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Quinclorac and bensulfuron – potential herbicides for direct-seeded rice

(Quinklorak dan bensulfuron – racun herba yang berpotensi untuk tanaman padi tabur terus)

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Key words: direct seeding, quinclorac, bensulfuron, molinate + 2,4–D IBE, *Echinochloa crus-galli*

Abstrak

Dua jenis racun herba yang baru, quinklorak atau nama kod BAS 514..H dan bensulfuron atau nama kod DPX-F5384 telah diuji. Seperti molinat pada kadar 3.0 kg a.i./ha + 2,4-D Isobutil ester (IBE) pada kadar 1.0 kg a.i./ha, quinklorak pada kadar 0.25 kg a.i./ha digunakan 10 hari selepas tabur (HLT) didapati berkesan mengawal *Echinochloa crus-galli* (L.) Beauv; manakala bensulfuron pada kadar 0.03 kg a.i./ha tidak berkesan. Walaupun quinklorak dan bensulfuron menyebabkan kesan fitotoksik yang sedikit terhadap anak benih padi buat sementara waktu, kawalan rumpai yang meluas telah dicapai dengan kombinasi penggunaan kedua-duanya. Sungguhpun quinklorak boleh dijadikan alternatif selepas molinat + 2,4-D IBE, kombinasinya dengan bensulfuron boleh dijadikan pilihan yang baik bila kawalan terhadap rusiga juga diperlukan. Hasil padi didapati lebih bergantung terhadap keberkesanan pengawalan *E. crus-galli* dengan racun-racun herba yang diuji.

Abstract

Two new herbicides, quinclorac or known as BAS 514..H and bensulfuron or known as DPX-F5384 were evaluated. Quinclorac at 0.25 kg a.i./ha, applied 10 days after sowing (DAS) completely controlled *Echinochloa crus-galli* whose efficacy was comparable to that of molinate at 3.0 kg a.i./ha + 2,4-D Isobutyl ester (IBE) at 1.0 kg a.i./ha whilst bensulfuron at 0.03 kg a.i./ha did not provide any control. Both quinclorac and bensulfuron caused slight, but temporary phytotoxic effect on rice seedlings, control of a broader spectrum of weed species was achieved when applied as mixtures. Although quinclorac could well be an alternative choice over that of molinate + 2,4-D IBE, its application in combination with bensulfuron would be a better substitute if the control for sedges was also needed. Grain yield was largely dependent on the efficacy of control of *E. crus-galli* with the tested herbicides.

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Introduction

A change of rice culture to direct seeding from transplanting has brought about a shift in rice weed community. Grassy weeds, especially *Echinochloa crus-galli* (L.) Beauv., has become increasingly important. Yield reduction of as much as 41% has been reported to be caused by *E. crus-galli* competition alone and when present together with other weed species a greater yield loss is experienced (Azmi 1985). Molinate at 3.3 kg/ha when applied 7 days before seeding (DBS) or 14 days after sowing (DAS) has been shown to be effective (Lim and Azmi 1985). However, the current recommended practice is to combine molinate with a phenoxy herbicide, such as 2,4-D IBE for a broader spectrum of control (Anwar 1986).

Quinclorac (3,7-dichloro-8-quinolinecarboxylic acid), a new herbicide of BASF Aktiengesellschaft, commonly known as BAS 514..H, has been reported to be effective against *Echinochloa* spp. when applied at germination to tillering stage. The rate suggested ranges between 0.15 and 1.0 kg/ha depending on the climatic environment, rice culture and the growth stage of *Echinochloa* spp. (Menck et al. 1985). Haden et al. (1985) and Carrol and Crawford (1985) also found quinclorac to be an outstandingly effective herbicide against *Echinochloa* spp. at 2–3 leaf stage when applied alone at 0.5–1.0 kg/ha. The chemical acts mainly via the soil on germinating and emerging *Echinochloa* plants. When it was applied onto saturated or dry soil, herbicidal efficiency was improved by raising the water level for a short period after aplication. Quinclorac can also be applied in combination with many other herbicides such as bensulfuron to provide a broader spectrum of weed control.

