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Herbicide combinations for early post-emergence applications in direct-seeded rice

(Kombinasi racun herba untuk penggunaan awal lepas cambah pada tanaman padi tabur terus)

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Key words: direct-seeded rice, herbicide combination, *Echinochloa crus-galli*

Abstrak

Beberapa kombinasi racun herba diuji pada tiga musim berturut-turut, iaitu luar musim 1987, musim utama 1987/88 dan luar musim 1988 di Stesen Penyelidikan MARDI, Bumbong Lima, Seberang Perai. Kadar racun herba yang sama telah diuji pada masa penggunaan lepas cambah yang berlainan. Kadar racun herba yang digunakan dalam campuran lebih rendah daripada yang disyorkan untuk penggunaan tunggal. Keberkesanan beberapa racun herba yang digunakan secara kombinasi sama ada campuran dalam tanki atau yang sudah sedia untuk kawalan rumpai yang meluas dalam tanaman padi tabur terus telah ditentukan.

Campuran propanil, iaitu propanil + molinate (pada kadar 1.0 + 2.0 kg b.a./ha) dan propanil + bentiokarb (pada kadar 1.0 + 1.5 kg b.a./ha) yang disembur pada 8 hari selepas tabur (HLT), sangat berkesan untuk mengawal *Echinochloa crus-galli*. Untuk kawalan rumpai yang lebih meluas, quinklorak + bensulfuron (pada kadar 0.25 + 0.03 kg b.a./ha) dan molinat + 2,4-D IBE (pada kadar 2.5 + 0.75 kg b.a./ha) yang disembur pada 10-14 HLT ialah campuran racun herba yang paling berkesan. Quinklorak dan molinat berkesan untuk mengawal *E. crus-galli* manakala bensulfuron dan 2,4-D IBE berkesan untuk mengawal rumpai daun lebar dan rusiga. Campuran racun herba lain yang berpotensi termasuklah molinat + bensulfuron (pada kadar 2.5 + 0.03 kg b.a./ha) dan bentiokarb + pirazosulfuron (pada kadar 2.0 + 0.01 kg b.a./ha). Tidak terdapat kesan keracunan yang serius terhadap tanaman padi disebabkan oleh campuran racun herba kecuali campuran oxadiazon. Kesemua petak yang disembur dengan kombinasi racun herba mengeluarkan hasil yang lebih baik daripada petak yang rumpainya dikawal secara manual. Potensi penggunaan kombinasi racun herba jelas sebagai suatu pendekatan untuk kawalan rumpai secara kimia yang berkesan dalam tanaman padi tabur terus.

Abstract

Several herbicide combinations were tested in three consecutive seasons viz. off season 1987, main season 1987/88 and off season 1988 at the MARDI Research Station, Bumbong Lima, Seberang Perai. Similar dosages of herbicides were studied with varied time of post-emergence applications. The rate of each herbicide used in mixtures was lower than that recommended for singular applications. The efficacy of several herbicides applied in combination either as a tank-mix or proprietary mixture as a broad spectrum weed control in direct-

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seeded rice was determined.

Propanil mixtures i.e. propanil + molinate (at 1.0 + 2.0 kg a.i./ha) and propanil + benthiocarb (at 1.0 + 1.5 kg a.i./ha) applied 8 days after sowing (DAS) were very effective against *Echinochloa crus-galli*. For a wide spectrum of control, quinclorac + bensulfuron (at 0.25 + 0.03 kg a.i./ha) and molinate + 2,4-D IBE (at 2.5 + 0.75 kg a.i./ha) applied 10-14 DAS were the most effective herbicide mixtures. Quinclorac and molinate were effective against *E. crus-galli*, whereas bensulfuron and 2,4-D IBE were effective in controlling broadleaved weeds and sedges. Other promising herbicide mixtures include molinate + bensulfuron (at 2.5 + 0.03 kg a.i./ha) and benthiocarb + pyrazosulfuron (at 2.0 + 0.01 kg a.i./ha). No serious crop toxicity was caused by the herbicide mixtures tested except oxadiazon mixtures. All the herbicide combination-treated plots produced better yields compared with those of hand-weeded plots. The potential use of herbicide combinations is apparent as one of the better approaches for effective chemical weed control in direct-seeded rice.

