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Creeping Bentgrass, Perennial Ryegrass, and Tall Fescue Tolerance to Topramezone During Establishment

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Topramezone controls weeds in tolerant, cool-season turfgrasses, but injury potential during establishment has received limited investigation. The objectives of this research were to evaluate the tolerance of 'Penn A-4' creeping bentgrass, 'Manhattan V' perennial ryegrass, and 'Titan' tall fescue to topramezone at 18.5, 37, or 74 g ae ha^{-1} during establishment. Grasses were seeded in strips in October, and treatments were applied at 0, 2, 4, or 6 wk after seeding (WAS). Perennial ryegrass and tall fescue had minimal ($\leq$ 8%) injury from all treatments, and ground cover was greater or equal to the nontreated at all application timings. Topramezone applied 4 WAS at 37 and 74 g ha^{-1} injured creeping bentgrass 16 and 23% at 2 wk after treatment, respectively. However, all other topramezone rates and timings caused $<$ 10% injury. Mesotrione at 175 g ai ha^{-1} injured creeping bentgrass 14 to 43% at all timings and was more injurious than topramezone. Mesotrione applied at 2, 4, or 6 WAS controlled lesser swinecress $\geq$ 99% at 20 WAS, whereas applications on the day of seeding provided 71% control. All topramezone treatments provided poor control ($<$ 70%) of lesser swinecress at 20 WAS. Overall, perennial ryegrass and tall fescue are tolerant to topramezone during establishment at the rates tested. Seedling creeping bentgrass has better tolerance to topramezone from 18.5 to 74 g ha^{-1}, than to mesotrione at 175 g ha^{-1} and may provide end-users an HPPD inhibitor for use during establishment.

Nomenclature: HPPD, 4-hydroxyphenylpyruvate dioxygenase; mesotrione; topramezone; creeping bentgrass, *Agrostis stolonifera* L. 'Penn A-4′; perennial ryegrass, *Lolium perenne* L. 'Manhattan V'; lesser swinecress, *Coronopus didymus* (L.) Sm.; tall fescue, *Festuca arundinacea* (Schreb.) S.J. Darbyshire 'Titan'.
Key words: HPPD inhibitor, planting, resistance, seed, turfgrass.

Topramezone controla malezas en céspedes de clima frío tolerantes, pero el potencial de daño durante el período de establecimiento ha sido investigado en forma limitada. Los objetivos de esta investigación fueron evaluar la tolerancia de *Agrostis stolonifera* 'Penn A-4′ , *Lolium perenne* 'Manhattan V', y *Festuca arundinacea* 'Titan' a topramezone aplicado a 18.5, 37, ó 74 g ae ha^{-1} durante el establecimiento. Los céspedes fueron sembrados en bandas en Octubre, y los tratamientos fueron aplicados a 0, 2, 4, ó 6 semanas después de la siembra (WAS). *L. perenne* y *F. arundinacea* sufrieron un daño mínimo ($\leq$8%) con todos los tratamientos, y su cobertura de suelo fue mayor o igual al testigo sin tratamiento para todos los momentos de aplicación. Topramezone aplicado 4 WAS a 37 y 74 g ha^{-1} dañó *A. stolonifera* 16 y 23% a 2 semanas después del tratamiento, respectivamente. Sin embargo, todas las dosis y momentos de aplicación de topramezone causaron $<$10% de daño. Mesotrione a 175 g ai ha^{-1} dañó *A. stolonifera* 14 y 43% en todos los momentos de aplicación y fue más dañino que topramezone. Mesotrione aplicado a 2, 4, ó 6 WAS controló *Coronopus didymus* $\geq$99% a 20 WAS, mientras que aplicaciones el día de la siembra brindaron 71% de control. Todos los tratamientos de topramezone brindaron un control limitado ($<$70%) de *C. didymus* a 20 WAS. En general, *L. perenne* y *F. arundinacea* son tolerantes a topramezone durante el establecimiento, a las dosis evaluadas. Las plántulas de *A. stolonifera* tienen una mejor tolerancia a topramezone desde 18.5 a 74 g ha^{-1}, que a mesotrione a 175 g ha^{-1}, así topramezone podría brindar a los usuario un inhibidor de HPPD durante el establecimiento.

Weed control is often critical for successful turfgrass establishment. Soil disruption, fertilization, and regular irrigation may promote germination of annual weeds that compete with turfgrasses (Peters et al. 1989). Controlling weeds with herbicides reduces competition during establishment and helps promote the growth of turfgrass seedlings. However, injury potential of susceptible species, such as creeping bentgrass, is a major limitation to herbicide selection during establishment.

