Current Status of Rice Herbicide Use in the Tropics

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Abstract

Chemical weed control for rice in the tropics began with the use of the chlorophenoxy herbicides in the 1950s. MCPA and 2, 4-D were used routinely in transplanted wetland rice for controlling broadleaved weeds and sedges. Propanil was introduced subsequently in the mid-1960s for postemergence control of annual grasses such as *Echinochloa crus-galli* and *Leptochloa chinensis*. Over the past decades, intensive research has led to the discovery, development and marketing of a wide spectrum of rice herbicides in the tropics. Those used include bensulfuron methyl, pyrazosulfuron-ethyl, cinosulfuron, bentazon, butachlor, piperophos thiobencarb, quinclorac, fenoxaprop-ethyl, molinate, pretilachlor oxadiazon, piperophos, dimethametryn, bifenox, pendimethalin and oxyfluorfen. The switch from transplanted to direct-seeded rice in recent years has triggered more weed infestation in tropical rice. Herbicides are the only logical alternative for weed control in direct seeding culture ; however, continuous herbicide application causes a distinct shift in the weed flora from annuals to perennials. Repeated use of the same herbicide also results in the development of herbicide—tolerant strains or resistant biotypes. Increasing herbicide usage has created concern regarding hazards to rice farmers' health. In the next decade, rice herbicide use in the tropics is expected to expand further because of increasing popularity of direct-seeded rice in the irrigated areas. It is therefore imperative to evaluate the impact of herbicides from the perspective of social implication such as potential environmental and health costs. Experiences of integrated weed management in Malaysia reveal that it is possible to reduce herbicide application through farmers' education with emphasis on proper cultural practices and good water management.

Key words : herbicides, weed shift, direct seeding

Introduction

The successful synthesis of phenoxy derivatives in the 1940s triggered a significant change in rice weed management in the tropics. The herbicide 2, 4-D (2, 4-dichlorophenoxy acetic acid) was initially tested in the Philippines in 1948 to eradicate weeds in lawns and pastures, and subsequently tested for weed control in rice. Other herbicides and growth inhibitors were subsequently studied in 1955 (Mercado, 1979). In Thailand, 2, 4-D was considered as the only promising herbicide for the rice crop when it was introduced in the late 1950s (Teerawatsakul, 1981). In Malaysia, chemical control for rice began with the use of 2, 4-D amine in the early 1960s in the Muda Irrigation Scheme. However, herbicide usage was limited. The introduction of the wettable powder formulation of 2, 4-D butyl ester in the early 1970s gave the impetus needed to boost the use of herbicides. This product was commonly hand-broadcasted in the rice fields together with urea and other granulated insecticides at 15-25 days after transplanting (DAT), thus saving time and labour for separate pesticide application (Ho, 1983). In Indonesia, progressive rice farmers in North Sumatra started using MCPA (2-methyl 4-chlorophenoxy acetic acid) to control broadleaved weeds and sedges in 1972. Farmers subsequently switched to 2, 4-D in 1978 due to the shortage of MCPA. Indonesian farmers preferred the use of 2, 4-D because the price was lower and it did not require sprayers for application (Sundaru, 1981).

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Since the introduction of phenoxy compounds four decades ago, intensive herbicide research has led to the discovery, development and marketing of a wide spectrum of herbicides. This has paved the way for wider herbicide use for rice cultivation in the tropics (Table 1). This paper deals with some aspects of the current status of herbicide use in transplanted and direct-seeded rice. Future challenges in chemical weed management in the tropics are also discussed.