Bensulfuron (methyl-2-[[(4,6-dimethoxpyrimidin-2-yl) amino-carbonyl] aminosulfonyl methyl] benzoate) or commonly known in coded form as DPX-F5384, is used as pre-emergence and early post-emergence herbicide in rice. It gave good control on broadleaves and sedges when used at 0.03 or 0.04 kg/ha (Peudpaichit et al. 1985).

The objective of this study was to evaluate quinclorac and bensulfuron, alone and as tank-mixture, to control weeds in direct-seeded rice.

Materials and methods

This study was carried out at the experimental field in MARDI Rice Research Station, Bumbong Lima, Seberang Perai during the off-season 1986. Molinate + 2,4-D IBE was included as standard treatment beside the weedy (unweeded) check. The details of the herbicide treatments and their rates used are given in *Table 1*.

Table 1. Herbicide treatments

Herbicide	Rate (kg a.i./ha)
Quinclorac + Bensulfuron	0.20 + 0.02
Quinclorac + Bensulfuron	0.25 + 0.02
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Quinclorac + Bensulfuron	0.25 + 0.03
Quinclorac + Bensulfuron	0.30 + 0.03
Bensulfuron alone	0.03
Quinclorac alone	0.25
Molinate + 2,4-D IBE	3.0 + 1.0
Unweeded (check)	

The experiment was arranged in a randomised complete block design replicated three times. Each treatment plot measuring 5 m x 5 m was suitably bunded with soil. Pre-germinated seeds of rice cultivar MR 84 were sown on May 10, 1986 at the rate of 60 kg/ha. The field was inundated at 7 DAS and maintained thereafter at 3 cm to 10 cm level. Herbicides were applied at 10 DAS.

Fertilizer was applied at the rate of 40 kg N, 40 kg K_2O and 40 kg P_2O_5 per hectare as top dressing at 15 DAS. Further application of N at 60 kg N/ha was equally split at 50 DAS and 80 DAS. Crop

Table 2. Visual assessment of phytotoxicity of herbicides and seedling density of MR 84 cultivar

Treatment	Rate (kg a.i./ha)	Crop density (no./m^2)*	Crop toxicity rating**
Quinclorac + Bensulfuron	0.20 + 0.02	152.8abc	3.0
Quinclorac + Bensulfuron	0.25 + 0.02	113.0bcd	3.3
Quinclorac + Bensulfuron	0.30 + 0.02	81.7d	3.5
Quinclorac + Bensulfuron	0.20 + 0.03	104.5cd	3.0
Quinclorac + Bensulfuron	0.25 + 0.03	115.7bcd	3.3
Quinclorac + Bensulfuron	0.30 + 0.03	99.7cd	3.8
Bensulfuron alone	0.03	178.7a	1.7
Quinclorac alone	0.25	113.7bcd	3.0
Molinate + 2,4-D IBE	3.0 + 1.0	83.3d	3.8
Unweeded (check)	–	160.7ab	0

*Taken 10 days after herbicides application from 1 m x 1 m quadrat sampling.
**Rated 7–14 days after herbicides application on a scale of 0–10 where 0 = no toxicity and 10 = complete kill. Means followed by a common letter within a column are not significantly different at the 5% level of probability according to DMR test.

protection measures were carried out as and when necessary.

The effect of the herbicides on rice plants was evaluated. Visual assessments of phytotoxicity was carried out between 7 days and 14 days after application of the herbicides. A crop injury rating from 0 to 10 was used in which 0 indicated no injury and 10 represented extensive damage leading to death of plants. Plant density was assessed by 1 m x 1 m quadrat randomly placed at three locations in each plot at 20 DAS, and plant height and tiller numbers were measured at various stages during the growth period and at maturity of the crop.

The effect of the herbicides on weeds was assessed at 60 DAS by random sampling. Weed distribution in the field was considered as random and that species distribution was normal. Three 1 m x 1 m quadrats were placed in each plot and weeds collected were separated into broadleaves, sedges, *E. crus-galli* and other grasses. The weed samples were then oven dried at 70 °C for 60 h to determine their dry weights.

