SEQUENTIAL PROGRAMS OF MOLINATE, THIOBENCARB, BENSULFURON AND MCPA FOR WEED CONTROL IN WATER-SEEDED RICE IN NEW SOUTH WALES

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Summary Substitution of thiobencarb for molinate and/or MCPA for bensulfuron can assist in controlling bensulfuron-resistant aquatic weeds in water-seeded rice in New South Wales, however neither strategy adopted individually assures ricegrowers of optimal weed control and crop performance.

Replicated field trials over two seasons (1994–95 and 1995–96) demonstrated that sequential programs of molinate applied pre-sowing, followed by thiobencarb plus bensulfuron early post-sowing offer robust weed control programs with multiple modes of action against *Cyperus difformis*. MCPA applied at early tillering provides a second MOA against all Alismataceae weeds (and *C. difformis*) with little effect on weed-free rice yield. Optimal rates of application in sequential programs were often below existing recommended label rates.

INTRODUCTION

In New South Wales, approximately 80–140 000 ha of irrigated rice are grown annually, established principally by water-seeding (pre-germinated rice broadcast into flooded bays).

Annual aquatic weeds are favoured by constant ponding, so water-seeded rice tends to be infested with *Cyperus difformis* L. (dirty Dora, CYPDI), *Damasonium minus* Buchen. (starfruit, DAMMI), *Sagittaria montevidensis* Cham. & Schecht. (arrowhead, SAGMO) and *Alisma lanceolatum* With. (alisma, ALSLA). Cultural control methods such as clean seedbeds, clean seed, laser guided land levelling, ridge rolling, farm hygiene and water depth are all important components of weed control programs in New South Wales rice production, however most growers cannot produce economic crops without herbicide inputs.

Bensulfuron methyl (Londax™) has been applied to in excess of 90% of the New South Wales rice crop (most often in combinations with molinate) for the past eight seasons, leading to the widespread development of bensulfuron-resistant populations of *C. difformis*, *D. minus* and *S. montevidensis* (Graham *et al.* 1994, Baines personal communication) Combination partners (with alternate modes of action) for bensulfuron in water seeded rice production have been difficult to find as most rice herbicides are not tolerated by germinating rice seedlings, but rather are used in transplanted rice culture (Taylor 1995). Thiobencarb is one possible partner, however advanced *Echinochloa crus galli* P.Beauv. (barnyard grass, ECHCG) and *C. difformis* can escape treatment once rice has advanced sufficiently to tolerate treatment.

One major objective of research sponsored by New South Wales ricegrowers has been to achieve at least two modes of herbicidal action per species per year. Three aspects of this research are presented:

1. Development of pre-sowing priming treatments of molinate (Ordram™) to suppress weeds until the two leaf stage of rice development; when thiobencarb (Saturn™) can be safely applied to the crop.
2. Definition of appropriate bensulfuron and thiobencarb rates (in tank mixtures) for two leaf stage rice application.
3. Assessment of the impact of mid-season MCPA treatments upon the grain yield of weed free rice.

MATERIALS AND METHODS

Glasshouse studies were conducted using clay loam soils sampled from commercial paddies in New South Wales. Pots (0.23 × 0.14 m) were filled with soil to 2 cm depth, then flooded and seeded with pre-germinated rice seed. Herbicide treatments were delivered directly into the floodwater.

All field experiments were conducted at dedicated, laser-levelled sites in the Murray and Murrumbidgee valley irrigation areas during the seasons (1994–95 and 1995–96). Randomized complete block designs of four replications of plots typically 4.5 × 8 m were used, with earthen bunding and independant watering. Normal agronomic practices were emulated, with pre-germinated seed sown by aircraft or dry sown plots (MCPA tolerance only) surfaced seeded using a 2.1 m linkage seeder.

Herbicide applications were made using simulated SCWIIRT treatments (Taylor 1995), administering neat or concentrated working solutions directly to floodwater or using a hand-held gas-powered small plot boom sprayer delivering 90–115 L ha^{-1}.

Trials were assessed using visual ratings of rice injury and weed control, counts of rice and weed seedling and inflorescence density and direct harvest of grain yields using Wintersteiger or Kincaid plot harvesters.

Table 1. Seedling density (plants pot^{-1}) and fresh weight (g plot^{-1}) of *Cyperus difformis* and *Echinochloa crus galli* affected by molinate rate and timing in a glasshouse, Cobram 1994.

Molinate g a.i. ha^{-1}	Timing DAF	Density CYPDI	Density ECHCG	Fresh weight CYPDI	Fresh weight ECHCG
0		81	78	4.4	9.9
480	0	57	53	2.6	6.0
960	0	47	45	3.8	5.1
1440	0	29	21	2.5	3.2
480	7	55	9	4.2	0.5
960	7	19	3	0.8	0.3
1440	7	12	1	0.6	0.1
480	14	35	37	1.9	6.3
960	14	16	21	0.9	3.5
1440	14	50	14	2.0	5.9
LSD (P=0.05)		22	31	1.7	3.0

Table 2. Percentage control ratings of *Echinochloa crus galli* in water-seeded rice affected by pre-sow priming treatments of molinate (subsequently treated with thiobencarb at 3000 g a.i. ha^{-1} plus bensulfuron at 30 g a.i. ha^{-1} at 2–3 leaf stage of rice).

Molinate rate g a.i. ha^{-1}	Trial number H24-94	Trial number H28-94	Average
0	76.3	71.5	73.9
480	86.5	82.5	84.5
960	93.3	94.8	94.1
1440	99.3	94.5	96.9
1920	97.5	97.8	97.7
LSD (P=0.05)	23.2	9.2	

Table 3. *Cyperus difformis* and *Sagittaria montevidensis* percentage control ratings (average of two trials) and grain yields (average of three trials) in water-seeded rice affected by bensulfuron rate (when tank-mixed with thiobencarb at 3000 g a.i. ha^{-1} at 2–3 leaf stage rice after prior treatment with molinate at 960–1440 g a.i. ha^{-1}), 1994–95 season.

