Pertanika 9(1), 23 – 33 (1986)

Chemical Weed Control in Direct Seeded Rice: The Evaluation of Selected Herbicides for Phytotoxicity to the Rice Plant

AZMI MAN and E.S. LIM
Department of Agronomy and Horticulture,
Faculty of Agriculture,
Universiti Pertanian Malaysia,
43400 Serdang, Selangor, Malaysia.

Key words: Herbicide; Phytotoxicity; 2,4-D amine; 2,4-DIBE-butachlor, butachlor; benthiocarb; molinate.

ABSTRAK

Kesan fitotoksik racun-racun herba 2,4-D amina, 2,4-DIBE-butachlor, butachlor, benthiocarb dan molinate dibuat penilaian ke atas tumbuhan-tumbuhan padi. Rawatan-rawatan dengan racun-racun herba tersebut yang dibuat pada berbagai masa menunjukkan bahawa sangat fitotoksik apabila diberikan sebagai racun pracambah. Apabila racun-racun herba diberikan sebagai awal lepas-cambah, ia juga memberi kesan-kesan fitotoksik teruk dan tumbesaran serta hasil bijirin terjejas. Rawatan yang lewat 8 hingga 10 minggu selepas menyemai kurang mencederakan sekali. Antara kesemua racun herba yang dikaji, didapati molinate merupakan racun herba yang kurang fitotoksik sekali.

ABSTRACT

The phytotoxic effect of 2,4-D amine, 2,4-DIBE-butachlor, butachlor, benthiocarb and molinate on rice plants were assessed. Applications of the herbicides at different time resulted in severe phytotoxicity when applied before seeding. Early postemergent applications were also generally phytotoxic, adversely affecting plant growth and grain yield. Late applications 8 to 10 weeks after seeding were least injurious. Among the herbicides, molinate was the least phytotoxic.

INTRODUCTION

In the control of weeds in rice fields various methods may be used. The use of chemicals is often resorted to when conditions for alternative methods of weeding are difficult, ineffective or when labour supply is inadequate. In Malaysia there is an increasing trend toward direct seeding of rice (Baki, 1982a). With direct seeding it is difficult to weed manually and the use of herbicides is more practical. At the moment the most widely used herbicide is 2,4-D which is effective for the control of broadleaf weed (Saharan, 1977). In the major rice growing regions of the country the weed flora include many grass species (MARDI Ann. Rep., 1982) and herbicides with a different weed control spectrum are necessary. Among the more promising are formulations such as 2,4-DIBE-butachlor, butachlor, benthiocarb and molinate (Baki, 1982b). Before a herbicide may be applied to the rice crop their phytotoxicity to various growth stages of the rice plant must first be evaluated.

MATERIALS AND METHODS

The herbicides, 2,4-D isobutylester-

butachlor (a proprietary mixture), butachlor, benthiocarb and molinate were tested for their effect on rice seed germination, seedling and plant growth. A commonly used herbicide, 2,4-D amine was included for comparison. These herbicides were tested for their effect on seed germination and early seedling growth at the rate of 10, 100, 500 and 1,000 mg a.i./l solution. Seeds of the cultivar Setanjung were soaked for 24 hours in distilled water and then transferred to petri dishes lined with filter paper. Fifty seeds were placed in each petri dish and 6 ml of each herbicide at the appropriate concentration given. A control was included in which distilled water was used. A completely randomised design with 4 replicates was used.

The effect of the herbicides on the growth and yield of the rice plant was evaluated in a pot experiment conducted in the glasshouse. Waterproof plastic containers (pots) of 28 cm diameter filled with an equal weight of a clay loam soil were used for growing the rice plants. Seven rice seedlings were grown in each container through direct seeding. This number of seedlings was equivalent to a seed rate of 40 kg/ha. Each of the five herbicides tested were applied at nine different periods ranging from four days before seeing upto 70 days after seeding at intervals of 14 days and also as split applications at 4 and 42 days after seeding, 4 and 56 days and 14 and 70 days. The application rate of the herbicides were based upon twice the recommended rates so as to provide a safety margin in their usage. The rates used are given in Table 1. In the case of split applications only half the rate is given at any one time. A control without any herbicide treatment was included. The experiment was replicated four times using a randomised complete block design.

