CONTROL OF WILD OATS AND TARTARY BUCKWHEAT WITH MIXTURES OF METRIBUZIN AND VARIOUS POSTEMERGENCE WILD OAT HERBICIDES

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The phytotoxicity of difenzoquat, flamprop, barban and diclofop to wild oats (*Avena fatua* L.) was reduced when each of these herbicides was applied in a tank mixture with metribuzin or metribuzin + MCPA. When metribuzin was applied immediately following, or 6 days after the wild oat herbicides, or when the inert ingredients in the metribuzin formulation were tank-mixed with each of the wild oat herbicides, no reduction in phytotoxicity to wild oat occurred, suggesting that the antagonism may be occurring in the spray tank as a result of an interaction between the metribuzin active ingredient and each of the wild oat herbicides. No loss of metribuzin or metribuzin + MCPA phytotoxicity to Tartary buckwheat (*Fagopyrum tataricum* L. Beauv.) occurred when these herbicides were tank-mixed with each of the four wild oat herbicides.

La phytotoxicité du difenzoquat , du flamprop, du barbane et du diclofop envers la folle avoine (*Avena fatua* L.) est réduite lorsque chacun de ces herbicides est mélangé sur place avec du métribuzin ou du métribuzin + du MCPA. L'application de métribuzin immédiatement ou 6 jours après celle des herbicides susmentionnés, ou lorsque les matières inertes de la préparation de métribuzin sont mélangées sur place avec chacun des herbicides, ne réduit en rien leur phytotoxicité envers la folle avoine, ce qui donne à penser que l'antagonisme pourrait se produire dans le réservoir de pulvérisation par suite d'une interaction entre la matière active du métribuzin et chacun des herbicides. Le mélange sur place de métribuzin ou de métribuzin + MCPA avec chacun des quatre herbicides ne produit aucune baisse de phytotoxicité envers le sarrasin de Tartarie (*Fagopyron tataricum* L. Beauv.).

Metribuzin is commonly used in western Canada as a postemergence application at 0.21–0.28 kg/ha for control of a variety of annual broad-leaved weeds such as hemp-nettle (*Galeopsis tetrahit* L.) and chickweed (*Stellaria media* L. Vill.) in wheat (*Triticum aestivum* L.). Metribuzin may also be mixed in the spray tank (tank mixture) with MCPA and this mixture may be selectively used to control additional broad-leaved weeds such as shepherd's-purse (*Capsella bursa-pastoris* L. Medic.) and flixweed (*Descurainia sophia* L. Webb) in wheat.

Wild oats (*Avena fatua* L.) are the most serious annual weed in western Canada (Banting 1974). There are currently four herbicides commonly used for post-emergence control of wild oats in wheat. These include barban, diclofop, difenzoquat and flamprop. It would be economical to mix metribuzin in the tank with some, or all, of these postemergence wild oat herbicides to provide control in one spray operation of wild oats and annual broad-leaved weeds.

The purpose of this work was to study the effect of mixing metribuzin, or metribuzin plus MCPA, with the postemergence herbicides for wild oat control and to evaluate these mixtures for control in wheat of wild oats and Tartary buckwheat (*Fagopyrum tataricum* L. Beauv.).

MATERIALS AND METHODS

Field Experiments

All field trials were conducted during 1978 and again during 1979 on a Ponoka loam soil which had an average composition of 50% sand, 28% silt and 22% clay. The organic matter content ranged from 8 to 10% and the pH was 6.8. Moisture content at wilting point and field capacity was 17 and 28%, respectively. Wheat cv. Neepawa was seeded in rows 23 cm apart. Wild oats and Tartary buckwheat were intersown separately between the rows of the crop. Experimental design was a randomized complete block with four replicates. Individual plot size was 2 × 6 m. All herbicide treatments were applied in 100 L of water/ha, at a pressure of 276 kPa using a motorized plot sprayer fitted with TeeJet 8001 nozzles.