Table 1 Hebicides used in tropical rice fields

Herbicides	Rate (kg a.i./ha)	Time of application
Bensulfuron	0.05-0.07	6 - 8 DAT or DAS
Bensulfuron + metsulfuron (P)	0.0165+ 0.0035	5 -18 DAT, 10-18 DAS
Bentazon	0.75−2.0	10-15 DAT or DAS
Bentazon + MCPA (P)	0.8+0.12	15-20 DAT or DAS
Bentazon + Propanil (P)	1 −1.3+ 2 −2.7	15-20 DAT or DAS
Bifenox	2.0	6 DAS
Bifenox + 2, 4-D	2.0+0.66	6 DAS
Butachlor	1.5−2.0	3 - 7 DAT, 6 - 8 DAS
Butachlor + safener (P)	0.75	3 DAS
Butachlor + 2, 4-D	0.75+0.6	6 - 8 DAS
Butralin	2.0	4 - 6 DAS
2, 4-D	0.5−0.8	15-25 DAT, 20 DAS
Cinosulfuron	0.04	8 -10 DAS
Chlorimuron ethyl	0.008	20 DAT or DAS
Chlorimuron ethyl + metsufuron	0.004+0.004	21 DAT or DAS
CNP	2.0	3 DAT or 5 DAS
EPTC + 2, 4-D	1.2+0.6	7 -10 DAT or 10-15 DAS
Fenoxaprop - ethyl	0.04−0.18	26-30 DAS
MCPA	0.5−0.8	20 DAT or DAS
Molinate	2.5−4.3	3 - 6 DAT, 8 -10 DAS
Molinate + Propanil (P)	2 −2.3+ 2 −2.3	10-14 DAS
Oxadiazon	0.75−1.5	10-14 DAS
Oxadiazon + propanil (P)	0.5+1.5	10-14 DAS
Oxyfluorfen	0.24	3 - 6 DAS
Pendimethalin	0.75−2.0	6 DAS
Pendimethalin + propanil (P)	2.6+1.07	8 -10 DAS
Piperophos + dimethametryn	0.4+0.1	4 - 6 DAS
Piperophos + 2, 4-D (P)	0.3+0.2	6 - 8 DAS
Pretilachlor + safener (P)	0.3−0.45	0 - 4 DAS
Propanil	3 − 4	10-14 DAS
Pyrazosuluron	0.015−0.030	3 -14 DAT, 7 -14 DAS
Quinclorac	0.25−0.50	0 - 5 DAT, 7 -14 DAS
Sethoxydim	0.2	25-30 DAS
Thiobencarb	2 − 3	10 DAS
Thiobencarb + 2, 4-D (P)	1.2+0.6	7 -14 DAT, 10-14 DAS
Thiobencarb + propanil (P)	0.5−1.0+1.4−2.8	10 DAS
Trifluralin + 2, 4-D (P)	0.6+1.0	10-15 DAS

DAT — days after transplanting
DAS — days after seeding
(P) — proprietory product

Status of herbicide use in transplanted rice

Manual weeding is still commonly practiced in transplanted rice. However, manual weeding is laborious and expensive. Moody (1994 a) reported that weeding transplanted rice once at the appropriate time required approximately 25 labour days/ha. Therefore, the use of herbicides is more practical, effective and economical than manual weeding in achieving weed control and reducing crop losses.

In the tropics, the chlorophenoxy herbicides 2, 4-D and MCPA are used as routine weed control measures for sedges and broadleaved weeds in transplanted wetland rice. The most common formulations are the sodium and potassium salts available as water soluble powder or water soluble liquid. Propanil was introduced in the mid-1960s as a postemergence contact herbicide for grassy weed control (De Datta and Herdt, 1983). Extensive studies conducted subsequently over the past three decades revealed that herbicides suitable for use in transplanted rice include bensulfuron-methyl, pyrazosulfuron-ethyl, bentazon, butachlor, 2, 4-D, MCPA, piperophos + 2, 4-D, propanil, thiobencarb, quinclorac and fenoxaprop-ethyl (Moody, 1994 b).

