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Full Length Research Paper

Efficacy of topramezone and mesotrione for the control of annual grasses

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Topramezone and mesotrione are two 4-hydroxyphenylpyruvate dioxygenase (HPPD) inhibiting herbicides used for broadleaf weed control in maize (*Zea mays* L.). Limited research has been reported on these herbicides for the control of annual grasses. Controlled environment experiments were conducted to determine the efficacy of topramezone (12.5 g ai ha^{-1}) and mesotrione (100 g ai ha^{-1}) on thirteen annual grass species at two development stages (2- to 3-leaf and 5- to 6-leaf). Topramezone provided consistent control of *Echinochloa crus-galli* (L.) Beauv. (barnyard grass), *Setaria glauca* (L.) Beauv. (yellow foxtail), *Setaria viridis* (L.) Beauv. (green foxtail), *Setaria faberi* Herrm. (giant foxtail), *Panicum miliaceum* L. (wild-proso millet), *Cenchrus longispinus* (Hack.) Fern. (longspine sandbur), and *Panicum capillare* L. (witchgrass) at both growth stages. Mesotrione provided consistent control of *Echinochloa crus-galli*, *Digitaria ischaemum* (Schreb.) Schreb. Ex Muhl. (smooth crabgrass), *Digitaria sanguinalis* (L.) Scop. (large crabgrass), and *Panicum miliaceum* at both growth stages. Both herbicides suppressed *Panicum dichotomiflorum* Michx. (fall panicum), but mesotrione also suppressed *Setaria glauca*, *Cenchrus longispinus*, *Panicum capillare*, and *Bromus tectorum* L. (downy brome). Topramezone provided poor control of *Bromus tectorum* and *Avena fatua* L. (wild oat), and mesotrione provided poor control of *Avena fatua*, *Setaria faberi*, and *Setaria viridis* at both growth stages. Increasing the growth stage of annual grasses generally did not alter the level of control by either herbicide. However, the control level of *Eragrostis cilianensis* (All.) Vign. Ex Janchen (stinkgrass) decreased from control to suppression with increasing growth stage with both topramezone and mesotrione. A similar decrease in the level of control was observed with topramezone on *Digitaria ischaemum*. Based upon the control levels determined from this research, weed management practitioners can select the appropriate herbicide for annual grass control in individual fields.

Keywords: Topramezone, mesotrione, HPPD-inhibiting, annual grasses, antagonism.

INTRODUCTION

Topramezone and mesotrione are relatively new herbicides registered for annual broadleaf weed control in maize (Zea mays L.). These herbicides inhibit 4-hydroxyphenylpyruvate dioxygenase (HPPD), a key enzyme in the carotenoid biosynthetic pathway of plants (Boger and Sandman, 1998). Carotenoid depletion causes disruption of chlorophyll in growing shoot tissues resulting in a bleaching affect which quickly turns necrotic in susceptible plant species (Grossmann and Ehrhardt, 2007).

Mesotrione has been available commercially since 2001 and more recently topramezone has been available to maize growers as a competitive alternative herbicide (Porter et al., 2005; Syngenta 2007). As these HPPD-inhibiting herbicides are not recommended as stand-alone products, appropriate tank-mixes need to be established to provide broad-spectrum weed control. Theoretically, herbicides that target grassy weeds, such as the acetolactate synthesis (ALS) inhibiting herbicides

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would make complementary tank-mix partners with topramezone and mesotrione. As many researchers are aware, tank-mixing different herbicides may lead to synergistic, antagonistic, or additive interactions as described by Colby (1967). Previous research by Schuster (2007) has shown that mesotrione antagonizes several ALS-inhibiting herbicides by reducing the efficacy of *Setaria viridis* (L.) Beauv. (green foxtail), *Setaria glauca* (L.) Beauv. (yellow foxtail), and *Sorghum bicolor* (L.) Moench (shattercane). Similar research has not been reported for topramezone.

Annual grass control with topramezone or mesotrione is not well known. Mesotrione applied postemergence provides control of *Echinochloa crus-galli* and *Digitaria species* (Wichert et al., 1999; Mitchell et al., 2001; Creech et al., 2004; and Schuster, 2007), while *Setaria* species are not controlled (Ohmes et al., 2000; Armel et al., 2003; Creech et al., 2004; Whaley et al., 2006; and Schuster, 2007). Control of these species with topramezone has not been published, nor is there additional control information on a wider range of annual grass species and growth stages for either of these HPPD-inhibiting herbicides.