TABLE 1
Equivalent application rates of herbicides evaluated

Herbicide	Rate (kg a.i./ha)
2,4-D amine	2.0
2,4-DIBE-butachlor	2.4
Butachlor	3.0
Benthiocarb	8.0
Molinate	6.7

Fertilizer application consisted of an early top dressing at the rate of 40 kg N, 40 kg K_2O and 40 kg P_2O_5 given at 20 days after sowing. Subsequent applications of urea to supply 20 kg N/ha were supplied at 35, 45 (active tillering) and 75 days after sowing (panicle initiation stage).

The visual assessment of phytotoxicity on the plants was carried out 14 days after the application of the herbicide. A crop injury rating of 1 to 10 was used in which 1 indicated no injury and 10 represented extensive damage leading to the death of plants.

The effect of the herbicides on the rice plant was also evaluated through measurements of vegetative and reproductive characters at various stages during the growth period and at maturity of the crop.

RESULTS

Seed Germination

In general the herbicides were found to have little effect on the germination of rice seeds (Table 2). The lowest rate of the herbicides used did not significantly influence germination. However, depending upon the herbicide, rates between 100 up to 1000 mg a.i./l caused significant reduction in germination. In the case of 2,4-D Amine, only the highest rate of 1,000 mg a.i./l reduced germination. The combination of 2,4-DIBE and butachlor significantly reduced germination when given at the rate of 100 mg a.i./l and above. The application of butachlor by itself did not significantly reduce the rate of germination at all the concentrations studied compared to the control. The adverse effect of 2,4-DIBE-butachlor is possibly due to the 2,4-D compound. Benthiocarb inhibited seed germination only at 1,00 mg a.i./l while molinate was inhibitory at 500 mg a.i./l and above.

TABLE 2
Effect of selected herbicides on germination and early growth of rice seedlings

Herbicide	Rate a.i. per litre	% seeds germination	plumule length (cm)	radicle length (cm)
2,4-D amine	10	98.5 ab	1.37 ab	0.00 g
	100	97.5 abc	1.33 bc	0.00 g
	500	97.0 abcd	1.21 c	0.00 g
	1000	76.0 f	0.42 hi	0.00 g
2,4-DIBE-butachlor	10	98.0 abc	1.34 bc	0.00 g
	100	94.0 de	0.71 ef	0.00 g
	500	94.0 de	0.37 i	0.00 g
	1000	94.0 de	0.31 i	0.00 g
Butachlor	10	97.5 abc	1.02 d	1.43 a
	100	96.5 abcd	0.60 fg	1.01 bc
	500	96.5 abcd	0.54 gh	0.80 d
	1000	96.0 abcd	0.35 i	0.42 e
Benthiocarb	10	98.0 abc	0.93 de	1.15 b
	100	96.5 abcd	0.63 fg	1.06 bc
	500	96.5 abcd	0.60 fg	0.90 c
	1000	95.5 bcd	0.55 fg	0.50 e
Molinate	10	97.0 abcd	0.61 fg	0.90 c
	100	96.0 abcd	0.59 fg	0.55 e
	500	95.0 cde	0.30 i	0.25 f
	1000	92.0 e	0.13 g	0.00 g
Control	0	99.0 a	1.55 a	1.40 a

In each column, means followed by the same letter are not significantly different at P = 0.05.

Plumule Length

In general, the herbicides severely inhibited the growth of the plumule. With the exception of the lowest rate of 2,4-D amine (10 mg a.i./l), all the rates tested for all the herbicides reduced the growth of the plumule (Table 2). Among the herbicides, molinate depressed plumule elongation most, while 2,4-D amine was least inhibitive.

