BROADLEAF WEED HERBICIDE EFFECTS ON WILD OAT: IMPLICATIONS FOR TANK MIXING HERBICIDES

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SUMMARY

Tank mixing the graminicide diclofop-methyl with the broadleaf weed herbicides bentazon, chlorsulfuron, dicamba and 2,4-D resulted in reduced control of wild oat. Diclofop-methyl applied alone did not reduce growth rate (measured as the rate of leaf extension) until at least 4 days after spraying. All herbicides applied with diclofop-methyl caused a decrease in growth rate during the first 3 days after spraying. Ten days after spraying, growth rates were greater for plants sprayed with diclofop-methyl/herbicide combinations than for plants sprayed with diclofop-methyl alone. Decreased growth rate during the first 3 days after spraying may cause herbicide antagonism of diclofop-methyl. Ways of overcoming this problem are discussed.

INTRODUCTION

Tank mixing the post-emergence graminicide diclofop-methyl with the broadleaf weed herbicides 2,4-D, bentazon, chlorsulfuron and dicamba can result in reduced control of wild oat (*Avena fatua* L.) and other annual grasses (Olson and Nalewaja 1981; Hall *et al* 1982a, b; Campbell and Penner 1982; Chow 1988). Reports that these broadleaf weed herbicides cause reduced uptake, metabolism and/or translocation of diclofop-methyl have not been confirmed and the reason for this antagonism is uncertain (Hoppe 1985; Shimabukuro *et al* 1986; Liebl and Worsham 1987).

Annual grasses must be growing rapidly for maximum diclofop-methyl activity (Dickson *et al* 1988; Andrews *et al* 1989a). The primary mode of action of diclofop-methyl is membrane disruption caused by depolarisation of membranes and inhibition of membrane synthesis (Hoppe 1985; Wright and Shimabukuro 1987; Harwood 1988). Andrews *et al* (1989a) proposed that diclofop-methyl efficacy will increase with increased rate of leaf expansion as demand for membrane synthesis and strain on vulnerable membranes will be greater. The critical period during which leaf expansion rate must be high for maximum diclofop-methyl activity is the first few days after spraying, before diclofop-methyl itself causes a decrease in growth rate (Andrews *et al* 1989a).

At recommended field rates, broadleaf weed herbicides usually have greater effects on dicotyledonous plants than monocotyledonous plants. However, it is possible that 2,4-D, bentazon, chlorsulfuron and dicamba cause a decrease in leaf expansion rate of annual grasses before diclofop-methyl has an effect. If so, this could afford an explanation for broadleaf weed herbicide antagonism of diclofop-methyl. This paper presents data from a series of experiments which tested this possibility.

MATERIALS AND METHODS

All experiments were carried out under the controlled environment conditions described previously (Andrews *et al* 1989a). Plants were supplied with a basal nutrient solution containing 5 mol/m^3 potassium nitrate (Andrews *et al* 1989b). All experiments were of completely randomised design with treatments replicated six times. An analysis of variance was carried out on all data. All effects discussed have a F ratio with a probability $P<0.01$.

Experiment 1 examined the effects of diclofop-methyl, 2,4-D and diclofop-methyl plus 2,4-D (same tank mix) on leaf extension rate during the week after spraying and on long term growth of wild oat (Table 1). Plants were sprayed at the three-leaf stage and unsprayed plants were used as controls.

Experiment 2 examined the effects of 2,4-D and diclofop-methyl on leaf extension rate of Italian ryegrass (*Lolium multiflorum* Lam.) at the three leaf stage and cultivated oat (*Avena sativa* L. cv. Amuri), soft brome (*Bromus mollis* L.) and perennial ryegrass (*Lolium perenne* L.) at the four leaf stage. Daily leaf extension rates during the week after spraying were determined (Table 2).

Experiment 3 examined the effects of 2,4-D, bentazon, chlorsulfuron and dicamba on diclofop-methyl control of wild oat. In all cases, the broadleaf weed herbicide and diclofop-methyl were applied from the same tank mix. Growth conditions were as in Experiment 1. In this case, plants were at the four-leaf stage at spraying. Daily leaf extension rates during the 10 days after spraying and shoot dry weight 52 days after spraying were determined (Table 3).