Early visual evaluations of crop tolerance were taken 2 wk after treatment. These ratings were based on a 0–9 scale where 0 = complete kill and 9 = no injury. Square meter samples were taken from the wild oat infested area of each plot for determination of crop yields and wild oat dry weights. A square meter sample was also taken from each plot for determination of dry weights of Tartary buckwheat.

Greenhouse Experiments

Wild oats and Tartary buckwheat were seeded separately in 15-cm-diam pots filled with a Ponoka loam soil with a composition as described for the field experiments. The pots were fertilized with ammonium nitrate at 112 kg of N/ha. After emergence, the plants were thinned to three uniform seedlings per pot. The greenhouse was maintained at 22°C in the day and 18°C at night with a 16-h photoperiod consisting of daylight supplemented by 17.2 klx of artificial light. Each experiment was a randomized complete block with four replicates.

All spray applications were with a motorized pot sprayer in 100 L of water/ha applied at a pressure of 276 kPa.

Shoot (aboveground parts) fresh weights for both species were determined 4 wk after herbicide application.

Herbicides, Formulations and Leaf Stages

The herbicides used in this study included a 50% wettable powder formulation of metribuzin, a 50% dimethyl amine formulation of MCPA, a 20% solution of difenzoquat, a 10.5% emulsifiable concentrate (E.C.) of flamprop, a 12% E.C. of barban, and a 19% E.C. of diclofop. In all experiments barban and diclofop were applied when the wild oats and Tartary buckwheat were in the two-leaf stage. Difenzoquat and flamprop were applied at the three-leaf stage of wild oats and Tartary buckwheat in greenhouse experiments and at the four-leaf stage of both species in field experiments. The wild oat herbicides were applied alone, sequentially with metribuzin, or mixed together in the spray tank (tank mixture) with metribuzin. In the sequential applications, metribuzin was applied immediately following a wild oat herbicide or 6 days after a wild oat herbicide. In four experiments, the inert ingredients (commercial formulation minus the active ingredient) in the metribuzin formulation were applied at rates (kg/ha) equivalent to their concentration in the commercial formulation.

RESULTS

Influence on Wild Oat Control of Tank-Mixing Metribuzin or Metribuzin + MCPA with Wild Oat Herbicides

In field experiments, metribuzin when tank-mixed with difenzoquat, flamprop (Table 1), barban (Table 2), or diclofop (Table 3) reduced the phytotoxicity of these herbicides to wild oats. Similar losses in wild oat control were obtained in greenhouse experiments when metribuzin or metribuzin + MCPA were tank-mixed with these wild oat herbicides (Table 4). When the inert ingredients in the metribuzin formulation were applied as a tank mixture with the wild oat herbicides there was no loss in phytotoxicity of difenzoquat, flamprop or diclofop and the phytotoxicity of barban to wild oats was enhanced (Table 5).

Influence on Wild Oat Control of Sequential Applications of Metribuzin and Wild Oat Herbicides

In the greenhouse, when metribuzin was applied immediately following or 6 days after difenzoquat, flamprop, barban or diclofop there was no loss in phytotoxicity to wild oats (Table 5).

Table 1. Influence of metribuzin in tank mixture with difenzoquat or flamprop on Tartary buckwheat and wild oat control in wheat (field experiment)

Treatment	Rate (kg/ha)	Tar. buck.† dry wt (g/m²)	Wild oat dry wt (g/m²)	Early wheat score (0–9)‡	Wheat yield (g/m²)
Weedy check	0.00	42 *a*	153 *a*	9	115 *cd*
Weed-free check	0.00	1 *c*	0 *c*	9	182 *a*
Metribuzin	0.21	2 *c*	194 *a*	8	111 *cd*
Metribuzin	0.28	2 *c*	171 *a*	8	133 *bc*
Difenzoquat	0.84	20 *b*	98 *b*	7	162 *ab*
Metribuzin+difenzoquat	0.21+0.84	6 *c*	187 *a*	6	110 *cd*
Metribuzin+difenzoquat	0.28+0.84	6 *c*	192 *a*	6	84 *d*
Flamprop	0.56	27 *b*	22 *c*	8	161 *ab*
Metribuzin+flamprop	0.21+0.56	2 *c*	156 *a*	8	108 *cd*
Metribuzin+flamprop	0.28+0.56	4 *c*	200 *a*	6	133 *bc*