Ethofumesate effectively controls annual weeds when applied before or after the emergence of perennial ryegrass and tall fescue seedlings (Anonymous 2014; Dernoeden et al. 2008b). Creeping

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bentgrass seedlings are susceptible to ethofumesate injury, and applications should be delayed until approximately 4 wk after emergence (Anonymous 2014; Dernoeden et al. 2008b). Siduron effectively controls crabgrass (*Digitaria* Haller spp.) during establishment of creeping bentgrass and other cool-season grasses, but efficacy is limited on broadleaves, sedges (*Cyperus* L. spp.), and many other grassy weeds (Johnson 1983; McElroy and Breeden 2007; Moshier et al. 1976; Willis et al. 2006). Fenoxaprop and quinclorac are labeled for weed control in established cool-season turfgrasses. However, applications may cause thinning or excessive injury to turfgrass seedlings (Dernoeden 1987; Hart et al. 2004; Johnson and Carrow 1993; McElroy and Breeden 2007).

Mesotrione is an HPPD inhibitor that disrupts carotenoid biosynthesis in susceptible weeds (Mitchell et al. 2001). Mesotrione may be applied immediately after seeding perennial ryegrass, tall fescue, and other tolerant species for controlling crabgrass, annual bluegrass (*Poa annua* L.), and broadleaf weeds (Beam et al. 2006; McCurdy et al. 2008; McElroy and Breeden 2007; Skelton et al. 2012). Creeping bentgrass is more susceptible to mesotrione injury than other cool-season grasses are (Beam et al. 2006; Dernoeden et al. 2008a). Moreover, sequential applications of mesotrione selectively control creeping bentgrass in tolerant turfgrass species (Jones and Christians 2007). Thus, practitioners are limited to using siduron or low rates of herbicides with turf-injury potential for weed control during creeping bentgrass establishment.

Topramezone is an HPPD inhibitor that was registered for turfgrass in 2014 (Grossman and Ehrhardt 2007). This herbicide effectively controls crabgrass, goosegrass [*Eleusine indica* (L.) Gaertn.], and certain broadleaf weeds in perennial ryegrass, tall fescue, and other tolerant species (Zhang et al. 2013; Zollinger and Ries 2006). Preliminary research indicated that creeping bentgrass has better tolerance to topramezone than it did to mesotrione. Aldahir et al. (2014) noted topramezone at 12 g ai ha^{-1} caused $< 5\%$ injury to a creeping bentgrass putting green. Venner et al. (2014) reported summer applications of topramezone at 25 g ha^{-1} caused no injury to creeping bentgrass at 3 wk after treatment (WAT). Thus, further research is needed for practitioners to incorporate this herbicide in turf management programs.

Topramezone is an efficacious herbicide that may provide an alternative mode of action for weed control in established creeping bentgrass. Similar to mesotrione, topramezone may have potential for use during cool-season turfgrass establishment. However, the tolerance of seedling cool-season grasses to topramezone has received limited investigation. The objective of this research was to evaluate topramezone application rates and timing on the establishment of creeping bentgrass, perennial ryegrass, and tall fescue from seed.

Materials and Methods

Plant Material and Establishment. Field experiments were conducted in Griffin, GA, from September 2013 to March 2014 and from September 2014 to February 2015. Plots in the second experiment were adjacent to the first experiment. Glyphosate was applied at 3 kg ae ha^{-1} to mature tall fescue grown on a Cecil sandy clay loam (fine, kaolinitic, thermic Typic Kandiudult) with a 6.0 pH and 2% organic matter in September of both years. Fields were scalped with a rotary mower, debris was removed, and soil was sliced in two directions at a 1-cm depth. ‘Penn A-4’ creeping bentgrass (Tee-2-Green Corp., Hubbard, OR), ‘Manhattan V’ perennial ryegrass (Pure Seed Testing Inc., Canby, OR), and ‘Titan’ tall fescue (Seed Research of Oregon, Inc. Tangent, OR) were seeded in strips measuring 0.9 × 21 m at 49,392, and 392 kg ha^{-1}, respectively, on September 30, 2013, and September 30, 2014. Creeping bentgrass seed was mixed with a 5–2–0 ($N–P_2O_5–K_2O$) fertilizer (Milorganite, Milwaukee, WI) at a 6 : 1 fertilizer : seed ratio to facilitate the accuracy of the targeted seeding rate. Species were randomized in four blocks, and fields were irrigated to promote turf establishment. During active growth, creeping bentgrass and perennial ryegrass were mowed at 1.3 cm with a reel-mower twice per week, and tall fescue was mowed weekly at 6.3 cm with a rotary mower. The initial mowing began at approximately 2 wk after seeding (WAS) and clippings were returned.