Radicle Growth

The growth of the radicle was severely restricted by the herbicides 2,4-D amine and 2,4-DIBE-butachlor such that it was not possible to measure it (Table 2). Butachlor at the lowest rate did not affect radicle elongation but all other higher dosages inhibited radicle elongation to varying extent. The results indicated that 2,4-D amine and 2,4-DIBE-butachlor cannot be applied at the time of seeding because of the severe inhibition of root growth.

Plant Injury

The extent of phytotoxicity was scored on a scale of 1 to 10, according to severity of the symptoms on the rice plants in the pot experiment. It was found that 2,4-D amine, butachlor, and benthiocarb were lethal to rice plants when applied as a preemergent 4 days before sowing (Table 3). Split applications of the herbicides that required one application of 2,4-D or Benthiocarb before seeding also killed the rice plants even though only half the rate was used. The early postemergent application of 2,4-D amine and benthiocarb, 14 days after seeding, also caused severe crop injury. Butachlor, 2,4-DIBE-butachlor and molinate were less damaging to

TABLE 3
Visual assessment of phytotoxicity on rice plants 14 days after herbicide treatment

Time of application	Rating of plant injury by herbicide				
	2,4-D amine	2,4-DIBE-butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	10	7	10	10	6
14 DAS	8	6	6	8	5
28 DAS	6	3	4	6	5
42 DAS	6	6	4	4	4
56 DAS	5	4	4	4	4
70 DAS	4	3	3	3	2
4 DBS & 42 DAS	10	4	4	10	4
4 DBS & 56 DAS	10	4	3	10	4
14 DAS & 70 DAS	8	6	5	6	5
Control	1	1	1	1	1

Rating of injury symptoms due to phytotoxicity: 1 = no injury, 10 = severe injury, plants killed.

DBS = days before seeding
DAS = days after seeding

the rice plants when applied as a postemergent 14 days after seeding. Late postemergent applications of the herbicides, 56 to 70 days after seeding, generally had the least phytotoxic effect on the rice plants.

The general phytotoxicity symptoms observed were the yellowing and drying up of leaves accompanied by thinning out of the rice stand. Injury resulting from the application of 2,4-D amine was characterised by the leaf tips being stuck to the leaf collar giving a looped appearance to the leaf blade. The looped leaf symptom was also found on plants treated with 2,4-DIBE-butachlor, possible due to the presence of the 2,4-D compound. The 2,4-D compound also produces a temporary condition in which injured leaves resembled onion leaves. The plants recovered from the onion leaf appearance within 7 to 14 days. Butachlor also produced a temporary reddish discoloration of the leaves. Various vegetative and reproductive parts of the plant were adversely affected to varying degrees by the herbicides.

Plant Height

All the herbicides applied caused a reduction in the plant height particularly when applied during early growth (Table 4). With the exception of 2,4-D amine, applications later than 28 days after seeding did not produce any significant difference in plant height. The 2,4-D amine treatment was deterimental to plant height increment for all applications that did not result in the death of the plants except when applied very late at 70 days after seeding. All postemergent applications of butachlor and benthiocarb did not significantly affect plant height.

Tiller Number

In most applications all the herbicides studied caused significant reductions in the number of tillers produced (Table 5). 2,4-D amine and 2,4-DIBE-butachlor were generally inhibitive to tiller production at all growth stages while only early postemergent applications of butachlor and benthiocarb reduced tillering.

TABLE 4
Effect of herbicide application on plant height (cm)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	74.1 a	#	#	65.8 c
14 DAS	60.8 bc	65.9 bc	72.3 a	#	66.4 c
28 DAS	63.7 bc	63.6 c	72.3 a	68.4	73.0 ab
42 DAS	53.8 c	71.3 ab	73.3 a	71.4	73.0 ab
56 DAS	64.5 bc	76.3 d	78.2 a	75.3	75.2 ab
70 DAS	67.9 ab	76.7 a	74.4 a	73.2	74.9 ab
4 DBS & 42 DAS	#	72.6 a	60.0 b	#	72.0 abc
4 DBS & 56 DAS	#	73.0 a	61.1 b	#	74.3 ab
14 DAS & 70 DAS	61.1 bc	70.5 ab	71.3 a	69.0	69.1 bc
Control	76.1 a	74.3 a	74.6 a	73.1	76.7 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.
Treatment means for Benthiocarb herbicide are not significantly different at P = 0.05.
DBS = days before seeding.
DAS = days after seeding. # plants killed by herbicide.