All assessments on crop performance during the growing stages and weed sampling were made within the 1-m wide border rows in each plot, whilst the remaining area of 4 m x 4 m was allocated for grain yield determination at harvest. This was done to minimise unnecessary disturbance to the crop.

Results

Phytotoxicity to rice plants

Rice seedlings from all the herbicide-treated plots showed varying degrees of injury 7 days after application *(Table 2)*. There was no marked difference in the extent of damage for the six herbicide mixtures of quinclorac + bensulfuron. Quinclorac was relatively more toxic than bensulfuron when applied singly at the rates tested. Increasing the dosage of quinclorac in the mixture with bensulfuron from 0.2 or 0.3 kg/ha caused a corresponding increase in the phytotoxic effect on the rice plants. The herbicide mixture with the highest rates caused the most damage similar to that shown by molinate + 2,4-D IBE.

Table 3. Effect of herbicides on plant height and tiller number of direct-seeded MR 84 rice cultivar

Treatment	Rate (kg a.i./ha)	Plant height (cm)				Tiller number /0.25 m x 0.25 m			
		30 DAS*	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Quinclorac + Bensulfuron	0.20 + 0.02	45.8	79.9	94.5	109.6a	31.9	31.3	31.4	29.5abc
Quinclorac + Bensulfuron	0.25 + 0.02	45.5	78.8	91.9	106.2a	30.0	30.7	33.9	32.6ab
Quinclorac + Bensulfuron	0.30 + 0.02	42.9	78.1	91.4	108.7a	26.7	30.5	30.6	29.4abc
Quinclorac + Bensulfuron	0.20 + 0.03	45.3	79.3	94.2	107.4a	29.2	29.5	30.9	29.1bc
Quinclorac + Bensulfuron	0.25 + 0.03	45.8	79.0	91.5	105.9a	34.0	34.3	35.9	34.2a
Quinclorac + Bensulfuron	0.30 + 0.03	44.7	79.5	91.7	106.2a	27.5	28.6	31.9	30.8abc
Bensulfuron alone	0.03	47.8	80.8	91.3	110.4a	31.4	31.9	34.3	32.8ab
Quinclorac alone	0.25	43.3	80.2	89.6	105.7a	27.9	29.8	31.7	32.1ab
Molinate + 2, 4-D IBE	3.0 + 1.0	41.1	76.1	89.9	109.5a	22.1	27.6	30.5	28.6bc
Unweeded (check)	–	45.5	76.9	89.8	99.6b	22.0	24.0	26.6	26.4c

Means followed by a common letter within a column are not significantly different at the 5% level of probability according to DMR test
*DAS – days after sowing

Table 4. Effect of herbicides on weed dry weight in direct seeded rice (MR 84 cultivar)

Treatment	Rate (kg a.i./ha)	Weed weight (g/m^2) at 60 DAS				Total biomass (g/m^2)	Proportion of *E. crus-galli* (%)
		Broadleaves	Sedges	+Grasses	*E. crus-galli*		
Quinclorac + Bensulfuron	0.20 + 0.02	0c (100%)	9.6b (80%)	4.9b (62%)	0b (100%)	14.5	0
Quinclorac + Bensulfuron	0.25 + 0.02	0.4c (97%)	40.9a (17%)	5.1b (60%)	0b (100%)	46.4	0
Quinclorac + Bensulfuron	0.30 + 0.02	0.5c (97%)	40.0a (19%)	4.8b (63%)	1.6b (98%)	46.4	3.4
Quinclorac + Bensulfuron	0.20 + 0.03	0c (100%)	1.6b (97%)	3.6b (72%)	0b (100%)	5.2	0
Quinclorac + Bensulfuron	0.25 + 0.03	0.1c (99%)	2.5b (95%)	8.0b (38%)	0b (100%)	10.6	0
Quinclorac + Bensulfuron	0.30 + 0.03	0.2c (99%)	7.5b (85%)	8.6b (33%)	0b (100%)	16.3	0
Bensulfuron alone	0.03	0.1c (99%)	13.8b (72%)	1.8b (86%)	80.7a (0%)	96.4	83.7
Quinclorac alone	0.25	5.4b (64%)	65.7a (0%)	1.9b (85%)	0b (100%)	73.0	0
Molinate + 2, 4-D IBE	3.0 + 1.0	3.8b (75%)	8.0b (84%)	3.1b (76%)	0b (100%)	14.9	0
Unweeded (check)	–	15.1a (0%)	49.4a (0%)	12.8a (0%)	76.7a (0%)	154.0	49.8