Introduction

Previously, rice in Peninsular Malaysia was mainly transplanted manually. The direct seeding technique of rice cultivation began to make inroads into irrigated lowland rice environments in the late 1970s. Since then, it has been adopted as a practice by farmers in major rice growing areas. Pregerminated or dry seeds are mainly hand broadcast and to some extent drill sown. Presently, about 35-45% of the total padi area is direct seeded annually. Insufficient labour and high cost of production are the main reasons as to why farmers prefer direct seeding to manual transplanting.

The change to direct seeding practice from transplanting has brought about a shift in weed flora (Azmi 1985; Ho and Md. Zuki 1988). The range of weeds in direct-seeded rice is much wider than those in transplanted rice. The major weeds in transplanted rice are broadleaved weeds (viz. *Monochoria vaginalis, Sagittaria guyanensis* and *Ludwigia hyssopifolia*) and sedges (viz. *Scirpus grossus, Fimbristylis miliaceae* and *Scirpus juncoides*). A wider range of weeds, especially those of grasses, are found infesting direct-seeded fields with *Echinochloa crus-galli* being the most dominant species. It establishes before the rice is flooded, and persists throughout the crop season, causing considerable reductions in grain yields.

Weed control is a major problem in direct-seeded rice because the rice seeds germinate at the same time as the weed seeds. Under such circumstances, it is extremely difficult to carry out manual weeding when seeds are broadcast. A suitable alternative to manual weeding is through the use of proper herbicides (Lo et al. 1987). Phenoxy compounds (2,4-D) which used to be sufficiently effective in transplanted rice (Saharan 1979) were no longer suitable with changes of weed flora that came with direct seeding.

Results obtained from a single-herbicide application in direct-seeded rice have been variable. Presently, molinate (3.0 kg a.i./ha) when applied at 7 days before sowing (DBS), 7 or 14 days after sowing (DAS) has been proven to be specifically effective against *E. crus-galli* (Lim and Azmi 1986). Propanil is effective against grassy weeds under dry conditions when the weeds are at the two to three-leaf stage (Mukhopadhyay 1983) whilst fenoxaprop-ethyl is effective in a wide range of post-emergence applications (Kuah and Salehuddin 1988). Benthiocarb, pretilachlor, quinclorac and oxadiazon (Lo 1988; Ooi 1988; Ooi and Cheong 1988 ; Weerd et al. 1988) are effective against grasses, certain sedges and broadleaved weeds when applied

during early post-emergence. Bensulfuron is only good in controlling sedges and broadleaved weeds (Chang 1988). Therefore, it is a good choice for use in combination with herbicides which have better efficacy against grassy weeds. Prolonged usage of one particular herbicide like 2,4-D in the past could lead to a shift in the weed flora where certain weeds, especially many grass species, developed resistance. The use of herbicide combinations is, therefore, appropriate in controlling various species of weeds.

Generally, a single application of a preemergence herbicide has not given sustainable weed control in direct-seeded rice. The use of herbicide combinations, whether the herbicides are applied simultaneously (tank-mixed) or sequentially, generally improves weed control compared with single-herbicide applications. Azmi and Anwar (1987) reported that post-emergence applications of quinclorac + bensulfuron at 10 DAS, and molinate + 2,4D IBE applied at 14 DAS controlled more weed species than a single application of either quinclorac or molinate.

A study was carried out to determine the efficacy of several herbicides applied in combination either as a tank-mix or proprietary mixture as a broad spectrum weed control in direct-seeded rice.

Materials and methods

The experiments were conducted during the off season 1987, main season 1987/88 and off season 1988 using MR 84 cultivar. The pregerminated seeds were broadcast onto puddled soil at a seed rate of 60 kg/ha.

The herbicide combinations tested, as in *Table 1,* were compared with single herbicide application treatments viz. fenoxaprop-ethyl for off season 1987 and main season 1987/88, and CGA 142464 (setoff) for main season 1988 experiments. Two more treatments i.e. two rounds of manual weeding at 20 and 40 DAS, and unweeded checks were included as comparison.

For each experiment, the treatments were replicated four times using 5 m x 5 m plots in a randomized complete block design. A fertilizer rate of 60 kg N, 40 kg P_2O_5 and 40 kg K_2O was applied at 15 DAS, and two applications of 20 kg N were made at maximum tillering and booting stage. Recommended insecticides were applied as necessary to control insect pests.

