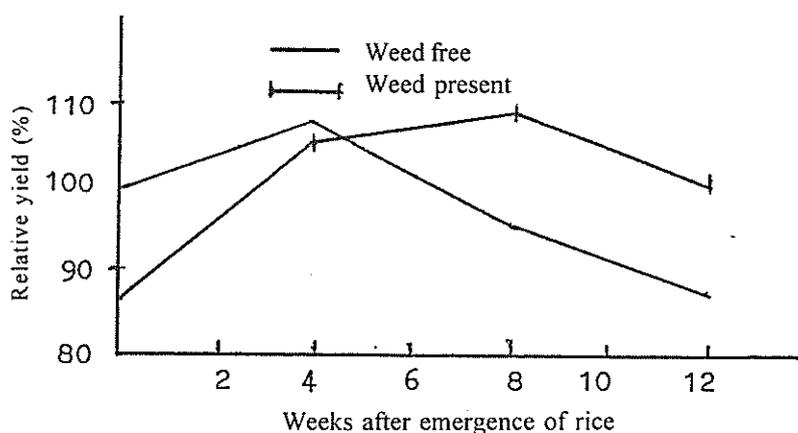


Figure 7. Critical period of the competition of *Echinochloa colona* in deep water rice at Ayuthaya, Thailand (Nantasomsaran, *et al.*, 1988)

7. Cropping system

Monoculture of rice leads to increase weed populations especially weed adapted to rice growing conditions. In deepwater rice in Thailand, a field crop can be grown before or the same time with rice. Some farmers grow sweet potato, sweet corn, mungbean, sesame, sorghum and soybean before rice. Sesame and mungbean were grown in rows at the same time with rice and 20 days prior to rice seeding. Herbicides namely oxadiazon and fenoxaprop-p-ethyl were used and it was found that oxadiazon can be used safely to all plants. It was found that *Ipomoea aquatica* seemed to have less number and dry weight in treatment that rice grown 20 days after sesame and mungbean (Table 8). Growing rice with sesame, mungbean tended to have less dry weight of *Cyanotis axillaris*, *Ipomoea aquatica* than growing sesame and mungbean (Table 8).

8. Manual weeding

According to the yield of deepwater rice is quite low and farmers in Thailand do not do hand weeding (Catling, 1992). Niyomwit (1984) found that farmers in Thailand controlled weed by 82% and divided into chemical, hand weeding and both at 74%, 3% and 5% respectively (Table 3). For hand weeding, the time of weeding is important. It should be coincided with the critical period of weed competition. Nantasomsaran (1988) studied competition of *Echinochloa colona* with deepwater rice and found that the critical period of this weed was 4 weeks after emergence of rice (Figure 7). Weed control should be done before the critical point. In Myanmar, farmers cut both rice

and weeds in the area where wild rice is a big problem, and cultivated rice can elongate stems better than wild rice (Saw Ler Wah, per. com., 1992). In Thailand Kuphkanchanakul, *et al.*, (1992) found that rice can be cut for herbage, which could reduce weed population as weed.

9. Biological control

Biological control is new approach to weed control and is safe to the environment. In deepwater rice, *Pistia stratiotes* is one common weed which can be controlled by an insect namely *Epipsammia pectinicornis* was introduced from U.S.A. in 1976 (Napompeth, 1992).

10. Chemical control

Herbicides offer the most practical, effective and economical way of reducing weed competition, crop losses and production losses in rice. Beyer (1991) stated that herbicides should be cost effective, flexible, reliable and convenient to use; safe to the crop, environment, user and consumer; low use rate to minimize the amount introduced into the environment; leave no harmful residues; persistence in the crop and soil tailored to desired effect, high specificity to target organisms, no off-target effects, easily integrated with best management practices and does not lead to pest resistance. Herbicides in deepwater rice can be applied as pre and post emergence. For pre-emergence herbicides, oxadiazon, butachlor, bifenox, thiobencarb and oxyflurofen were sprayed after seeding and good weed control was obtained especially *Echinochloa colona* (Table 12). Molinate-propanil, thiobencarb-propanil, ioxynil 2, 4-

Table 9. Percentage of *Echinochloa colona* at various stages of growth killed under different depths of water (Komson, *et al.*, 1994).

Weed growth (days after emergence)	Height (cm)	Water depth (cm)			
		0	30	50	70
10	3.92	0	100	100	100
20	24.26	0	0	100	100
30	49.26	0	0	100	100
40	54.50	0	0	0	66.7

LSD 0.05 (weed growth) = 4.5

LSD 0.05 (water depth) = 4.5

CV (%) = 7.7

Table 10. Effect of preemergence herbicides on density of *Echinochloa colona* and yield of DWR in a farmer's field. Phu Khao Tong, Ayutthaya province, Thailand, 1983 WS. (Vongsaroj, *et al.*, 1988).

Treatment*	Application rate (kg ai/ha)	<i>E. colona</i> plants** (no./sq. m)	Yield (t/ha)
Oxadiazon	1.0	48 a	2.0
Butachlor + ioxynil - 2, 4 - D	0.75 + 0.07 - 0.43	60 a	1.7
Butachlor + 2, 4 - D	0.75 + 0.5	62 a	1.7
Butachlor	2.0	68 ab	1.8
Bifenox	2.0	74 abc	2.0
Thiobencarb	3.0	91 bc	2.4
Oxyfluorfen	0.5	100 c	1.8
Untreated check	-	169 d	1.9

* (+) = tank mix

** Counts at 70 days after application of herbicide

Table 11. Effect of postemergence herbicides on density of *Echinochloa colona* and yield of DWR in a farmer's field. Phu Khao Tong, Ayutthaya, Thailand, 1983 WS. (Vongsaroj, *et al.*, 1988).