All herbicides in these experiments were applied with a portable sprayer fitted with Teejet 8001 nozzles which delivered 250 litres water/ha at 275 kPa.

RESULTS AND DISCUSSION

Effects of 2,4-D

Control of grass weeds is often reduced if diclofop-methyl is applied with chlorophenoxy herbicides such as 2,4-D and MCPA (Olson and Nalewaja 1981; Hall *et al* 1982a,b). This antagonism has been reported to occur with no apparent effects on uptake, de-esterification or translocation of diclofop-methyl (Hill *et al* 1980; Hall *et al* 1982b). Antagonism of diclofop-methyl activity by 2,4-D and MCPA does not appear to involve an auxin versus anti-auxin competition for receptor sites (Hall *et al* 1982; Hoppe 1985; Shimabukuro *et al* 1986; Fitzsimons *et al* 1988). If chlorophenoxy herbicides cause a decrease in the rate of leaf expansion of grasses during the first few days after spraying, this could explain their antagonistic effect on diclofop-methyl activity (Andrews *et al* 1989a).

TABLE 1: Mean daily extension rate of the youngest leaf during the first 3 days after spraying and on the eighth day after spraying and shoot dry weight 72 days after spraying wild oat with 1.0 kg ai/ha diclofop-methyl (D-M), 1.1 kg ai/ha 2,4-D and 1.0 kg ai/ha D-M plus 1.1 kg ai/ha 2,4-D.

Herbicide	Leaf extension rate (mm/day) 0-3 days	Leaf extension rate (mm/day) 8 days	Shoot dry weight (g) 72 days
0	28.9	29.8	3.12
D-M	28.1	3.4	0.14
2,4-D	21.1	19.6	1.75
D-M + 2,4-D	19.6	17.2	0.81
SEM	1.2	1.0	0.17

Data in Table 1 show the antagonistic effect 2,4-D can have on diclofop-methyl activity against wild oat. At harvest, shoot dry weight was greater for plants sprayed with diclofop-methyl plus 2,4-D than for plants sprayed with diclofop-methyl alone. This occurred, despite the finding that both diclofop-methyl and 2,4-D caused decreased growth when applied alone. Application of 2,4-D, with or without diclofop-methyl, caused a decrease in leaf extension rate during the first 3 days after spraying but diclofop-methyl alone did not cause a decrease in leaf extension until 4 days after spraying. Eight days after spraying, leaf extension rate for the different treatments showed a similar pattern to dry weight at harvest and decreased with treatment in the order: unsprayed > 2,4-D alone > diclofop-methyl + 2,4-D > diclofop-methyl alone (Table 1).

TABLE 2: Mean daily extension rate of the youngest leaf of four grass species during the 3 days after spraying with 1.0 kg ai/ha diclofop-methyl with or without 1.1 kg ai/ha 2,4-D in the same tank mix.

Herbicide treatment	Leaf extension rate (mm/day) Cultivated oat	Soft brome	Perennial ryegrass	Italian ryegrass
− 2,4-D	30.1	26.3	25.3	10.1
+ 2,4-D	21.5	17.6	15.1	9.6
SEM	0.4	1.3	1.6	2.3

As with wild oat, leaf extension rates of cultivated oat, soft brome and perennial ryegrass during the first 3 days after spraying were lower for plants sprayed with diclofop-methyl plus 2,4-D than for plants sprayed with diclofop-methyl alone (Table 2). These data show that amongst grasses, wild oat is not exceptional in being rapidly affected by 2,4-D. Diclofop-methyl with or without 2,4-D had a more rapid effect on Italian ryegrass than on the other grass species. Three days after spraying, regardless of herbicide treatment, leaf extension rate for all Italian ryegrass plants was less than 5 mm/day. This greater sensitivity to diclofop-methyl with Italian ryegrass may be a species related effect or due to the difference in growth stage between this species (3-leaf stage) and the others (4-leaf stage) at spraying. Younger plants have been shown to be more sensitive to the herbicide (Andrews *et al* 1989a).