The phytotoxicity on the plant was visually assessed at 10 days after application of the herbicides. A crop injury rating of 0 to 10 was used in which 0 indicated no injury and 10 represented extensive damage leading to the death of plants. Weeds sampled outside a 4 m x 4 m area from four 50 cm x 50 cm quadrats per plot at 60 DAS were separated into sedges, grasses and broadleaved weeds, and dried at 80 °C for at least 48 h for weight determination. Yield data were obtained from the centre of the 4 m x 4 m area of each plot. Grain yield samples were converted to kilogram per hectare at 14% moisture.

Results and discussion

The major weed species present in the three experiments were essentially similar, with the grassy weed *E. crus-galli* predominating, particularly in the off season 1988 *(Figure 1).* The broadleaved weeds found were *M. vaginalis, Sagittaria guyanensis, Bacopa rotundifolia* and *L. hyssopifolia.* Those for sedges included *Cyperus iria, Scirpus juncoides, F. miliacea* and *Scirpus grossus.*

Echinochloa crus-galli was the most competitive weed in the area studied. The crop yield obtained in the unweeded plots was 2 376, 3 203 and 1 030 kg/ha for the off season 1987, main season 1987/88 and off season 1988 respectively. In these seasons, the yields obtained were inversely proportional to the presence of *E. crus-galli* at 52.5, 49.8 and 61.9% respectively. The higher the proportion of *E. crus-galli,* the lower the yield. This varied proportion of weed might be dependent on the water availability during crop establishment.

Table 1. Herbicide treatments for three consecutive seasons, MARDI Research Station, Bumbong Lima, Seberang Perai

Treatment	Rate (kg a.i./ha)	Time of application (DAS)		
		Off season 1987	Main season 1987/88	Off season 1988
Benthiocarb / 2,4-D IBE	2.0	7	11	9
Propanil + benthiocarb	1.0 + 1.5	8	12	10
Propanil + 2,4-D IBE	1.5 + 0.75	8	12	nt
Oxadiazon / propanil	1.0 + 1.0	8	14	nt
Propanil + quinclorac	1.5 + 0.25	nt	nt	10
Propanil / molinate	1.0 + 2.0	8	12	10
Oxadiazon + 2,4-D IBE	1.0 + 1.0	10	14	nt
Oxadiazon + bensulfuron	1.0 + 0.03	10	14	nt
Oxadiazon / propanil	1.0 + 2.0	8	14	nt
CGA 142464	0.04	nt	nt	8
Quinclorac + CGA 142464	0.2 + 0.02	nt	nt	8
Metsulfuron / 2,4-D Na salt	0.005 + 0.75	nt	nt	20
Quinclorac + bensulfuron	0.25 + 0.03	10	14	12
Quinclorac + 2,4-D IBE	0.25 + 0.75	10	14	12
Molinate + bensulfuron	2.5 + 0.03	8	12	10
Molinate + 2,4-D IBE	2.5 + 0.75	10	14	12
Pretilachlor + bensulfuron	0.5 + 0.03	4	8	6
Piperophos + bensulfuron	1.00 + 0.03	7	11	9
EPTC / 2,4-D IBE	0.8 + 0.40	10	14	12
Butachlor + bensulfuron	0.75 + 0.03	7	11	9
Butachlor + 2,4-D IBE	0.75 + 0.75	7	11	nt
Pyrazosulfuron + benthiocarb	0.01 + 2.0	nt	nt	10
Pyrazolate + propanil	3.0 + 1.0	8	12	10
Fenoxaprop-ethyl + bensulfuron	0.1 + 0.03	nt	nt	16
Fenoxaprop-ethyl	0.10	12	14	nt
Weeding at 20 & 40 DAS				
Unweeded check				

/ means that the herbicides were formulated as a proprietary mixture
+ means that the herbicides were tank-mixed and applied at the same time
DAS = days after sowing
nt = not tested

Usually, the season with plenty of water available through rainfall i.e. during the main season exhibited reduced emergence of *E. crus-galli* but encouraged growth of more broadleaved weeds.