Bensulfuron rate g a.i. ha^{-1}	CYPDI % Control	SAGMO % Control	Grain yield t ha^{-1}
0	91.5	8.4	6.61
3	95.1	31.3	
6	99.4	85.0	7.76
12	100	100	7.80
24	100	100	7.53
30	100	100	7.79

Table 4. Grain yields (t ha^{-1}) of weed-free rice across three sites over two seasons (1994–95 and 1995–96) after treatment with MCPA sodium at 700 g a.i. ha^{-1}.

Treatment	1994–95 (n=8)	1995–96 (n=7)	1995–96 (n=13)	Mean
Untreated	8.33	3.81	6.80	6.31
MCPA sodium	8.06	3.42	6.70	6.06
Reduction	3.2%	10.2%	1.5%	4.0%

n = number of varieties at each site.
Yields are averaged for all varieties and across two timings in 1995–96 trials.

Table 5. Average weed control and rice injury ratings (0–100%) and grain yields from three trials in water-seeded rice, New South Wales, 1995–96 season.

Treatment rate g a.i. ha^{-1}	Application timing	Weed control ratings ECHCG n=3	CYPDI n=3	DAMMI n=3	SAGMO n=1	Rice injury ratings n=3	Grain yields t ha^{-1} n=2
Molinate 2400 + bensulfuron 30	post	93.3	75.4[A]	99.6	100	9.6	6.70
Thiobencarb 3000 + bensulfuron 30	post	87.9	100	99.9	100	26.7	5.46
Molinate 1440 f/b	pre	97.3	100	99.9	100	42.5	6.59
Thiobencarb 3000 + bensulfuron 30	post						
Pre-sow	pre	95.1	99.9	95	90	13.3	6.36
Molinate 960–1440 f/b	post						
Thiobencarb 1200–1600 + bensulfuron 12							

n = number of trials.
[A] Includes one suspected bensulfuron-resistant population.

RESULTS

Pre-sow priming with molinate Initial glasshouse screening (data not presented) showed that pre-sow priming with molinate at 2880 g a.i. ha^{-1} (less than the full label rate of 3600 g a.i. ha^{-1}) followed by thiobencarb and bensulfuron at lowest label rates resulted in excessive rice injury (especially to the long grain variety 'Pelde'). Lowering molinate rate to 960 g a.i. ha^{-1} reduced rice injury levels.

Glasshouse studies also confirmed that lower rates of molinate (960–1440 g a.i. ha^{-1}) significantly suppressed *C. difformis* and *E. crus galli* seedling growth; with greatest reductions when application was timed seven days after flooding (DAF, see Table 1).

Two field experiments in 1994 (Table 2) and numerous replicated (Table 5) and commercial demonstrations in 1995 demonstrated the value in low application rates (960–1440 g a.i. ha^{-1}) of molinate as pre-sow priming treatments to ensure *E. crus galli* and *C. difformis* did not escape control by subsequent thiobencarb plus bensulfuron treatments.

Definition of thiobencarb and bensulfuron rates Thiobencarb application rates were maintained at 3000 g a.i. ha^{-1} in much of the work in order to retain a high selection pressure against *C. difformis* and to ensure effective *E. crus galli* control.

Bensulfuron rates were reviewed in tank mixtures with thiobencarb (after pre-sow priming treatments of molinate). Both *C. difformis* and *S. montevidensis* were effectively controlled by bensulfuron at lower rates than 30 g a.i. ha^{-1} (the minimum label rate) and grain yields did not rise substantially with rates in excess of 6 g a.i. ha^{-1} (Table 3).

Sequences of molinate at 960–1440 g a.i. ha^{-1} followed by thiobencarb at 3000 g a.i. ha^{-1} plus bensulfuron at 30 g a.i. ha^{-1} exhibited increased injury to rice compared to commercial standards (Table 5). Reduction of thiobencarb (and bensulfuron) dose consistently alleviated rice injury, with a small drop in efficacy against *D. minus* and *S. montevidensis*.

MCPA tolerance by weed free rice Rice grain yields were depressed by an average of 4.0% by MCPA sodium at 700 g a.i. ha^{-1} over two seasons and three sites (Table 4). Grain yield reductions were worst at a late-sown site where cold-induced infertility severely reduced yield potential.

DISCUSSION

Initial attempts to combine thiobencarb with bensulfuron (to achieve a second MOA against *C. difformis*) were plagued by rice injury and poor control of *E. crus galli*. Development of pre-sow priming treatments of molinate have enabled thiobencarb to be reliably incorporated into local rice weed control programs. A pesticide permit for commercial use of pre-sow priming treatments of molinate was issued by NSW Agriculture in 1995.

Where thiobencarb is preceded by molinate, it may be possible to reduce the thiobencarb dose in order to alleviate crop injury, yet retain efficacy against *C. difformis* and *E. crus galli*. Thiobencarb rates of 1600 g a.i. ha^{-1} showed promise for this purpose during the 1995–96 season.

Given that thiobencarb is largely inactive against Alismataceae weeds, additional MOA herbicides are needed in programs. MCPA sodium tolerance experiments have shown yield penalties to be low in most instances, thus enabling MCPA to be used as this second MOA against all aquatic weeds. Where MCPA sodium is to be applied, low rates of bensulfuron may suffice to suppress early aquatic weed competition, yet reduce the selection pressure for bensulfuron resistance.

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