In Malaysia, 2, 4-D isobutyl ester and 2, 4-D amine are more popular than the other phenoxy derivatives. Approximately 95 % of rice farmers who practiced chemical weed control in the Muda Irrigation Scheme use these two herbicides for postemergence weed control in transplanted fields against sedges such as *Fimbristylis miliacea* (L.) Vahl, *Cyperus difformis* Linn, *Scirpus grossus* Linn. f. and annual broadleaved weeds such as *Monochoria vaginalis* (Burm. f) Presl, *Sagittaria guyanensis* Humb and *Limnocharis flava* (L.) Buch (Ho and Md. Zuki, 1989). The extensive use of 2, 4-D compounds for postemergence application has enabled the Muda farmers in Malaysia to keep the annual sedges and broadleaved weeds under control. However, aquatic ferns, such as *Marsilea minuta and Salvinia molesta* D. S. Mitchell, which are tolerant to 2, 4-D, remain problematic in the transplanted fields (Ho, 1991). In the late 1980s and early 1990s, sulfonylurea herbicides became popular because of their excellent control over *M. minuta, S. molesta* and *Sphenoclea zeylanica* Gaertn (Ho, 1994).

In the Philippines, selective herbicides such as butachlor and thiobencarb are popular as preemergence and postemergence herbicides for annual grassy weed control. Remarkable selectivity against *Echinochloa* and other weeds species makes thiobencarb an excellent herbicide for transplanted rice (De Datta and Herdt, 1983).

In Thailand, 2, 4-D and butachlor are the most popular herbicides based on the total quantity imported. The most common herbicides used for transplanted rice are thiobencarb, bifenox, butachlor CNP, oxadiazon, piperophos, dimethametryn and bensulfuron methyl. These herbicides are generally applied 5 - 8 days after transplanting. The effectiveness of these herbicides is very much dependent on the maintenance of a suitable water level in transplanted rice (Vongsaroj, 1993).

In Indonesia, the application of slow-release formulations of thiobencarb and butachlor is currently being studied. Preliminary investigations indicate that although these chemicals do not give better weed control than the existing commercial formulations, they are more compatible with integrated fish-rice culture (Suyud, 1992).

Status of herbicide use in direct-seeded rice

In recent years, the increase in irrigated areas, availability of inexpensive herbicides, development of early maturing modern varieties, knowledge on efficient fertilizer management, and socio-economic constraints encouraged many farmers in the Philippines, Thailand and Malaysia to switch from the traditional transplanted to direct-seeded rice culture (De Datta, 1986). Escalation of transplanting cost and shortage of farm labour provided further impetus to widespread adoption of the labour-saving direct seeding technique in Southeast Asia.

Weed control is more critical and difficult in direct-seeded rice than in transplanted rice, because of the similarity in size and morphology of rice seedlings and grass weeds of the same age (De Datta and Bernasor, 1973). Yield losses due to uncontrolled weed growth at IRRI, Philippines were on an average 9 % higher in wet-seeded rice than in transplanted rice (Moody, 1983). In dry-seeded rice, weed problems are more acute than in other types of rice culture because a lack of water at early crop establishment stage enhances weed infestation. Moody and Cordova (1985) reported that herbicides are the only logical alternative for weed control in wet-seeded rice.

In Malaysia, virtually all the rice farmers who practiced direct seeding in the Muda area adopted chemical weed control (Table 2). Herbicides commonly used for grassy weed control in the direct-seeded fields are propanil, propanil + thiobencarb, pretilachlor + safener, quinclorac, molinate, molinate + propanil and fenoxaprop-ethyl (Ho, 1994). Baki and Azmi (1992) reported that pretilachlor at 0.5 kg a.i./ha applied 3 - 5 DAS, or a mixture of molinate + 2, 4-D IBE (2.5 + 0.5 kg a.i./ha); molinate + bensulfuron (2.5 + 0.03 kg a.i./ha); thiobencarb + 2, 4-D IBE (2.5 + 0.5 kg a.i./ha); oxadiazon + 2,4-D IBE (0.5 + 0.5 kg a.i./ha); propanil + molinate (2.5 + 0.5 kg a.i./ha) and cinosulfuron (0.04 kg a.i./ha) applied at 8 - 10 DAS on moist or moderately inundated field conditions (5 - 10 cm depth), can control a broad spectrum of sedges, grasses and broadleaved weeds.