TABLE 5
Effect of herbicide application on tiller number

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	12.5 d	#	#	9.5 e
14 DAS	13.3 b	15.3 cd	9.0 cd	#	21.8 d
28 DAS	6.0 cd	17.3 c	19.0 cd	18.5 bc	31.5 a
42 DAS	3.8 d	12.5 d	22.0 ab	26.0 a	33.0 a
56 DAS	10.3 bc	16.3 bcd	22.5 ab	23.8 ab	23.0 d
70 DAS	13.8 b	21.0 abc	25.3 a	23.5 ab	22.5 d
4 DBS & 42 DAS	#	16.8 bcd	4.5 d	#	26.5 b
4 DBS & 56 DAS	#	22.8 ab	5.0 d	#	22.3 d
14 DAS & 70 DAS	7.5 c	17.8 bcd	12.5 c	11.7 c	22.5 d
Control	24.3 a	27.5 a	22.8 ab	29.1 a	24.8 c

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.
DBS = days before seeding.
DAS = days after seeding. # Plants killed by herbicide.

Late applications of butachlor and benthiocarb 42 days or later after seeding did not affect the tiller number. Molinate severely inhibited tiller production when applied as a preemergent but postemergent application between 28 and 42 days after seeding stimulated tillering instead, with increases of between 25 to 30% in tiller production.

Root Development

The development of the root system was indicated by the dry weight of the roots (Table 6). Herbicides that contain the 2,4-D compound severely reduced the amount of roots produced. 2,4-D amine was more deterimental to root development than 2,4-DIBE-butachlor. The other herbicides, butachlor, benthiocarb and molinate, only adversely affected root development when applied early. The application of these three herbicides later than 28 to 42 days from seeding did not significantly affect root growth.

Biological Yield

The biological yield of the plant consisted of the dry matter obtained from the entire plant. The effect of the herbicides on the biological yield is similar to that on the root development. With the exception of a few treatments, all herbicide applications resulted in a significant loss of vegetative growth (Table 7). Only late applications of butachlor and molinate, 42 to 70 days after seeding did not result in any significant reduction in dry matter production. Early applications of all herbicides were especially deterimental to plant dry matter accumulation.

Panicle Emergence

Application of the herbicides significantly delayed panicle emergence in most treatments (Table 8). The duration from seeding to 50% panicle emergence was extended by the application of 2,4-D amine irrespective of the time of application. In the case of 2,4-DIBE-butachlor

TABLE 6
Effect of herbicide application on the mean dry weight of roots per treatment (g)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	15.0 cd	#	#	6.1 d
14 DAS	5.9 c	8.4 f	5.2 a	#	22.3 c
28 DAS	5.9 c	8.9 f	15.3 b	10.2 c	23.6 bc
42 DAS	2.5 c	10.3 ef	24.6 a	22.4 b	32.7 a
56 DAS	13.0 b	19.2 c	21.8 a	26.4 a	29.4 ab
70 DAS	12.2 b	26.2 ab	26.0 a	28.0 a	30.0 ab
4 DBS & 42 DAS	#	18.1 cd	2.5 d	#	26.4 abc
4 DBS & 56 DAS	#	25.0 ab	3.7 d	#	21.6 c
14 DAS & 70 DAS	4.9 c	13.9 de	8.4 c	11.7 c	24.1 bc
Control	28.1 a	35.0 a	24.5 a	29.1 a	31.2 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.

DBS = days before seeding.

DAS = days after seeding.

plants killed by herbicide.