Effects of bentazon, chlorsulfuron and dicamba

Bentazon, chlorsulfuron and dicamba also have been found to decrease diclofop-methyl activity against a range of grasses (Campbell and Penner 1982; Hall *et al* 1982a, b; Chow 1988). It has been reported that bentazon and chlorsulfuron can antagonise diclofop-methyl activity without affecting its uptake into, or translocation and metabolism within the plant (Hall *et al* 1982b; Liebl and Worsham 1987). In Experiment 3, bentazon, chlorsulfuron and dicamba reduced diclofop-methyl activity against wild oat (Table 3). All three broadleaf weed herbicides sprayed with diclofop-methyl caused a substantial decrease in leaf extension rate during the first 5 days after spraying but diclofop-methyl alone did not cause a decrease in leaf extension rate until 6 days after spraying. Ten days after spraying, leaf extension rates for plants sprayed with broadleaf weed herbicide/diclofop-methyl combinations were intermediate to those for unsprayed plants and those sprayed with diclofop-methyl alone (Table 3).

It is concluded that the data are in agreement with the proposal that antagonism of diclofop-methyl by the broadleaf weed herbicides used here is due to decreased growth rate during the first few days after spraying.

TABLE 3: Mean daily extension rate of the youngest leaf during the first 5 days after spraying and on the tenth day after spraying and shoot dry weight 52 days after spraying *Avena fatua* with 1.0 kg ai/ha diclofop-methyl (D-M), alone or in combination with 1.1 kg ai/ha 2,4-D, 0.3 kg ai/ha bentazon (B), 15 g ai/ha chlorsulfuron (C) and 0.3 kg ai/ha dicamba (D).

Herbicide	Leaf extension rate (mm/day) 0-5 days	10 days	Shoot dry weight (g) 52 days
0	31.4	35.0	4.30
D-M	31.5	4.2	0.32
D-M + 2,4-D	23.5	21.2	1.59
D-M + B	17.3	16.0	1.02
D-M + C	20.2	16.8	1.09
D-M + D	23.4	22.4	1.84
SEM	1.5	1.7	0.12

Avoiding herbicide antagonism

It is proposed that broadleaf weed herbicide antagonism of diclofop-methyl activity is due to decreased growth rate during the first few days after spraying. If this is the case, then antagonism should not occur if the broadleaf weed herbicide and diclofop-methyl are applied sequentially with a few days between sprayings. Previously, this approach has been shown to avoid antagonism (Dortenzio and Norris 1979; Olson and Nalewaja 1981).

Diclofop-methyl phytotoxicity is primarily due to effects on meristematic tissue. If the amount of diclofop-methyl reaching the active site can be increased, this could counter antagonism by broadleaf weed herbicides. Increased herbicide concentration at the active site can be achieved by increasing the rate of herbicide application and by the use of adjuvants. Both approaches have been used successfully to overcome broadleaf weed herbicide antagonism of diclofop-methyl (Olson and Nalewaja 1981; Chow 1988; Eberlein *et al* 1988).

If broadleaf weed herbicide antagonism of diclofop-methyl action is due to decreased leaf expansion rate, it is possible that application of a growth regulator which increases expansion rate could avoid antagonism. Gibberellic acid (GA) can increase the efficacy of diclofop-methyl against oats (Dickson *et al* 1988; Andrews *et al* 1989a) but has not been tested with the broadleaf weed herbicides used here. If GA is to be of use in countering antagonism between broadleaf weed herbicides and diclofop-methyl, it is likely that it would have to be applied 2 days prior to spraying and not from the same tank mix as the herbicides (Dickson *et al* 1988; Andrews *et al* 1989a). A possible disadvantage of using gibberellic acid with a selective post emergence herbicide such as diclofop-methyl is that there may be unwanted effects on the crop plant. Gibberellic acid enhancement of herbicides appears to have greater potential with broad spectrum herbicides such as glyphosate (Dickson *et al* 1989).