In the Philippines, the shift to wet seeding resulted in a shift to herbicide use (Casimero *et al*., 1994). Studies conducted in Nueva Ecija revealed that 71% of the rice farmers who practiced wet seeding used only chemical control, whereas 52% of the farmers who transplanted their crops used only herbicides for weed control (Table 3) (Erguiza *et al*., 1990). The herbicides most widely used in the Philippines are butachlor and thiobencarb (De Datta and Flinn, 1986).

In Thailand, some commonly used herbicides are butachlor, thiobencarb, oxadiazon. piperophos and dimethametryn (Vongsaroj, 1987). Bifenox and oxadiazon are often used after the rice seeds have been broadcast in dry-seeded, wet-seeded and deep water rice. Herbicide combinations such as 2, 4-D + propanil, propanil + molinate and propanil + thiobencarb are applied when weeds reach the 2 - 3 leaf stage. For upland rice, bifenox, pendimethalin, oxadiazon and oxyfluorfen are used after seeding (Vongsaroj, 1987).

Issues related to herbicide use

1. Weed shift

Reliance on a single herbicide could result in quantitative changes in the structure of the weed population in as few as 5 years (Mahn and Helmecke, 1979). In the tropics, a distinct shift in the weed flora from annuals to perennials occurs after continuous herbicide application. Repeated applications of herbicides in the Philippines have resulted in *Echinochloa crus-galli* and perennial sedge becoming increasingly dominant (Vega *et al*., 1971; De Datta, 1977). Annual weeds in the early croppings were replaced by the perennial grass *Paspalum distichum* L. after continuous treatment with piperophos + 2, 4-D, pendimethalin and butachlor (Janiya and Moody, 1987).

In Indonesia, the population of *Echinochloa crus-galli* (L.) Beauv. is increasing in transplanted rice with the continuous use of 2, 4-D and metsulfuron methyl for broadleaved weed control (Moody, 1991).

In the Muda area of Malaysia, continuous use of 2, 4-D applied as postemergence control has caused

Table 2 Comparison of herbicide usage under different crop establishment methods (first season) in the Muda area, Malaysia
Source: MADA (1994)

Farmers' weed control	1988		1994	
	Transplanting	Direct seeding	Transplanting	Direct seeding
Average herbicide cost (US$/ha)	4.8	24.8	6.0	48.0
Farmers using herbicide (%)	82	98	86	100
Frequency of herbicide application (rounds/season)	1.2 (1-2)	2.9 (2-4)	1.0 (1)	2 (1-3)

* Figures in parentheses denote the range of herbicide application frequency

Table 3 Weed control practices by crop establishment method Nueva Ecija, Philippines, 1986 dry season (Adapted from Erguiza *et al*., 1990)

Weed control method	Transplanted		Broadcast-seeded flooded	
	Farms (no)	%	Farms (no)	%
Manual only	9	8	0	0
Chemical only	57	52	44	71
Combination of	37	34	17	27
None	7	6	1	2
Total	110	100	62	100

the suppression of the easy-to-control weeds such as *Monochoria vaginalis* and *Fimbristylis miliacea*, resulting in a distinct dominance of *Echinochloa crus-galli, Sphenoclea zeylanica, Marsilea minuta, Cyprus iria* and *C. babakan*. The application of pretilachlor with fenclorim as safener has shown remarkable crop selectivity and bio-efficacy in grassy weed suppression, but provided a conducive environment for *Sagittaria guyanensis* and *M. minuta* to prevail (Fig. 1). Molinate suppresses *E. crus-galli*, but results in escalated infestation of *Leptochloa chinensis* (L.) Nees and *Ischaemum rugosum* Salisb. (Ho, 1991).

2. Herbicide resistance

Herbicide-tolerant strains or resistant biotypes could evolve through repeated use of the same herbicide over a long period. Le Baron and Mc Farland (1990) revealed that there are 113 weed biotypes which are resistant to the 15 classes of herbicides in the world. A few of these are found to have evolved resistance to some herbicide classes by cross resistance.