†Tar. buck. = Tartary buckwheat.
‡9 score = complete tolerance, 0 score = complete kill.
a-d Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 2. Influence of metribuzin in tank mixture with barban on Tartary buckwheat and wild oat control in wheat (field experiment)

Treatment	Rate (kg/ha)	Tar. buck.† dry wt (g/m²)	Wild oat dry wt (g/m²)	Early wheat score (0–9)‡	Wheat yield yield (g/m²)
Weedy check	0.00	28 *a*	191 *a*	9	63 *d*
Weed free check	0.00	2 *c*	0 *c*	9	227 *a*
Metribuzin	0.21	11 *bc*	218 *a*	9	86 *d*
Metribuzin	0.28	2 *c*	212 *a*	9	74 *d*
Barban	0.35	29 *a*	45 *c*	9	194 *ab*
Metribuzin+barban	0.21+0.35	20 *ab*	142 *b*	8	160 *bc*
Metribuzin+barban	0.28+0.35	14 *bc*	111 *b*	8	133 *cd*

†Tar. buck. = Tartary buckwheat.
‡9 score = complete tolerance, 0 score = complete kill.
a-d Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 3. Influence of metribuzin in tank mixture with diclofop on Tartary buckwheat and wild oat control in wheat (field experiment)

Treatment	Rate (kg/ha)	Tar. buck.† dry wt (g/m²)	Wild oat dry wt (g/m²)	Early wheat score (0–9)‡	Wheat yield (g/m²)
Weedy check	0.00	57 *a*	149 *a*	9	277 *ab*
Metribuzin	0.28	6 *b*	109 *a*	9	245 *b*
Diclofop	0.70	62 *a*	0 *c*	9	311 *a*
Metribuzin+diclofop	0.28+0.70	13 *b*	46 *b*	7	286 *a*

†Tar. buck. = Tartary buckwheat.
‡9 score = complete tolerance, 0 score = complete kill.
a-c Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 4. Influence of tank mixtures of metribuzin at 0.21 kg/ha or metribuzin + MCPA at 0.21 + 0.56 kg/ha on wild oat (WO) control with various wild oat herbicides (greenhouse experiments)

	Wild oat herbicide† and shoot fresh wt (g/pot)			
Treatment	Difenzoquat 0.84 kg/ha	Flamprop 0.56 kg/ha	Barban 0.35 kg/ha	Diclofop 0.70 kg/ha
Check (no herbicide)	14.3 *a*	16.3 *a*	15.5 *a*	14.9 *a*
Metribuzin	15.5 *a*	12.7 *b*	13.8 *ab*	13.1 *a*
WO herb.	5.8 *c*	3.2 *e*	8.0 *c*	4.3 *b*
MCPA	13.2 *a*	12.2 *b*	14.1 *ab*	12.2 *a*
WO herb. + metribuzin	8.8 *b*	6.0 *d*	11.2 *b*	10.2 *a*
WO herb. + metribuzin + MCPA	10.3 *b*	9.0 *c*	12.2 *ab*	10.2 *a*

†Each wild oat herbicide was applied only where "WO herb." appears in the treatment column.
a-e Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 5. Influence on wild oat control of timing of application of metribuzin at 0.21 kg/ha in relation to various wild oat (WO) herbicides (greenhouse experiments)