Treatments. Treatments were applied perpendicular to turf strips in a randomized complete-block design. A factorial combination of four

Table 1. Turfgrass injury, ground cover, and grid counts following mesotrione and topramezone applications during establishment of 'Penn A-4' creeping bentgrass in two field experiments, 2013–2015, Griffin, GA. Results were pooled over years.[a]

Application timing	Herbicide	Rate[c]	Injury (WAT)[b]			Ground cover (WAS)					Grid counts
			2	4	6	4	8	12	16	20	20 WAS
WAS		$g\ ha^{-1}$	%								% of nontreated
0	Mesotrione	175	14	0	0	39	60	68	69	68	97
	Topramezone	18.5	0	0	0	59	66	61	59	60	97
		37	0	0	0	58	69	66	64	64	100
		74	4	0	0	53	69	74	75	74	100
2	Mesotrione	175	43	9	1	30	48	58	55	54	89
	Topramezone	18.5	0	0	0	59	63	58	55	56	100
		37	3	0	0	51	57	54	52	53	100
		74	9	2	0	43	60	62	55	56	100
4	Mesotrione	175	34	24	19		56	68	70	69	100
	Topramezone	18.5	3	1	1		69	68	63	63	100
		37	16	2	1		66	68	65	65	97
		74	23	8	4		68	74	71	68	97
6	Mesotrione	175	12	24	31		59	74	79	79	100
	Topramezone	18.5	1	0	0		48	50	46	46	100
		37	2	2	0		57	62	61	63	100
		74	8	6	0		58	67	64	67	100
—	Nontreated	0				58	59	59	58	58	100
		$LSD_{0.05}$	6	5	3	10	13	11	12	12	8

[a] Abbreviations: WAT, weeks after treatment; WAS, weeks after seeding.

[b] Creeping bentgrass was seeded at 49 kg ha^{-1} on September 30, 2013, and September 30, 2014. Application dates were September 30, October 14, October 28, and November 11 in 2013 and September 30, October 13, October 28, and November 10 in 2014.

[c] Rate for mesotrione is the active ingredient, and rate for topramezone is in acid equivalent.

application timings and four herbicide treatments were evaluated. Treatments included mesotrione at 175 g ai ha^{-1} and topramezone at 18.5, 37, or 74 g ae ha^{-1}. Applications were made at 0, 2, 4, or 6 WAS. Herbicides applied the day of establishment were applied immediately after strips were seeded. Applications dates are presented in Table 1. A nontreated check was included. Mesotrione was chosen as a standard for comparison with topramezone at a recommended rate for perennial ryegrass and tall fescue (Anonymous 2008). The topramezone rates were chosen to simulate one-half, one, and two times the labeled use rates for established perennial ryegrass and tall fescue (Anonymous 2015). Applications were made with CO_2-pressured sprayers calibrated to deliver 374 L ha^{-1} with a single flat-fan nozzle (TeeJet, Spraying Systems Co., Wheaton, IL) at 222 kPa.

Measurements. Turfgrass cover was visually measured every 4 wk on a percentage scale, where 0 equaled no turf cover and 100 equaled complete plot cover. Injury was visually evaluated biweekly on a percentage scale, where 0 equaled no injury and 100 equaled dead turf. Injury was primarily expressed as the percentage of tissue bleaching and necrosis. Grid counts were made for each species by counting the number of 161-cm^2 squares within a 0.58-m^2 grid (36 total squares per grid) with shoots present (yes/no) of the desirable turf species at 20 WAS. Results were converted to the percentage of the nontreated for each species with the following equation:

$$\text{Percentage of nontreated grid counts} = 100 \times (A/B), \qquad [1]$$

where A equals the treated plot, and B equals the nontreated plot by replication. Lesser swinecress cover was visually evaluated monthly, from 4 to 20 WAS, on a percentage scale, where 0 equaled no cover and 100 equaled complete plot coverage. Lesser swinecress control was calculated by dividing the reduction in ground cover per plot from the cover in the nontreated with the following equation:

$$\text{Control} = 100 \times [(B - A)/B], \qquad [2]$$

where A equals the treated plot, and B equals the nontreated plot by replication.

Experimental Design and Data Analysis. The experimental design was a randomized complete block with four replications. Data were subjected to ANOVA with the general linear model procedure in SAS software (v. 9.3, SAS Institute, Cary, NC). Species were analyzed separately, similar to previous research (Gomez de Barreda et al. 2013; Lycan and Hart 2005). Means were separated with Fisher's protected LSD test at $\alpha = 0.05$. Year-by-treatment interactions were not detected, and thus, years were combined.