Therefore, the objective of this research was to investigate the efficacy of topramezone and mesotrione applied at two growth stages (2- to 3-leaf and 5- to 6-leaf) on thirteen annual grass species under controlled environment experiments.

MATERIALS AND METHODS

Controlled environment experiments were conducted at the University of Guelph, Guelph, Ontario, Canada. Thirteen annual grass species found commonly in Ontario were selected for this experiment: *Echinochloa crus-galli* (L.) Beauv. (barnyard grass), *Setaria glauca* (L.) Beauv. (yellow foxtail), *Setaria viridis* (L.) Beauv. (green foxtail), *Setaria faberi Herrm.* (giant foxtail), *Eragrostis cilianensis* (All.) Vign. Ex Janchen (stinkgrass), *Digitaria ischaemum* (Schreb.) Schreb. Ex Muhl. (smooth crabgrass), *Panicum miliaceum* L. (wild-proso millet), *Cenchrus longispinus* (Hack.) Fern. (longspine sandbur), *Panicum capillare* L. (witchgrass), *Digitaria sanguinalis* (L.) Scop. (large crabgrass), *Panicum dichotomiflorum* Michx. (fall panicum), *Bromus tectorum* L. (downy brome), and *Avena fatua* L. (wild oat).

Annual grass seeds were germinated in trays containing clay Turface® (Profile Products LLC, Buffalo Grove, IL) or fine clay Turface® for small grass seeds such as *Eragrostis cilianensis.* The trays were covered with clear plastic trays to increase humidity for germination. After 5 d, uniformly developed plants at the one-leaf stage were transplanted into 400 ml pots filled with Pro-mix PGX® growing media (Premier Horticulture Inc., Quakertown, PA). Plants were watered at the soil surface with a 20-20-20 fertilizer solution as needed to ensure maximum growth. The plants were grown in a controlled environment room maintained at 25/20 ± 2 C (day/night) temperatures with 50 to 60% relative humidity. A photoperiod of 16:8 h (light:dark) was maintained by incandescent and fluorescent lights (PPFD = 200 µmol m-2 s-2).

The experiments were established as a randomized complete block design with six replications. Each experiment repeated twice over time. Treatments included a non-treated control and topramezone (12.5 g ai ha-1) or mesotrione (100 g ai ha-1) applied at two growth stages (2- to 3-leaf and 5- to 6-leaf) to the thirteen annual grass species. All herbicide treatments included Assist® oil concentrate at 1.25% v/v. Growth stages and heights for each grass species at the time of application are shown in Table 1. Prior to herbicide application, the soil surface was covered with a layer of coarse vermiculite to prevent the roots from being exposed to the herbicide solution. Herbicide treatments were applied with a motorized spray chamber equipped with a stainless steel TeeJet® 8002 even flat fan spray tip (Spraying Systems Co., Wheaton, IL) calibrated to deliver 210 L ha-1 of herbicide spray solution at 276 kPa approximately 46 cm above the plant canopy. Following application, the vermiculite was removed from the soil surface and plants were returned to the controlled environment and not watered for 24 h. Plants were spaced apart to reduce pot-to-pot interactions and trays were rearranged every 3 days to reduce the impact of lighting variation across the experimental area.

Prior to harvest, annual grass species were classified into three categories based upon their response to topramezone or mesotrione: control (≥85% biomass reduction), suppression (50-84% biomass reduction), or poor control (<50% biomass reduction). Grasses that were “controlled” showed typical bleaching symptoms and necrosis with no visual signs of regrowth or greening of meristematic tissues. Grasses that were “suppressed” displayed bleaching symptoms, but regrowth and greening of meristematic tissues including the tillers occurred. Grasses that were “poorly controlled” illustrated asymptomatic conditions, growing much like the non-treated control. Fourteen days after treatment (DAT), above ground biomass was clipped at the soil surface and oven dried for one week at 80 C.

Dry matter data were converted to biomass reduction, expressed as a percent of the non-treated control within each replicated block to remove variation across the experimental area. Data transformations were performed but did not affect the level of significance within the data set. Therefore, the non-transformed biomass reduction data are presented. Analyses of variance were conducted using the PROC GLM procedure of SAS version 9.1.3 (SAS Institute, Cary, NC). Significant variances of biomass reduction were partitioned into fixed

Table 1. Average seedling height at the time of herbicide application.