In off season 1987, plots treated with herbicides and those handweeded, produced higher yields than the untreated check *(Table 2)*. The handweeded plots yielded the highest. All herbicide combinations, except oxadiazon + propanil, oxadiazon + 2,4-D IBE and EPTC + 2,4-D IBE, produced yields not significantly different from the hand-weeded plots. This was due to excellent control of various types of weeds. All herbicide combinations also resulted in superior yields than the single-herbicide treatment. Fenoxaprop-ethyl alone gave better control on grasses but poor control on sedges and broadleaved weeds. In addition, it also caused severe reduction in crop stand, resulting in lower yields which were slightly more than that of the unweeded checks.

In main season 1987/88, all herbicide treatments produced better yields than those of unweeded plots *(Table 3)*. The herbicide combinations tested gave excellent weed control, with quinclorac + bensulfuron producing the highest yields. Other herbicide combinations viz. molinate and propanil mixtures, quinclorac + 2,4-D IBE, butachlor + bensulfuron, pretilachlor + bensulfuron and oxadiazon + 2,4-D IBE, produced yields not significantly different from that of

Table 2. Effect of herbicide mixtures on the weeds and direct-seeded rice MR 84 cultivar at Bumbong Lima, Seberang Perai, off season 1987

Treatment	Visual toxicity rating#	Weed wt. (g/m²) at 60 DAS			Grain yield (kg/ha)
		Broadleaved	Sedges	Grasses	
Benthiocarb / 2,4-D IBE	1	34.0bcd	49.0bcd	146.2ab	3 799abcd
Propanil + benthiocarb	1	45.8bc	8.2cde	37.0bcdef	4 911a
Propanil + 2,4-D IBE	3	3.9def	93.8bc	168.3ab	3 813abcd
Oxadiazon / propanil	5	23.9cde	96.8ab	184.0a	2 672cde
Propanil / molinate	1	95.6ab	33.4bcde	18.8cdef	4 802a
Oxadiazon + 2,4-D IBE	6	5.3def	0.8de	20.2cdef	3 065bcde
Oxadiazon + bensulfuron	5	3.2ef	3.5de	118.6abcd	3 928abc
Quinclorac + bensulfuron	1	6.4def	13.1cde	0 f	4 629a
Quinclorac + 2,4-D IBE	1	5.1def	1.9de	0 f	4 188ab
Molinate + bensulfuron	1	3.8def	2.5de	80.6abcde	3 979abc
Molinate + 2,4-D IBE	1	16.1cdef	11.5cde	14.7def	4 380ab
Pretilachlor + bensulfuron	1	0.1f	0.1e	78.7abcdef	4 574a
Piperophos + bensulfuron	1	0.7f	0.7e	60.0abcdef	4 470ab
EPTC / 2,4-D IBE	1	26.3cde	29.9bcde	108.2abcd	3 090bcde
Butachlor + bensulfuron	3	0.7f	11.9cde	52.2abcdef	4 129ab
Butachlor + 2,4-D IBE	3	31.7bcd	14.8cde	59.7abcdef	4 196ab
Pyrazolate + propanil	1	9.5def	0.9de	37.8bcdef	4 032abc
Fenoxaprop-ethyl	7	136.8a	128.8a	4.6ef	2 509de
Weeding at 20 & 40 DAS	-	4.3def	0.5e	0.9ef	5 023a
Unweeded check	-	62.8bc	81.7bc	160.0ab	2 376e

/ means that the herbicides were formulated as a proprietary mixture
+ means that the herbicides were tank-mixed and applied at the same time
# Rated at 10 days after application on a scale of 1-10 where 1 = no toxicity and 10 = complete kill
DAS = days after sowing
Means in each column with same letter are not significantly different at the 5% level

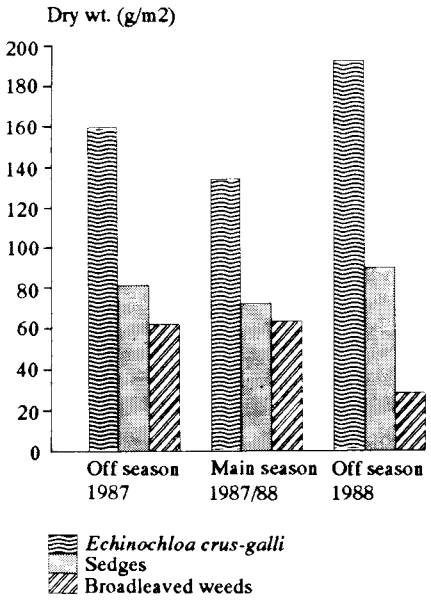

Figure 1. Weed regrowth in unweeded plots

handweeded plots. Fenoxaprop-ethyl again failed to control the weeds adequately and the yields obtained were not significantly different from the unweeded check. This was due to its poor control on sedges and broadleaved weeds apart from causing severe phytotoxic effect at rating 6 to 7 on rice plants even though it was applied at 14 DAS.