+Excluding *E. crus-galli*. Figures in parenthesis indicate % of weed control. Means followed by a common letter within a column are not significantly different at the 5% level of probability according to DMR test

Table 5. Weed control spectrum of different herbicide treatments

Group	Weed species	Herbicide			
		Bensulfuron	Quinclorac	Bensulfuron + Quinclorac	Molinate + 2, 4-D IBE
Grasses	*Echinochloa crus-galli*	*	***	***	***
	Echinochloa colona	*	***	***	***
	Leersia hexandra	*	*	*	*
	Paspalum vaginatum	*	*	*	*
	Panicum amplexicaule	*	**	**	**
Broad-leaves	*Sagittaria guyanensis*	**	*	***	***
	Monochoria vaginalis	***	*	***	***
	Limnocharis flava	***	*	***	***
Sedges	*Scirpus juncoides*	**	*	**	**
	Scirpus lateriflorus	**	*	**	**
	Cyperus iria	*	*	*	**
	Fimbristylis miliaceae	***	*	***	**

***Good: 75–100% control,
**Moderate: 50–75% control,
*Poor: below 50% control

Seedling density

The effects of the two herbicides on seedling density of rice plants were apparent; quinclorac reduced significantly the seedling number per meter square when compared to bensulfuron *(Table 2)*. Higher rates of quinclorac in the mixture, to some extent, tended to reduce seedling density, although the differences were not significant.

Plant height and tiller number

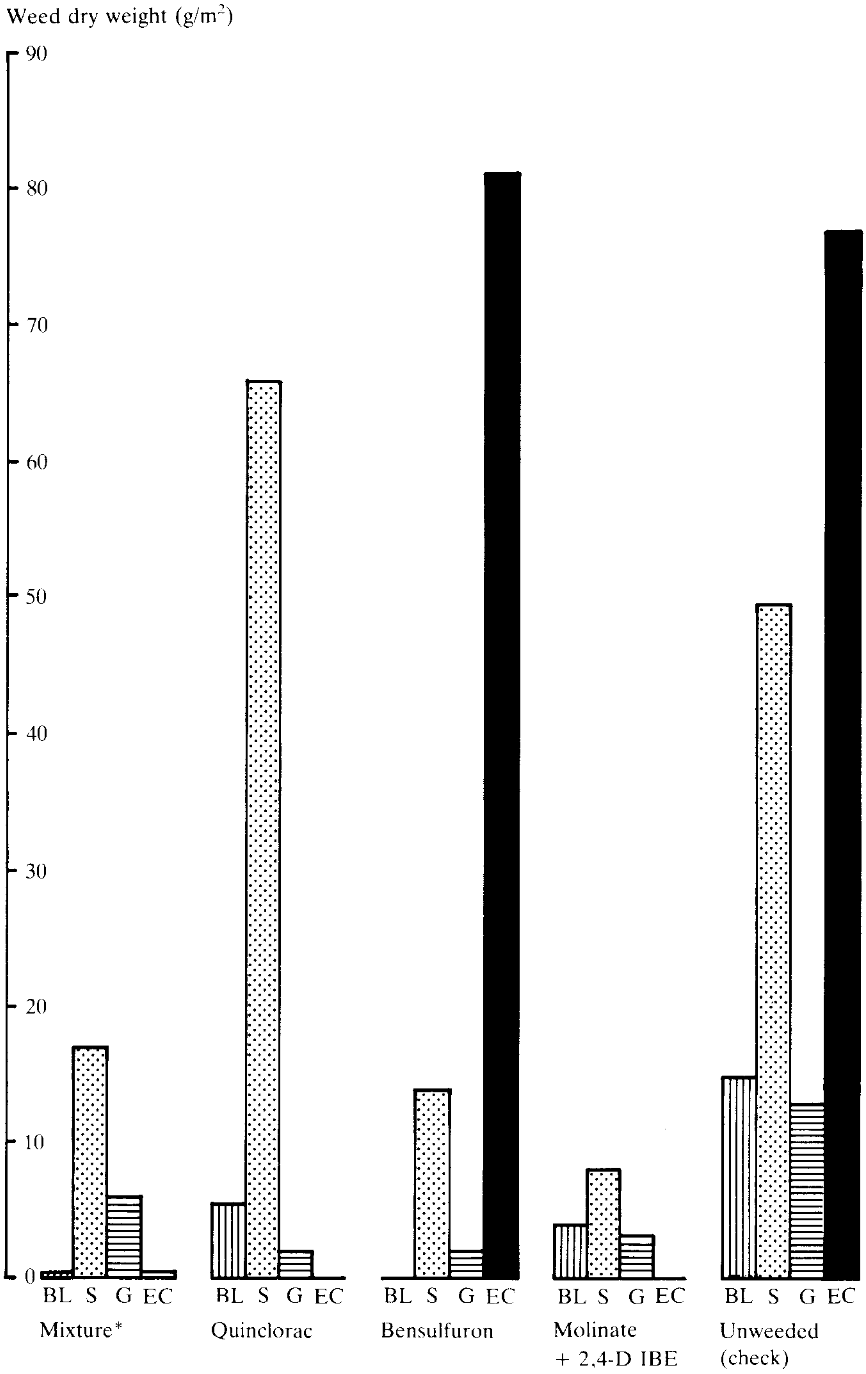
All the herbicides applied caused a significant increase in plant height of MR 84 rice cultivar over those of the unweeded check only at the 120 DAS stage *(Table 3)*. At earlier stages the differences were not at all distinct. There was no inhibition of tiller production, nor was there a significant increase from the application of both the herbicides either alone or in mixture even as late as 120 DAS when compared to that of molinate + 2,4-D IBE. However, both bensulfuron at 0.03 kg/ha and quinclorac at 0.25 kg/ha increased tillering over the untreated plot, whilst the commonly used mixture did not.