	Height (cm) ± 1	
Scientific name (common name)	**2-3 leaf**	**5-6 leaf**
Echinochloa crus-galli (barnyard grass)	7	17
Setaria glauca (yellow foxtail)	9	17
Setaria viridis (green foxtail)	5	11
Setaria faberi (giant foxtail)	6	18
Eragrostis cilianensis (stinkgrass)	3	11
Digitaria ischaemum (smooth crabgrass)	4	10
Panicum miliaceum (wild-proso millet)	5	14
Cenchrus longispinus (longspine sandbur)	5	13
Panicum capillare (witchgrass)	4	13
Digitaria sanguinalis (large crabgrass)	5	13
Panicum dichotomiflorum (fall panicum)	9	22
Bromus tectorum (downy brome)	9	14
Avena fatua (wild oat)	17	35

effects of grass species and herbicide treatments and the random effects of trial and replicated block-by-trial interaction. Error assumptions of the variance analysis (random, homogeneous, and normal distribution of error) were confirmed using studentized residuals and the Shapiro-Wilk normality test, while outliers were removed following Lunds test (Lund, 1975). As there were no significant effects between the two replicated trials, data were combined for the final analysis. Treatment means were separated using Fisher's protected LSD. The Type I error was set at 0.05 and 0.01 for statistical comparisons.

RESULTS AND DISCUSSION

Topramezone provided consistent control of seven annual grass species including: *Echinochloa crus-galli, Setaria glauca, Setaria viridis, Setaria faberi, Panicum miliaceum, Cenchrus longispinus, and Panicum Capillare* when applied at the 2- to 3-leaf or 5- to 6-leaf stage of seedling growth (Table 2). Efficacy fell between control and suppression for *Digitaria sanguinalis* (85-84%). Control was achieved when topramezone was applied at the 2- to 3-leaf stage for *Eragrostis cilianensis* (95%) and *Digitaria ischaemum* (94%), but was reduced to suppression (81 and 84% respectively) at the 5- to 6-leaf stage of seedling growth. Topramezone provided suppression of *Panicum dichotomiflorum* (77 to 62%) when applied at either growth stage. Control of *Bromus tectorum* (≤30%) and *Avena fatua* (≤16%) was poor.

Mesotrione provided consistent control of four annual grass species including: *Echinochloa crus-galli, Digitaria ischaemum, Panicum miliaceum,* and *Digitaria sanguinalis* when applied at the 2- to 3-leaf or 5- to 6-leaf stage of seedling growth (Table 2). Similar results for the control of *Digitaria species* and *Echinochloa crus-galli* have been reported previously (Wichert et al., 1999; Mitchell et al., 2001; Creech et al., 2004; and Schuster, 2007). In contrast, Whaley et al. (2006) reported that mesotrione (105 g ai ha-1) only provided suppression of *Digitaria sanguinalis* under field conditions up to eight weeks after postemergence application. Variability in control of the *Digitaria species* may be attributed to differences in application timing, weed density, and environmental conditions.

Mesotrione also provided control for *Eragrostis cilianensis* (95%) when applied at the 2- to 3-leaf stage, but was reduced to suppression (83%) at the 5- to 6-leaf stage of seedling growth (Table 2). Mesotrione provided suppression of *Setaria glauca, Cenchrus longispinus, Panicum capillare, Panicum dichotomiflorum,* and *Bromus tectorum* when applied at either growth stage. Mesotrione provided poor control of *Setaria viridis, Setaria faberi,* and *Avena fatua*. Previous research under field conditions have also indicated poor control of *Setaria* species with mesotrione (Ohmes et al., 2000; Armel et al., 2003; Creech et al., 2004; Whaley et al., 2006; and Schuster, 2007).

Contrasts between herbicides determined that topramezone provided greater control of *Setaria glauca, Setaria viridis, Setaria faberi, Cenchrus longispinus, Panicum capillare,* and *Avena fatua* compared to mesotrione, while mesotrione provided greater control of *Echinochloa crus-galli, Digitaria ischaemum, Digitaria sanguinalis*, and *Bromus tectorum* (Table 2).