The weed population in off season 1988 was different from the previous two seasons in which a high proportion of the total dry weight was recorded for *E. crus-galli* in the unweeded plots. The yields obtained in herbicide-treated plots were related to the efficacy in controlling *E. crus-galli.* All herbicide-treated plots produced higher yields than the unweeded checks *(Table 4).* Quinclorac + bensulfuron mixtures gave a wide spectrum of weed control resulting in the highest yield obtained. Other promising herbicides

Table 3. Effect of herbicide mixtures on the weeds and direct-seeded rice MR 84 cultivar at Bumbong Lima, Seberang Perai, main season 1987/88

Treatment	Visual toxicity rating#	Weed wt. (g/m²) at 60 DAS			Grain yield (kg/ha)
		Broadleaved	Sedges	Grasses	
Benthiocarb / 2,4-D IBE	1	36.7abc	10.9c	185.9b	3 706e
Propanil + Benthiocarb	1	34.6abc	17.7bc	66.3cd	4 917abcd
Propanil + 2,4-D IBE	1	4.2c	2.4c	109.6bcd	5 031abcd
Oxadiazon / propanil	4	66.2a	23.1bc	187.0b	4 291cde
Propanil / molinate	1	46.3abc	7.0c	0.0d	5 954a
Oxadiazon / 2,4-D IBE	6	1.4c	0.1c	120.6bcd	4 585abcde
Oxadiazon + bensulfuron	6	7.3bc	0.1c	318.1a	3 770de
Quinclorac + bensulfuron	1	2.6c	2.9c	0.0d	6 022a
Quinclorac + 2,4-D IBE	1	13.7bc	10.5c	5.1d	5 810abc
Molinate + bensulfuron	1	2.9c	1.4c	0.0d	5 687abc
Molinate + 2,4-D IBE	1	47.4abc	17.6bc	4.6d	5 973a
Pretilachlor + bensulfuron	1	0.4c	34.5abc	8.5d	5 931ab
Piperophos + bensulfuron	1	2.4c	1.3c	47.0cd	5 609abc
EPTC / 2,4-D IBE	1	13.9bc	21.2bc	64.2cd	5 302abc
Butachlor + bensulfuron	1	0.4c	0.0c	47.1cd	5 681abc
Butachlor + 2,4-D IBE	1	12.0bc	6.5c	65.9cd	4 391bcde
Pyrazolate + propanil	1	4.8c	1.1c	23.3cd	5 924ab
Fenoxaprop-ethyl	6	53.9ab	55.3ab	1.6d	3 770de
Weeding at 20 & 40 DAS	-	3.6c	0.1c	1.2d	5 993a
Unweeded check	-	63.7a	72.2a	134.6bc	3 203e

/ means that the herbicides were formulated as a proprietary mixture
+ means that the herbicides were tank-mixed and applied at the same time
# Rated at 10 days after application on a scale of 1-10 where 1 = no toxicity and 10 = complete kill
DAS = days after sowing
Means in each column with same letter are not significantly different at 5% level

included all bensulfuron mixtures except piperophos, propanil mixtures, quinclorac + CGA 142464, and pyrazosulfuron + benthiocarb which gave yields not significantly different from that of handweeded plot. CGA 142464 alone gave better control on sedges and broadleaved weeds, and moderately controlled *E. crus-galli*. This herbicide appears promising for mixing with other herbicides which have better efficacy on *E. crus-galli* for a broader weed control spectrum.

The timing of application was important in determining the effectiveness of a particular herbicide combination. Weed control was effective with early application at 7 DAS, but it was usually toxic to rice crop. Late application, at 14 DAS, was good for crop growth but it was usually less effective in controlling the desired weeds. The period between 7 and 14 DAS was found suitable for effective weed control for most herbicides with respect to toxicity to rice plants. Fenoxaprop-ethyl and oxadiazon mixtures were the only herbicides that caused serious injury to rice crop when applied during this period. Fenoxaprop-ethyl mixture still gave serious crop injury even though it was applied as late post-emergence up to 16 DAS. However, the crop injury disappeared 2-3 weeks after herbicide application and subsequent vegetative growth of rice was not adversely affected. The herbicides which showed good weed control efficacies and were less injurious to crop could be applied earlier than 14 DAS.