Biomass and spectrum of weed species control

Bensulfuron applied at 10 DAS at the rate of 0.03 kg/ha accorded no control over *E. crus-galli,* although its effect on other grasses, sedges and broadleaves was significantly evident *(Table 4)*. A complete control was achieved on the grass species with quinclorac. This herbicide was also more than moderately effective against other grasses and broadleaves but not against sedges which remain largely unaffected. In general, the mixtures of the two herbicides gave an almost complete control of *E. crus-galli* with a fairly wide spectrum of control on the other weed species *(Table 5)*. However, the efficacy of quinclorac and bensulfuron was not comparable to that of molinate + 2,4-D IBE particularly against sedges which was found in more than double their populations *(Figure 1)*.

Grain yield

The grain yield of all the herbicide-treated plants was significantly higher than the untreated except for plants which received straight application of bensulfuron where the yield increases from 47.3% to 65.6% *(Table 6)*. Although the highest yield was



BL – Broadleaves, S – Sedges, G – Other grasses,
EC – *E. crus-galli*

*Figure 1. Effect of herbicides on four categories of weeds at 60 DAS in the off season 1986 direct-seeded rice crop. (*For mixture of quinclorac + bensulfuron pooled averages of six treatments are included)*

Table 6. Effect of herbicides on grain yield of direct-seeded MR 84 rice cultivar cropped during off season 1986, at Bumbong Lima, Seberang Perai

Herbicide	Rate (kg a.i./ha)	Yield* (kg/ha)	% increase over unweeded plots
Quinclorac + Bensulfuron	0.20 + 0.02	5 949a	50.2
Quinclorac + Bensulfuron	0.25 + 0.02	6 242a	57.6
Quinclorac + Bensulfuron	0.30 + 0.02	6 363a	60.6
Quinclorac + Bensulfuron	0.20 + 0.03	5 835a	47.3
Quinclorac + Bensulfuron	0.25 + 0.03	6 178a	56.0
Quinclorac + Bensulfuron	0.30 + 0.03	5 982a	51.6
Bensulfuron alone	0.03	4 253b	8.6
Quinclorac alone	0.25	5 936a	49.9
Molinate + 2, 4-D IBE	3.0 + 1.0	6 570a	65.6
Unweeded (check)	–	3 915b	0

*Means followed by a common letter are not significantly different at the 5% level of probability according to DMR test

obtained with molinate + 2,4-D IBE, the value was not significantly more than those which received quinclorac or its mixtures with bensulfuron.