	Metribuzin application relative to WO herb.	Wild oat herbicide† and shoot fresh wt (g/pot)			
Treatment		Difenzoquat 0.84 kg/ha	Flamprop 0.56 kg/ha	Barban 0.42 kg/ha	Diclofop 0.70 kg/ha
Check (no herbicide)	–	21.7 *a*	15.8 *a*	19.2 *a*	20.5 *a*
WO herb.	–	3.4 *de*	2.5 *de*	6.3 *d*	0.4 *d*
WO herb. + metribuzin	Tank mix	6.5 *c*	3.9 *c*	12.0 *c*	5.9 *c*
WO herb. + metribuzin	Immediately after	4.2 *cd*	3.2 *cd*	2.2 *e*	0.8 *d*
WO herb. + metribuzin	6 days after	1.2 *e*	1.4 *e*	2.4 *e*	0.2 *d*
Metribuzin	–	17.9 *b*	13.6 *b*	15.2 *b*	16.8 *b*
WO herb + metribuzin IE‡	Tank mix	2.2 *de*	1.7 *e*	2.3 *e*	0.2 *d*

†Each wild oat herbicide was applied only where "WO herb." appears in the treatment column.
‡IE = inert ingredients of metribuzin.
a-e Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Influence on Tartary Buckwheat Control of Tank-Mixing Wild Oat Herbicides with Metribuzin

Control of Tartary buckwheat with metribuzin was not affected under field conditions when metribuzin was tank-mixed with difenzoquat, flamprop (Table 1), barban (Table 2), or diclofop (Table 3). Similar results were obtained in greenhouse experiments when metribuzin was tank-mixed with the wild oat herbicides (Table 6) and control of Tartary buckwheat was excellent in tank mixtures containing metribuzin + MCPA and the wild oat herbicides (Table 6). Tartary buckwheat fresh weights were significantly reduced with both difenzoquat and flamprop when applied alone. However, the degree of control was not good enough to be commercially acceptable (Table 6).

Wheat Tolerance to Mixtures of Metribuzin with Wild Oat Herbicides

Early wheat tolerance to tank mixtures of metribuzin + difenzoquat or flamprop (high metribuzin rate only) was poor and final wheat yields were unacceptable (Table 1). Wheat tolerance to the metribuzin + barban tank mixtures at 2 wk after treatment was

Table 6. Influence of tank mixtures of various wild oat (WO) herbicides with metribuzin at 0.21 kg/ha or metribuzin + MCPA at 0.21 + 0.45 kg/ha on Tartary buckwheat control (greenhouse experiments)

	Wild oat herbicide† and shoot fresh weight (g/pot)			
Treatment	Difenzoquat 0.84 kg/ha	Flamprop 0.56 kg/ha	Barban 0.42 kg/ha	Diclofop 0.70 kg/ha
Check (no herbicide)	20.5 *a*	32.5 *a*	25.4 *a*	27.3 *a*
Metribuzin	10.5 *b*	12.2 *b*	4.6 *cd*	1.4 *de*
WO herb.	11.0 *b*	12.3 *b*	17.5 *b*	20.2 *b*
MCPA	7.4 *bc*	2.8 *c*	3.3 *cd*	5.3 *cd*
WO herb. + metribuzin	10.8 *b*	9.1 *b*	4.2 *cd*	3.0 *de*
WO herb. + metribuzin + MCPA	2.0 *d*	3.9 *c*	0.0 *d*	0.1 *e*

†Each wild oat herbicide was applied only where "WO herb." appears in the treatment column.
a-e Numbers within columns followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test. Data shown for each wild oat herbicide are part of a larger test.

good (Table 2). However, wheat yields with these mixtures were lower than yields for the weed-free checks, and yield with the metribuzin + barban (0.28 + 0.35 kg/ha) mixture was lower than the yield with barban (Table 2). Even though early wheat tolerance to the metribuzin + diclofop mixture was only fair, and wild oat control was reduced, wheat yield was not significantly reduced over diclofop (Table 3).