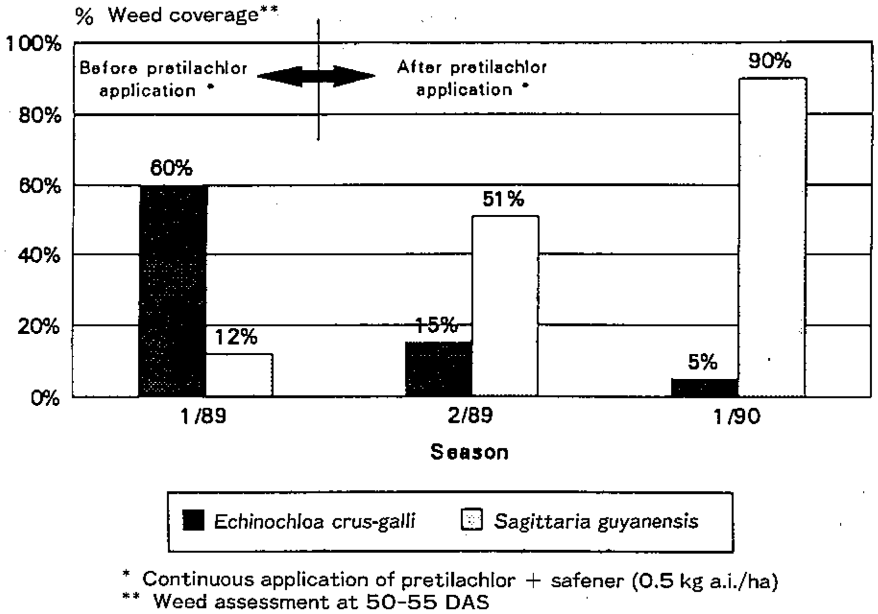
In Southeast Asian rice fields, the 2, 4-D tolerant biotype of *Sphenoclea zeylanica* was first reported in the Philippines (Migo *et al*., 1986). Subsequent studies by Mercado *et al*. (1987) reported that this tolerance is attributed to the thicker cuticle observed in the third and fifth leaf position which possibly resulted from continuous use of 2, 4-D.

In the Muda area of Malaysia, a 2, 4-D resistant biotype of *Fimbristylis miliacea* was first detected in 1989 in a farmer's field where 2, 4-D has been seasonally applied since 1975 (Ho, 1992). Subsequent studies conducted by Watanabe *et al*. (1994) indicated that the resistant biotype recovered after the application of 2, 4-D amine at 16 times strength over the recommended dosage. This resistant biotype showed cross-resistance to other phenoxy compounds such as 2, 4-D isobutyl ester, 2, 4-D sodium salt and MCPA.

3. Herbicide poisoning

In recent years, increasing use of herbicides in rice cultivation has created concern regarding the hazards to the health of rice farmers. In Malaysia, a recent survey on pesticide usage and associated incidence of poisoning in the Muda area indicated that herbicides were most commonly used when compared with insecticides, fungicides and rodenticides. Approximately 51.3% of the responding farmers reported that they had experienced symptoms associated with pesticide poisoning. The highest incidence was due to herbicide application alone (24.8%), followed by insecticides (14.7%). Farmers rarely experienced poisoning symptoms due to rodenticides or fungicides. Headache and dizziness (71.6%) were most commonly experienced by the respondents. The types of herbicide identified by farmers and spray operators were 2, 4-D, paraquat, molinate and metsulfuron methyl (Ho *et al*., 1990).

In the Philippines, studies conducted by Rola and Pingali (1992) found that the use of phenoxy derivatives was linked to the incidence of pterygium (eye irritation), bronchial asthma, pulmonary disorders, low haemoglobin concentration and polyneuropathy. The reported incidence of pterygium in the surveyed villages was five to seven times greater than that in the control villages that did not use herbicides in rice production.