Discussion

In direct-seeded rice early application of herbicides either as pre-emergence or early post-emergence is usually sought for so as to allow an early control of weeds. In many instances, early applications of herbicides can cause some degree of injury to the rice crop even though timing of application is strictly followed. In this study, phytotoxicity was all too apparent on plants treated with herbicides *(Table 2)*. The usual symptoms such as yellowing and drying of leaf tips observed did not exceed 4 on a scale of 0 to 10 according to severity of the symptom. This could be considered as tolerable and transient effect since most of the affected plants were recovered within 7 to 14 days.

Quinclorac applied as early post-emergence at 10 DAS was comparatively more injurious than bensulfuron; the effect of which is reflected in the reduction of seedling number. The phytotoxicity of these herbicides was slightly dose dependent. Even this may be so, the crop density was relatively higher than plants that were treated with the commonly used mixture of molinate + 2,4-D IBE. The fact that neither quinclorac nor bensulfuron had any deleterious influence on the vegetative growth of rice plants when compared with those treated with molinate + 2,4-D IBE further indicated the low phytotoxicity effect of the former herbicides.

In terms of efficacy, both quinclorac and bensulfuron showed some degree of selectivity in the control of weed species. While quinclorac was most effective against *E. crus-galli* and not sedges, bensulfuron displayed quite the opposite role, although both herbicides on their own were, to a large extent, effective in suppressing other grass species and broadleaf weeds *(Figure 1)*. It would appear then, that for a broadleaf weed control spectrum a mixture formulation of the two herbicides is needed if an alternative choice to molinate + 2,4-D IBE is sought for. In this study, it was found that the mixture of bensulfuron + quinclorac performed as efficiently as in weed species control and the grain yield obtained was comparable *(Figure 2)*.

It is obvious that the grass species, *E. crus-galli* played a dominant role in grain yield reduction which could be clearly seen in the unweeded check plots and when bensulfuron failed to suppress it and consequently could not enhance yield to those levels achieved by other herbicide treatments. Although the total weed biomass in the untreated plot, with nearly half of population comprising *E. crus-galli*, was about 38% more than the bensulfuron treated plot, the proportion of this grass species increased to about 85% of the total weed under this herbicide regime which even at the expense of other