TABLE 7
Effect of herbicide application on biological yield (g total dry matter)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	41.1 def	#	#	25.9 e
14 DAS	26.7 c	36.9 f	26.4 e	#	70.3 c
28 DAS	16.7 cd	36.0 f	57.2 c	38.2 d	76.9 bc
42 DAS	8.4 d	39.6 ef	72.4 ab	62.9 c	84.3 a
56 DAS	40.9 b	61.2 c	70.4 b	69.7 bc	75.5 bc
70 DAS	49.6 b	74.4 b	75.3 ab	80.6 b	91.7 a
4 DBS & 42 DAS	#	51.1 d	10.7 f	#	69.0 cd
4 DBS & 56 DAS	#	66.5 c	13.3 f	#	62.3 d
14 DAS & 70 DAS	20.8 c	47.9 de	38.9 d	37.8 d	70.3 cd
Control	79.9 a	95.1 a	79.5 a	84.4 a	88.8 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.
DBS = days before seeding.
DAS = days after seeding. # plants killed by herbicide.

TABLE 8
Effect of herbicide application on the time of panicle emergence (days from seeding)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	122.5 d	#	#	135.5
14 DAS	144.5 bc	139.8 a	149.3 a	#	125.5
28 DAS	149.5 ab	136.4 ab	131.8 cd	139.3 a	131.8
42 DAS	155.8 a	127.8 bcd	128.0 d	133.0 ab	127.5
56 DAS	128.5 d	121.0 d	129.3 d	129.3 ab	128.3
70 DAS	123.0 d	119.3 d	119.5 e	117.0 b	126.3
4 DBS & 42 DAS	#	124.5 d	138.5 bc	#	126.8
4 DBS & 56 DAS	#	125.3 cd	140.3 b	#	124.0
14 DAS & 70 DAS	144.3 bc	133.3 abc	134.5 bcd	139.5 a	124.5
Control	113.0 e	123.8 d	117.8 e	115.0 b	120.0

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.
Treatment means for Molinate herbicide are not significantly different at P = 0.05.
DBS = days before seeding.
DAS = days after seeding. # Plants killed by herbicide.

and benthiocarb, applications 42 days after seeding and later did not significantly affect the time of panicle emergence. Butachlor did not significantly influence panicle emergence only when applied very late at 70 days after seeding. Molinate had no significant effect on the time of panicle emergence.

Panicle Length

The length of the panicles were mainly affected by the application of 2,4-D amine which resulted in significantly shorter panicles (Table 9). 2,4-DIBE-butachlor, butachlor and benthiocarb did not significantly affect panicle length. However, applications of molinate until 42 days after seeding reduced panicle length significantly.

Spikelet Number

All herbicides affected the number of spikelets produced per panicle to varying extent (Table 10). 2,4-D amine significantly reduced the number of spikelets at all periods of application except when applied at the very late growth stage of 70 days after seeding. With 2,4-DIBE-butachlor, only applications that included an early postemergent application at 14 days after seeding significantly reduced the number of spikelets. However, butachlor by itself, reduced spikelet number significantly when the treatment included an application before seeding. In the case of molinate, applications upto 42 days after seeding caused significant reductions in spikelet number; later applications did not affect the spikelet number.

Grain Yield

The grain yield of the herbicide treated plants was generally lower than the untreated (Table 11). Severe yield depression occurred with 2,4-D amine irrespective of the time of application. The grain yield from treatments with butachlor and benthiocarb was also significantly

TABLE 9
Effect of herbicide application on panicle length (cm)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	17.5	#	#	16.7 bc
14 DAS	14.5 c	15.7	17.0	#	17.0 bc
28 DAS	15.6 bc	16.0	16.6	16.4	16.1 c
42 DAS	14.5 c	17.5	17.6	16.9	17.1 bc
56 DAS	14.7 c	17.5	17.3	16.8	17.6 ab
70 DAS	16.3 b	17.6	16.5	17.6	17.8 ab
4 DBS & 42 DAS	#	17.3	15.9	#	17.4 abc
4 DBS & 56 DAS	#	17.0	15.0	#	17.3 abc
14 DAS & 70 DAS	15.1 bc	16.9	17.8	17.4	17.3 abc
Control	18.4 a	18.0	17.6	18.1	18.7 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.