Results also indicated that herbicide combinations generally gave an additive effect and could control weeds up to 60 DAS. In addition, these herbicide combinations showed ability to control a wider spectrum of weeds than each of the combination components.

Table 4. Effect of herbicide mixtures on the weeds and direct-seeded rice MR 84 cultivar at Bumbong Lima, Seberang Perai, off season 1988

Treatment	Visual toxicity rating#	Weed wt. (g/m^2) at 60 DAS			Grain Yield (kg/ha)
		Broadleaved	Sedges	Grasses	
Benthiocarb / 2,4-D IBE	1	23.0bcde	16.8cde	267.4a	2 457d
Propanil + Benthiocarb	1	28.9abc	58.3abc	147.2abc	3 119cd
Propanil + quinclorac	1	54.8a	19.6bcde	0.0e	3 791abc
CGA 142464	1	3.5defg	0.7e	69.0cde	4 019abc
Propanil / molinate	1	66.9a	21.1bcde	7.3de	3 965abc
Quinclorac + CGA 142464	1	2.3efg	18.2bcde	0.0e	4 247abc
Metsulfuron / 2,4-D Na salt	1	0.4fg	56.1abc	164.6abc	3 353bcd
Quinclorac + bensulfuron	1	0.1g	20.9bcde	0.0e	4 686a
Quinclorac + 2,4-D IBE	1	11.1bcdefg	16.1cde	0.0e	4 197abc
Molinate + bensulfuron	1	8.0cdefg	5.0e	2.0e	4 505ab
Molinate + 2,4-D IBE	1	71.5a	19.7bcde	0.0e	4 148abc
Pretilachlor + bensulfuron	1	0.5fg	2.8e	177.4abc	3 920abc
Piperophos + bensulfuron	1	0.0g	3.0e	272.0a	2 594d
EPTC / 2,4-D IBE	1	39.8ab	31.0abcd	147.2abc	2 412d
Butachlor + bensulfuron	1	1.7efg	18.1cde	100.8bc	3 820abc
Pyrazosulfuron + benthiocarb	1	0.0g	0.0e	8.4de	4 430ab
Pyrazolate + propanil	1	29.9abc	7.5de	95.1bcd	3 599abcd
Fenoxaprop-ethyl + bensulfuron	5	14.9bcde	63.7abc	6.6de	3 773abc
Weeding at 20 & 40 DAS	-	2.7defg	2.1e	7.1de	3 985abc
Unweeded check	-	28.4abc	90.2a	192.5ab	1 030e

/ means that the herbicides were formulated as a proprietary mixture
+ means that the herbicides were tank-mixed and applied at the same time
# Rated at 10 days after application on a scale of 1-10 where 1 = no toxicity and 10 = complete kill
DAS = days after sowing
Means in each column with same letter are not significantly different at 5% level

Conclusions

Combinations of herbicide in a mixture or in sequential application were more effective than treatment with only one herbicide. When grassy weeds developed in rice fields because of improper cultural management system, timely application of effective rates of molinate, quinclorac, propanil, fenoxaprop-ethyl, pretilachlor or benthiocarb was able to reduce losses from such weeds. Likewise, when sedges and broadleaved weeds infested rice fields, timely treatment with bensulfuron, pyrazosulfuron, CGA 142464 or 2,4-D herbicides could significantly reduce damage inflicted by them. Combining one of the herbicides for grassy weed control with one of the herbicides for sedges and broadleaved weed control, enhanced an additive effect with a broader spectrum of weed control and thus resulting in higher yields.

The herbicide combinations for post-emergence applications recommended for use in direct-seeded rice for a broader weed control spectrum are

- quinclorac + bensulfuron (at 0.25 + 0.03 kg a.i./ha),
- molinate + 2,4-D IBE (at 2.5 + 0.75 kg a.i./ha),
- molinate + bensulfuron (at 2.5 + 0.03 kg a.i./ha) and
- benthiocarb + pyrazosulfuron (at 2.0 + 0.01 kg a.i./ha).

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