Treatment*	App. rate (kg ai/ha)	Weed control**	<i>E. colona</i> *** (no./sq.m)	Yield (t/ha)
Molinate-propanil	1.0 + 1.0	5	47 a	1.0
Thiobencarb-propanil	1.3 + 1.7	3	47 a	1.1
Ioxynil-2, 4-D-propanil	1.0	4	53 ab	1.2
Bifenox + propanil	1.5 + 1.5	6	53 ab	1.1
Oxadiazon+propanil	0.8 + 1.5	6	54 abc	1.1
Propanil-2, 4-D	1.67 - 0.33	7	67 abc	1.3
Ioxynil-2, 4-D	0.14 - 0.86	1	67 abc	1.4
Propanil	2.0	2	77 bc	1.0
Bromoxynil + MCPA	1.0 + 1.0	3	85 c	1.1
Butachlor + propanil	0.8 + 1.5	4	88 c	1.3
2, 4-D	0.75	0	206 d	1.3
Untreated Check	-	0	191 d	0.8

* (-) = proprietary mixture, (+) = tank mix

** Visual rating, 23 days after herbicide application, on a scale of 0-10 :

0 = no control, 10 = complete control.

*** Counts at 62 days after application. Mean of 4 replications.

Table 12. Selectivity of herbicide in deepwater rice (Vongsaroj, 1987).

Weed species	1	2	3	4	5	6	7	8
<i>Ipomoea aquatica</i>	S	S	HS	R	HS	HS	HS	S
<i>Aeshynomene indica</i>	S	R	HS	R	HS	HS	HS	S
<i>Pentapetes phoenicea</i>	HS	S	HS	R	HS	HS	HS	S
<i>Melochia corchorifolia</i>	HS	S	HS	R	HS	HS	HS	HS
<i>Cyanotis axillaris</i>	S	S	HS	R	HS	HS	HS	S
<i>Echinochloa colona</i>	S	S	R	HS	HS	HS	R	HS
<i>Ischaemum rugosum</i>	S	HS	R	HS	HS	HS	R	HS
<i>Setaria geniculata</i>	S	S	R	HS	HS	HS	R	HS

HS = Highly susceptible S = susceptible
 MS = moderately susceptible R = resistant
 MR = moderately resistant
 1 = Bifenox 2 = Oxadiazon
 3 = 2,4-D 4 = Propanil
 5 = 2,4-D/propanil 6 = 2,4-D/molinate
 7 = 2,4-D/ioxynil 8 = Propanil/thiobencarb

Table 13. Number of wild rice and yield of rice treated with antidote and herbicides (0.1% wt. by seed wt.) (Supatanakul and Vongsaroj, 1976).

Herbicides	Rate (kg ai/ha)	Number of wild rice/sq.m	Yield of rice* (kg/ha)
Amiben	2.0	5	1904.69 ab
Amiben	4.0	4	1914.06 ab
Amiben	8.0	1	1934.50 ab
Alachlor	0.1	4	1809.38 abc
Alachlor	0.3	2	1932.81 ab
Alachlor	1.0	1	1956.25 a
Butachlor	3.0	4	1707.81 c
Butachlor	6.0	3	1882.81 abc
Butachlor	12.0	1	1956.25 a
Molinate	3.0	4	1742.19 bc
Molinate	6.0	2	1925.00 ab
Molinate	12.0	1	1950.00 a
Untreated check	-	10	1175.00 d

CV (%) 11.87

* Value followed by the same letter are not significantly different at 5% by DMRT.

D, propanil, bifenox propanil, propanil 2,4-D is the most popular herbicide in Thailand and control broadleaf weeds and sedges effectively (Vongsaroj and Chinawong, 1982). Antidote namely NA (1,8-naphthalic anhydride) is used to have more selectivity between wild rice and rice when high rate of herbicides is applied (Parker, 1976). Supatanakul and Vongsaroj (1976) found that amiben, alachlor were safe to rice when mixed rice seeds were treated with NA at 0.01% by weight of rice seed and wild rice population was reduced (Table 13). Butachlor and molinate, recommended rice

herbicides minimized wild rice population and had no harm to rice even high rate of application were sprayed with antidote, (Table 13).

CONCLUSION

Weeds in deepwater rice is dynamic, they change with the land condition which is entirely depended on rainfall, land preparation that is totally relied on the beginning of heavy rain and the distribution of rainfall. If there is enough dry period after heavy rain, the degree of successful weed

control from one or more plowings or harrowing are very high. Weed free rice seeds is effective for the reduction of wild rice infestation especially with antidote and it can easily be done with the cooperation with rice breeders to provide rice seeds to the farmers. The cultivar that is going to release in India for the competition with weeds but it will suppress weeds at the certain stage of rice plant. It can not compete the weeds at the early stage of rice growth. The cropping systems in deepwater rice will take sometime to prove for weed control but better soil improvement and income from other legume crops will be obtained as well as a maximum uses of farmer labour. The difficulty of cropping systems also depend on rainfall distribution.

Manual weeding now is getting more difficulty because of the shortage of labour, highly expensive and low yielded of rice. The biological control is new approach for weed control, but only one weed can be controlled in the case of *Pistia stratiotes*, hence further research is urgently needed. For chemical weed control, it is very effective but costly. Some of the farmers in deepwater can afford it.

Weed management in deepwater rice need not comprise all methods of weed control. The most practical and suitable methods to the farmers are needed to minimize weed problem into a certain level that should be put in practice. Then consistent weed control will be obtained with a pleasure of farmers for elaboration.

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