Treatment means for each of the herbicides 2,4-DIBE-butachlor, butachlor and benthiocarb are not significantly different at P = 0.05.

DBS = days before seeding.

DAS = days after seeding.

TABLE 10
Effect of herbicide application on the number of spikelets per panicle

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	51.4 ab	#	#	45.3 bc
14 DAS	39.1 bc	40.4 bc	50.2 a	#	42.3 c
28 DAS	41.6 bc	44.4 abc	49.7 a	38.8 b	42.6 c
42 DAS	33.0 c	46.6 abc	48.7 a	45.7 ab	42.9 c
56 DAS	37.2 bc	52.8 a	53.5 a	48.5 c	51.0 ab
70 DAS	47.3 ab	51.2 ab	47.4 ab	53.3 a	50.9 ab
4 DBS & 42 DAS	#	45.5 abc	39.7 bc	#	44.9 bc
4 DBS & 56 DAS	#	46.8 abc	36.6 c	#	49.0 abc
14 DAS & 70 DAS	35.5 c	39.5 c	51.3 a	49.2 a	48.2 abc
Control	54.6 a	54.4 a	54.5 a	53.1 a	53.6 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.

DBS = days before seeding.

DAS = days after seeding.

TABLE 11
Effect of herbicide application on grain yield (g)

Time of application	Herbicide				
	2,4-D amine	2,4-DIBE butachlor	Butachlor	Benthiocarb	Molinate
4 DBS	#	8.6 d	#	#	8.5 d
14 DAS	6.0 bc	8.3 d	6.8 f	#	14.2 c
28 DAS	3.4 cd	8.7 d	13.2 d	9.1 c	14.3 bc
42 DAS	2.0 d	9.1 d	13.9 cd	14.2 b	17.3 bc
56 DAS	6.5 b	12.9 c	16.4 ab	16.8 a	17.6 b
70 DAS	8.8 b	18.2 b	14.9 bc	17.4 a	17.2 bc
4 DBS & 42 DAS	#	11.6 c	1.8 g	#	16.8 bc
4 DBS & 56 DAS	#	13.9 c	3.1 g	#	15.4 bc
14 DAS & 70 DAS	3.2 cd	12.2 c	9.4 e	9.5 c	14.9 bc
Control	16.6 a	21.8 a	17.4 a	18.4 a	21.0 a

For each herbicide, means followed by the same letter are not significantly different at P = 0.05.

DBS = days before seeding.

DAS = days after seeding.

reduced except when treatment was given 56 to 70 days after seeding. Molinate caused significant yield reductions at all growth stages but was most severe when given as a preemergent.

DISCUSSION

The timing of herbicide application is an important factor in respect of the ease of application, phytotoxicity and efficiency of weed control. In direct seeded rice, early application of the herbicide is usually desirable for several reasons. The application of the herbicide before seeding is easier to carry out than at a later stage after the seedlings have emerged. Early application of the herbicide also allows weeds to be controlled from the beginning so that the growth of the rice seedlings would not be restricted. Therefore, ideally, the initial application of the herbicide should be during the preemergent stage or the early postemergent stage. Unfortunately, the study has shown that the rice crop is most susceptible to the herbicides at this early stage. At the rates studied, most of the herbicides affected the germinating seed and were rather injurious to the rice plants when applied before seeding. 2,4-D amine, butachlor and benthiocarb were extremely phytotoxic causing the death of the plants when applied before seeding. For these herbicides even the split application involving only half the amount of herbicide at each application was toxic when the first application was made prior to seeding. The susceptibility of the rice plants to herbicides during the early growth stages was also high. Only butachlor and molinate may be considered for early application during the first 4 weeks of growth. Although all the herbicides evaluated caused some temporary injury to the rice seedlings, the least injurious at this stage of growth were butachlor and molinate. The plants were able to recover from the phytotoxic symptoms within one to three weeks. The temporary injury caused setbacks in the vegetative and reproductive growth. Molinate, in general, caused the least growth and yield depression followed by butachlor. On the basis of the phytotoxic reactions of the plants, early weed control can only be carried out using butachlor or molinate if severe yield depression is to be avoided.