DISCUSSION

The phytotoxicity of difenzoquat, flamprop, barban and diclofop to wild oats was reduced when these herbicides were tank-mixed with metribuzin and as a result, use of these mixtures ot obtain broad-spectrum weed control is not possible. Similar reductions in phytotoxicity to wild oats with metribuzin tank mixtures have been reported by other workers; for example, with difenzoquat (McBeath 1977c), flamprop (Vanden Born et al. 1979), barban (McBeath 1977a) and diclofop (Friesen 1976; McBeath 1977b). In greenhouse experiments no loss of wild oat control was experienced in this study when metribuzin was applied immediately following the wild oat herbicides. Consequently, the possibility of obtaining satisfactory wild oat and broad-leaved weed control under field conditions with a single trip over the field using a double-boom, double-tank system to apply metribuzin and a wild oat herbicide separately, but at the same time, deserves evaluation. Since early wheat tolerance was poor to fair when tank mixtures of metribuzin with difenzoquat, flamprop (0.28 kg/ha metribuzin only) and diclofop were applied and the final effect on yields was masked by poor wild oat control in the tank mixtures, the double-boom-type applications would have to be evaluated for efficacy on wild oats and crop tolerance.

If the nature of an antagonistic interaction between two herbicides is biological (i.e. occurring as a result of interference between the two herbicides on metabolic processes within the plant), one would expect that the antagonism would occur irrespective of whether the herbicides were applied as a tank mixture (assuming no direct tank mix incompatability) or as separate applications but at the same time. Furthermore, if enough time is allowed for the first herbicide to produce phytotoxic symptoms on the target species before application of the second herbicide, then the antagonism can usually be overcome. A biological mechanism for antagonism has, for example, been described for the interaction between 2,4-D and diclofop by Todd and Stobbe (1976) and a minimum of 4 days must elapse between application of these two herbicides to prevent loss of phytotoxicity of diclofop on wild oats (Vanden Born et al. 1977). In the present study, sequential applications of metribuzin immediately following the wild oat herbicides did not significantly reduce the phytotoxicity of the wild oat herbicides, though the actual foliage weights for these sequential applications were slightly greater than for the wild oat herbicides in three of four cases (Table 5). Thus, a biological mechanism for the interaction between metribuzin and the various wild oat herbicides would appear to be ruled out and since antagonism did occur in wild oats when the herbicides were tank-mixed, some type of physical or chemical interaction must be occurring between metribuzin and the wild oat herbicides in the tank. Also, since the inert ingredients in the metribuzin formulation were not involved in the antagonism of wild oat control, the tank mix interaction must be occurring between the metribuzin active ingredient and the wild oat herbicides. A possible explanation for the slight (not significant) loss of control with three of the four separate applications may be that in separate applications of two herbicides, using spray volumes of 100 L/ha, there would likely be droplet overlap on the leaf surface and hence a chance for physical or chemical interactions to occur between metribuzin and a wild oat herbicide at that location.

No loss of metribuzin phytotoxicity to Tartary buckwheat occurred in tank mixtures with the wild oat herbicides. If a chemical or physical interaction is responsible for loss of wild oat control, then a similar loss of Tartary buckwheat control might be expected. One possible explanation for the absence of such a loss may be that the new compound or compounds formed in the tank mix interaction may still be phytotoxic to Tartary buckwheat but not wild oats. Another possibility is that Tartary buckwheat may be less susceptible to a metribuzin rate reduction (as in the case where a certain amount of each herbicide may be inactived by an equilibrium reaction in the tank) than the wild oat herbicide. The most likely explanation is that in six out of eight applications (Tables 1, 2, 3 and 6), the wild oat herbicides used alone provided significant control of Tartary buckwheat over the untreated check. This control may be more than enough to offset any loss of metribuzin control on Tartary buckwheat as a result of metribuzin tie-up in a tank mixture.

Loss of wild oat control when MCPA amine is tank-mixed with difenzoquat (O'Sullivan and Vanden Born 1978), flamprop (O'Sullivan and Vanden Born 1980) and diclofop (O'Sullivan et al. 1977) has been recorded. Thus, the loss of wild oat control when metribuzin + MCPA was tank-mixed with the wild oat herbicides was not unexpected.

The reason for the metribuzin enhancement of wild oat control in sequential applications with barban is not presently understood, but since the inert ingredients of the metribuzin formulation caused a similar enhancement when used in a tank mixture with barban, it may be a formulation-related effect.

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