Table 2. Biomass reduction of annual grass species treated with topramezone (12.5 g ai ha $^{-1}$) or mesotrione (100 g ai ha $^{-1}$) at the 2- to 3-leaf or 5- to 6-leaf stage of seedling growth in a controlled environment [a].

	Topramezone[b]			Mesotrione[b]			Contrast[d]
Scientific name (common name)	2-3 leaf	5-6 leaf	Contrast[c] Growth stage	2-3 leaf	5-6 leaf	Contrast[c] Growth stage	Topramezone vs Mesotrione
Echinochloa crus-galli (barnyard grass)	96 a	88 a	**	97 a	90 ab	**	92 vs 94 *
Setaria glauca (yellow foxtail)	96 a	88 a	**	80 c	72 d	**	92 vs 76 **
Setaria viridis (green foxtail)	96 a	87 ab	**	19 f	17 h	NS	91 vs 18 **
Setaria faberi (giant foxtail)	95 ab	85 ab	**	8 g	14 h	**	90 vs 11 **
Eragrostis cilianensis (stinkgrass)	95 abc	81 c	**	95 ab	83 c	**	88 vs 89 NS
Digitaria ischaemum (smooth crabgrass)	94 abc	84 bc	**	95 ab	93 ab	**	89 vs 94 **
Panicum miliaceum (wild-proso millet)	92 bcd	85 abc	**	92 b	86 c	**	89 vs 89 NS
Cenchrus longispinus (longspine sandbur)	92 cd	85 ab	**	67 d	63 f	**	89 vs 65 **
Panicum capillare (witchgrass)	91 d	85 abc	**	63 e	51 g	**	88 vs 57 **
Digitaria sanguinalis (large crabgrass)	85 e	84 bc	NS	96 ab	94 a	**	84 vs 95 **
Panicum dichotomiflorum (fall panicum)	77 f	62 d	**	69 d	68 e	NS	70 vs 69 NS
Bromus tectorum (downy brome)	30 g	7 e	**	70 d	70 de	NS	19 vs 70 **
Avena fatua (wild oat)	16 h	6 e	**	7 g	5 i	NS	11 vs 6 **

[a]Data expressed as biomass reduction (percent of the non-treated control where 0 = no control and 100 = control), values within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P<0.01$).
[b]Topramezone and mesotrione included Assist® oil concentrate at 1.25% v/v.
[c]Contrasts according to Fisher's Protected LSD test *($P<0.05$), **($P<0.01$), and NS (No Significance).
[d]Contrast of topramezone vs mesotrione is calculated on mean % biomass reduction for combined growth stages within each herbicide treatment.

Topramezone and mesotrione provided equivalent control of *Eragrostis cilianensis, Panicum miliaceum, and Panicum dichotomiflorum*.

In general, an increase in growth stage caused a change in biomass reduction, but did not alter the level of control. For example, when topramezone was applied to *Echinochloa crus-galli,* consistent control (96 and 88%) was maintained at both growth stages (Table 2). Occasionally, an increase in growth stage caused a large change in biomass reduction, therefore altering the level of control. For example, topramezone provided control of *Digitaria ischaemum* at the 2- to 3-leaf stage (94%), but only provided suppression at the 5- to 6-leaf stage (84%) of seedling growth. Similar changes in the level of control were observed with topramezone or mesotrione applied to *Eragrostis cilianensis.* In contrast, an increase in growth stage did not affect biomass reduction for *Digitaria sanguinalis* when topramezone was applied, or *Setaria viridis, Panicum dichotomiflorum*, *Bromus tectorum*, and *Avena fatua* when mesotrione was applied.

CONCLUSIONS

Although both topramezone and mesotrione are HPPD-inhibitors, this research identified a wide range in selectivity on annual grasses with these two herbicides. From these results, topramezone controlled a greater range of annual grasses than mesotrione, most notably at the earlier stage of seedling growth. In terms of commercially acceptable control, both herbicides had only two species in common, *Echinochloa crus-galli* and *Panicum miliaceum*. Neither herbicide controlled *Avena fatua.* Interestingly, for several species that were suppressed by one of the herbicides, control was obtained by the other. This would suggest that if these products were to be positioned for broad - spectrum annual grass control, tank-mixtures of both herbicides should be considered as a viable approach to the market.

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