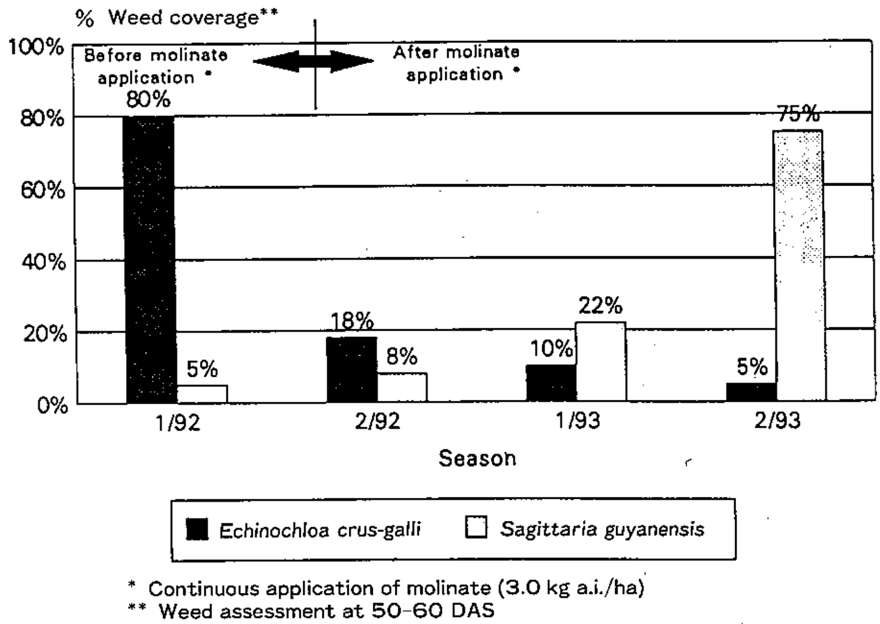


Fig. 1 Changes in weed dominace after continuous herbicide application in the Muda area

Outlook of herbicide use in the tropics

In the next decade, it is envisaged that rice weed management will not differ drastically from current practices. However, the area treated with herbicide is expected to expand because of the increasing popularity of direct seeding in the irrigated rice areas (Moody, 1994 b). In the tropics, the rice herbicide market is expanding. Woodburn (1993) reported that herbicide use in Thailand had increased dramatically in the late 1980s and early 1990s. Products such as bensulfuron methyl, pretilachlor and fenoxaprop ethyl have benefitted although the old herbicides 2, 4-D and butachlor remained important. A similar trend is being observed in Malaysia (Ho, 1994).

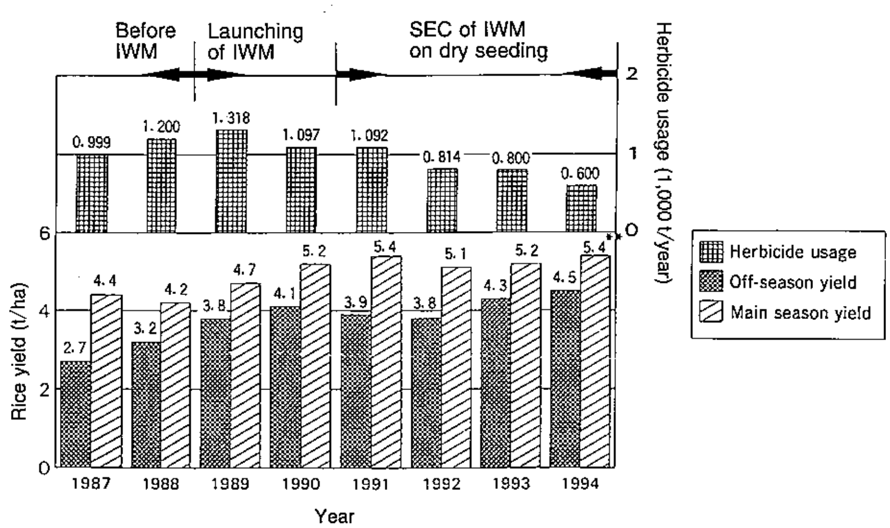
The adoption of herbicides is very much dependent on the return of input investment relative to other weed control measures. Ampong Nyarko and De Datta (1991) showed that the marginal benefit-cost ratio of chemical weed control in transplanted rice was 16 : 1 whilst that for manual weeding was only 3.3 : 1. The relatively low cost and efficacy of herbicides and their contribution towards reducing drudgery in manual weeding are indeed a remarkable achievement in modern rice cultivation. However, it is imperative to evaluate the impact of chemical weed management technologies from the perspective of social implications of herbicide use. Some of the potential environmental and health costs listed by Naylor (1994) are as follows : -

- Chronic health and environmental damage associated with the contamination of ground and surface waters.
- Herbicide residues in food chains.
- Increased mortality and alteration of population among the flora and fauna in the rice agro-ecosystem.
- Occurrence of weed shifts and herbicide-resistant weeds.
- Elimination of beneficial plants as refuge for biological agents.