REFERENCES

Andrews, M., Dickson, R.L., Foreman, M.H., Dastgheib, F. and Field, R.J., 1989a. The effects of different external nitrate concentrations on growth of *Avena sativa* cv. Amuri treated wtih diclofop-methyl. *Ann. of Appl. Biol.* (In Press).

Andrews, M., Love, B.G. and Sprent, J.I., 1989b. The effects of different external nitrate concentrations on growth of *Phaseolus vulgaris* cv. Seafarer at chilling temperatures. *Ann. of Appl. Biol. 114:* 195-204.

Campbell, J.R. and Penner, D., 1982. Compatability of diclofop and BAS 9052 with bentazon. *Weed Sci. 30:* 458-462.

Chow, P.N.P., 1988. Effect of chlorsulfuron on four graminicides for weed control and wheat yield. *Weed Res. 28:* 145-150.

Dickson, R.L., Andrews, M. and Field, R.J., 1988. Leaf expansion effects on post-emergence herbicide performance. *Proc. 41st N.Z. Weed and Pest Control Conf.:* 53-56.

Dickson, R.L., Field, R.J. and Andrews, M., 1989. The susceptibility of *Avena* spp. to sequential applications of gibberellic acid and post emergence herbicides. *Proc. 42nd N.Z. Weed and Pest Control Conf.:*

Dortenzio, W.A. and Norris, R.F., 1979. Antagonistic effects of desmedipham on diclofop activity. *Weed Sci. 27:* 539-544.

Eberlein, C.V., Miller, T.L. and Wiersma, J.V., 1988. Influence of thiameturon and DPX-L5300 on wild oats (*Avena fatua*) control with barban, diclofop, AC222,293, and difenzoquat. *Weed Sci. 36:* 792-799.

Fitzsimons, P.J., Barnwell, P. and Cobb, A.H., 1988. A study of auxin-type herbicide action based on dose response analysis of H+ – efflux. *Proc. European Weed Res. Soc. Symp.:* Factors Affecting Herbicidal Activity and Selectivity, pp 63-68.

Hall, C., Edgington, L.V. and Switzer, C.M., 1982a. Effects of chlorsulfuron or 2,4-D upon diclofop-methyl efficacy in oat (*Avena sativa*). *Weed Sci. 30:* 672-676.

Hall, C., Edgington, L.V. and Switzer, C.M., 1982b. Translocation of different 2,4-D, bentazon, diclofop, or diclofop-methyl combinations in oat (*Avena sativa*) and soybean (*Glycine max*). *Weed Sci. 30:* 676-682.

Harwood, J.L., 1988. The site of action of some selective graminacous herbicides is identified as acetyl CoA carboxylase. *Trends in Biochemical Science, 13:* 330-331.

Hill, B.D., Todd, B.G. and Stobbe, E.H., 1980. Effect of 2,4-D on the hydrolysis of diclofop-methyl in wild oat (*Avena fatua*). *Weed Sci. 28:* 725-729.

Hoppe, H.H., 1985. Differential effect of diclofop-methyl on fatty acid biosynthesis in leaves of sensitive and tolerant plant species. *Pestic. Biochem. and Physiol. 23:* 297-308.

Liebl, R. and Worsham, A.D., 1987. Effect of chlorsulfuron on the movement and fate of diclofop-methyl in Italian ryegrass (*Lolium multiflorum*) and wheat (*Triticum aestivum*). *Weed Sci. 35:* 623-628.

Olson, W.A., and Nalewaja, J.D., 1981. Antagonistic effects of MCPA on wild oat (*Avena fatua*) control with diclofop. *Weed Sci. 29:* 566-571.

Shimabukuro, R.H., Hoerauf, R.A. and Walsh, W.C., 1986. Reciprocal antagonism between the herbicides, diclofop-methyl and 2,4-D in corn and soybean tissue culture. *Plant Physiol. 80:* 612-617.

Wright, J.D. and Shimabukuro, R.H.., 1987. Effects of diclofop and diclofop-methyl on the membrane potentials of wheat and oat coleoptiles. *Plant Physiol. 85:* 188-193.