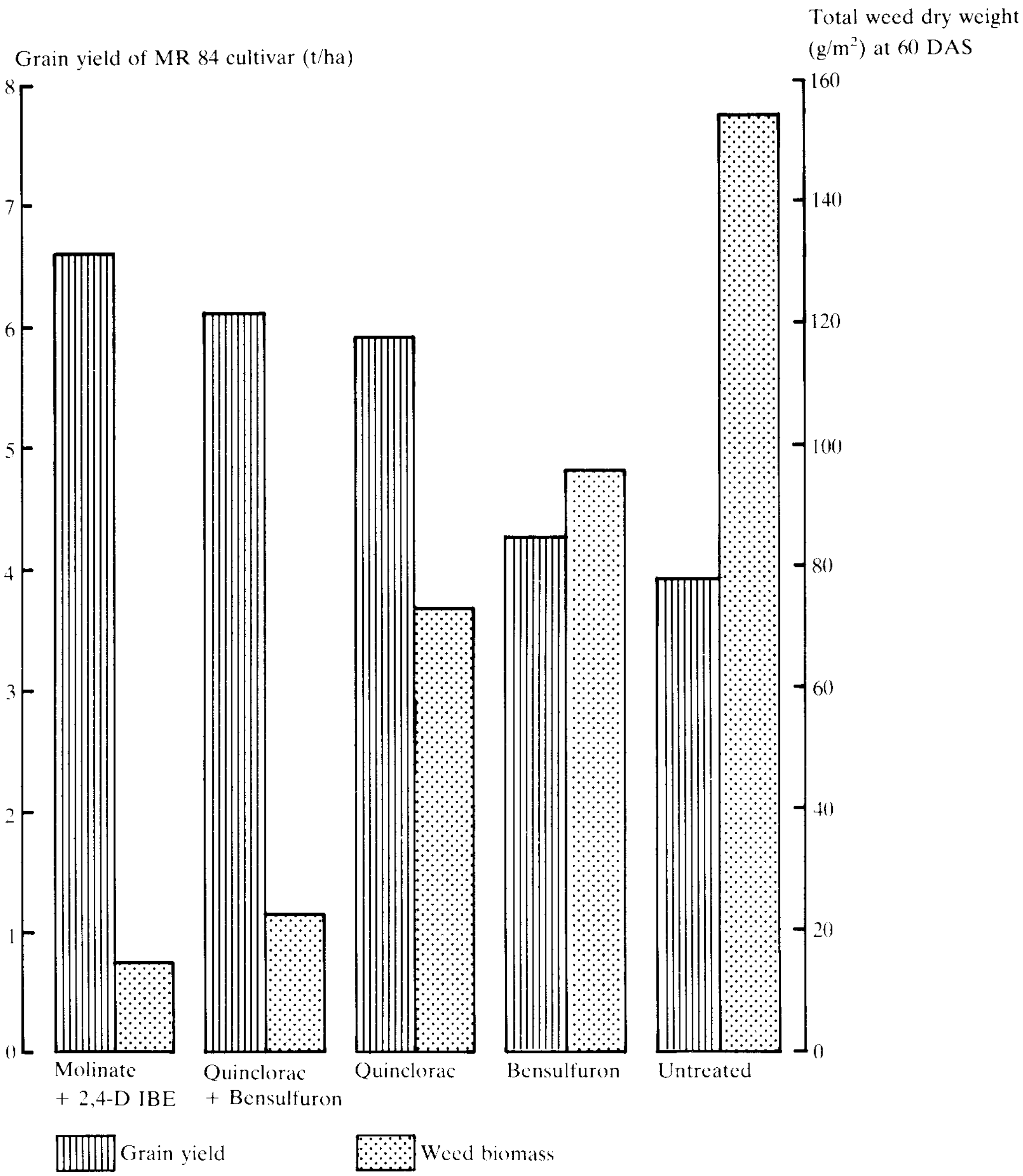


Figure 2. The influence of weed control treatments on the relationship of grain yield and total weed biomass at 60 days after sowing (DAS)

weed species was not sufficient to allow significant grain yield increase.

Although quinclorac was most effective in controlling *E. crus-galli* and was able to ensure comparable yield increase, the herbicide on its own cannot be considered for use as it lacked the needed spectrum of control particularly against sedges. It has been shown that it could be used in combination with bensulfuron to achieve the desired control spectrum as those of molinate + 2,4-D IBE without any detrimental effect on grain production. The usefulness and efficacy of quinclorac and bensulfuron could be further explored in combination with some other already established and cheaper herbicides.

To be effective, herbicides must be phytotoxic to the target weed species. 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 quinclorac and bensulfuron caused less to moderate seedling injury to rice plants when applied at early post-emergence 10 days after seeding. Their mixtures, at higher rate (0.30 + 0.03 kg/ha) showed a greater extent of injury but were less toxic to that observed by molinate + 2,4-D IBE. In grain yield, no optimal combination for the two mixtures can be suggested as efficacy in weed control was readily apparent. The mixtures consisting of 0.20 and 0.03 kg/ha quinclorac and bensulfuron respectively appeared to be the best combination amongst the six mixtures tested in terms of their suppression on weed growth from even up to 60 days after sowing with minimal phytotoxicity effect on rice seedling.

The advantages of using herbicide mixtures of quinclorac and bensulfuron are evidently glaring in terms of their broader spectrum of control irrespective of the rates used. Although quinclorac on its own gave an almost complete control of *E. crus-galli* it was, however, not effective against sedges, while the reverse was true for bensulfuron. None of the mixtures could be said to be superior to the molinate + 2,4-D IBE, but they certainly offer another alternative in chemical weed control for direct-seeded rice.

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