The plants were more tolerant to the herbicides as they grew older and consequently late postemergent application of the herbicides caused minimal crop injury and were less deterimental to growth and yield except in the case of split applications where part of the herbicide was applied early. Applications between 8 and 10 weeks after seeding were least injurious to the crop and, with the exception of herbicides containing the 2,4-D compound, affected vegetative and reproductive growth least. For many of the plant characters measured (plant height, tiller number, root dry weight, panicle length, spikelet number), there were no significant differences when compared to the untreated plants. The grain yields, however, were significantly lower than the control even though they were significantly greater than that of plants receiving early postemergent applications. Among the five herbicides, molinate has been found to be the least damaging to the rice plant and postemergent applications later than 2 weeks after seeding were as safe as later applications on the basis of vegetative development as well as grain yield. Butachlor and benthiocarb were more suitable for late applications to rice plants more than 4 weeks old. Benthiocarb, however, should not be applied before seeding or within 2 weeks of seeding as it is extremely phytotoxic at this stage. 2,4-D herbicides appeared to be rather phytotoxic to rice plants even though it is a common herbicide for the control of broadleaf weeds in rice. This herbicide caused severe depressions on growth and yield irrespective of the time of application. Applications of 2,4-D herbicides carried out as late as 10 weeks after seeding even resulted in yield depressions up to half the grain yield of untreated plants.

Herbicides to be effective must be phytotoxic and it is only natural that the crop on which it is used suffer from some of the effect of this phytotoxic quality. The degree of damage depend upon the selectivity of the herbicide which may be biological, chemical or physical. Therefore, even though a herbicide has been found to cause some phytotoxic reaction on the crop, its potential use in the crop would depend upon the relative benefits to be obtained from its use compared to the effect of alternative weed

control methods or the effect of weed infestation. Among the herbicides studied, 2,4-D amine was the most phytotoxic, but inspite of this, it is widely used as a postemergent broadleaf herbicide in flooded rice. Its benefits in the control of weeds must have been considerable and outweighs its toxic effect and yield depression.

The safest time to apply the herbicide may not be the optimum time for weed control application. It merely indicates the time of application least likely to damage the crop at a given rate. For efficient weed control and minimal crop damage the phytotoxicity information should therefore, be used in conjunction with weed control data before a herbicide may be recommended for use.

CONCLUSION

The herbicides 2,4-D amine, 2,4-DIBE-butachlor, butachlor, benthiocarb and molinate caused severe seedling and plant injury when applied prior to seeding. 2,4-D amine, butachlor and benthiocarb were lethal to the rice plants when applied 4 days before seeding.

Early postemergent application was less injurious than the preemergent application but caused temporary injury leading to depression of vegetative and reproductive growth. Only molinate and butachlor may be considered for application during the first 4 weeks of growth.

Late postemergent application of the herbicides had the least phytotoxic effect. Applications 8 to 10 weeks after seeding caused less plant damage and yield depression than earlier treatments but plant growth and yield were significantly poorer than with untreated plants.

Molinate was found to be the least injurious among all the herbicides evaluated. Applications 2 weeks after seeding were similar to later applications in terms of vegetative growth and grain yield.

REFERENCES

BAKI, B.B. (1982a): Weed problems in principal rice-growing areas in Peninsular Malaysia: A preliminary diagnosis. Rice branch, MARDI, 15 pp.

BAKI, B.B. (1982b): Weed management in direct seeding. Workshop on direct seeded rice, MARDI. 43 pp.

MARDI, (1982). Annual report, Malaysian Agricultural Research and Development Institute, Serdang, Selangor.

SAHARAN, H.A. (1977): Rice weed control in Malaysia. *Proc. Rice Review,* MARDI. pp. 250 – 258.

(Received 20 May, 1985)