Over-reliance on herbicides discourages the development of other weed management alternatives. This will seriously hinder any reduction of dependence on herbicides (Moody, 1994). Integrated weed management (IWM) which emphasizes the integration of several weed control measures applied simultaneously (Moody and De Datta, 1982) is the best approach from the agronomic, economic, social and ecological standpoints. In the Muda area of Malaysia, the successful launching of a large-scale campaign during 1989 based on the IWM concept reduced *Echinochloa* infestation by 66% and increased rice yields by 27% (Ho *et al*., 1990).

Lessons learned from continuous monitoring of weed-rice interaction in the Muda area of Malaysia indicated that the total eradication of weeds is not practical in the rice agro-ecosystem. The removal of the last 5% of weeds remaining in the rice fields is usually not cost-effective. Besides, additional herbicide usage for total weed control creates concern about environmental side-effects.

Although the use of herbicides is more widespread and expenditure in chemical control per hectare has increased (Table 2), the total quantity of herbicides used in the Muda area, Malaysia has declined in recent years (Fig. 2). This is because improvement in cultural practices has reduced the frequency of herbicide application. Studies in the Muda area showed that farmers practicing proper land preparation and



* IWN= Integrated Weed Management
** yield for main season 1994 is an estimation only.

Fig. 2 Yield performance and herbicide usage in the Muda area (1987-1994)

good water management could manage their weed problems with only one round of herbicide application, whereas farmers adopting poor cultural practices usually apply herbicides 3 to 4 times per season to control weeds (Ho, 1994). Besides, the widespread adoption of pretilachlor (0.5 kg a.i./ha), fenoxaprop-ethyl (0.06 kg a.i./ha to replace molinate (3.0 kg a.i./ha), and the use of sulfonyl urea compounds (0.004 to 0.05 kg a.i./ha) to replace 2, 4-D (0.8 to 1.0 kg a.i./ha.) also contribute to reducing herbicide usage and fish toxicity problems in the rice agro-ecosystem.

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Discussion

Lim Jit Kim (Malaysia): There have been many reports on the abuse and misuse of herbicides in developing countries. The industries have spent a great deal of time and resources for the development of training and product stewardship programs. MADA has also implemented extension programs for the farmers. What do you think should be done further to solve the problems of herbicide poisoning ?

Answer: The hazards related to herbicide applications stem from misuse rather than use. Extension should be further promoted along with a closer collaboration between researchers and extension workers.

Bay-Petersen (FFTC, Taiwan): What about the relation between the cost of herbicides and the rice price ? Has it been stable ?

Answer: In Malaysia the situation is favourable, as the farmers enjoy benefits including subsidies for the purchase of inputs as well as for the maintenance of irrigation facilities.

Hossain, Md. Amzad (Bangladesh): Direct seeding culture appears to be as labour-intensive as transplanting, because in the case of direct seeding culture, herbicides and fertilizers must be applied several times to suppress weeds and increase the yield of rice. In transplanting culture, field becomes a canopy earlier than in the case of direct seeding, which reduces weed growth. As a result, labour and fertilizer consumption are reduced and a higher yield can be achieved. Transplanting system also leads to a reduction of weed germination.

Answer: In Malaysia there is a potential to achieve a very high yield of rice (6–7 t/ha). Due to the labour shortage, we apply direct seeding culture as we would have to depend on labour from southern Thailand to implement transplanting. To control weeds, improvement of cultural practices including water management and land preparation is being promoted. I would like to emphasize that the climatic conditions in Malaysia are extremely favourable and that the amount of solar radiation available could support a yield of 9 t/ha.