Results and Discussion

Creeping Bentgrass. Treatment-by-application timing interactions were detected ($P < 0.05$) for turfgrass injury and cover, and thus, results are presented across all combinations (Table 1). At 2 WAT, all topramezone rates and timings injured creeping bentgrass $\leq$ 16%, except 74 g ha^{-1} applied 4 WAS. This treatment caused 23% injury and was the highest levels observed from a topramezone application. Creeping bentgrass injury did not exceed 8% from any topramezone treatment at 4 and 6 WAT. Mesotrione applied 2 and 4 WAS injured creeping bentgrass 43 and 34% at 2 WAT, respectively, but treatments on the day of seeding or at 6 WAS caused $<$ 15% injury (Table 1). Creeping bentgrass injury persisted from mesotrione applied 4 and 6 WAS, ranging 19 to 31% at 6 WAT.

Mesotrione caused significant bleaching and stunted growth to creeping bentgrass seedlings that are similar to previous reports. Jones and Christians (2007) noted that mesotrione at various rates caused significant foliar bleaching and up to 43% injury on creeping bentgrass. Topramezone causes similar bleaching to creeping bentgrass, but applications were less injurious than mesotrione. The injury symptoms from HPPD inhibitors on creeping bentgrass seedlings are significantly different from the chlorosis observed from other POST herbicides. For example, Carroll et al. (1992) reported discoloration and thinning on an established creeping bentgrass putting green from fenoxaprop at 45 g ai ha^{-1}. Other researchers noted similar injury to creeping bentgrass after fenoxaprop and quinclorac applications (Dernoeden 1989; Hart et al. 2004; Shim and Johnson 1992). Dernoeden et al. (2008b) reported an acetolactate synthase inhibitor, bispyribac-sodium, caused excessive injury to creeping bentgrass seedlings during fall establishment that resulted in significant stand thinning.

Ground cover of the nontreated creeping bentgrass reached 58% at 20 WAS (Table 1). Creeping bentgrass ground cover after all topramezone treatments was greater or equal to the nontreated control from 4 to 12 WAS. However, mesotrione reduced creeping bentgrass ground cover more than topramezone treatments did. At 4 WAS, mesotrione applied at 0 and 2 WAS reduced ground cover 19 and 28% from the nontreated check, respectively. Similar reductions in creeping bentgrass density have been reported with quinclorac during establishment (Hart et al. 2004). Despite significant injury from mesotrione, creeping bentgrass ground cover was similar or greater than the nontreated control from 8 to 20 WAS. Mesotrione applied 2 WAS reduced grid counts 11% from the nontreated check, but all other treatments were similar at 20 WAS. Differences between ground cover and grid count ratings for this treatment may have resulted from weed pressure in plots that caused inconsistencies with these measurements.

Creeping bentgrass is particularly susceptible to bleaching from mesotrione and sequential applications may control established populations in tolerant turfgrasses (Jones and Christians 2007). Perhaps, a single mesotrione application could control creeping bentgrass seedlings in polyculture with other turfgrasses, such as tall fescue. Although mesotrione caused substantial bleaching followed by stunted growth, weed control and subsequent recovery may enhance creeping bentgrass establishment at low to moderate rates. Further research is needed to evaluate application rates of mesotrione that effectively control weeds and minimize injury to creeping bentgrass seedlings.

Creeping bentgrass injury from HPPD inhibitors is distinctly different from the chlorosis typically observed from other chemistries. However, the stunted growth that occurs after the initial foliar bleaching could delay establishment similar to other

Table 2. Ground cover and grid counts following mesotrione and topramezone applications during establishment of ‘Manhattan V’ perennial ryegrass in two field experiments, 2013–2015, Griffin, GA. Results were pooled over years.[a]

Herbicide	Rate[b]	Ground cover (WAS)[c] 4	8	12	16	20	Grid counts 20 WAS
	g ha^{-1}	%					% of nontreated
Mesotrione	175	69	77	80	86	86	100
Topramezone	18.5	68	78	78	80	80	100
	37	67	78	78	82	81	100
	74	67	77	78	83	82	100
Nontreated	0	70	77	74	74	74	100
	$LSD_{0.05}$	NS	NS	4	4	4	NS
Application timing (WAS)[d]							
0		70	80	81	88	87	100
2		65	76	75	79	79	100
4			78	79	84	83	100
6			76	78	80	80	100
Nontreated		70	77	74	74	74	100
	$LSD_{0.05}$	NS	3	4	4	4	NS

[a] Abbreviations: WAS, weeks after seeding, NS, not significant.

[b] Rate for mesotrione is the active ingredient, and rate for topramezone is in acid equivalent.

[c] Perennial ryegrass was seeded at 392 kg ha^{-1} on September 30, 2013, and September 30, 2014.

[d] Application dates were September 30, October 14, October 28, and November 11 in 2013 and September 30, October 13, October 28, and November 10 in 2014.

herbicides. In Maryland, bensulide at 14 kg ha^{-1}, ethofumesate at 0.84 kg ai ha^{-1}, and prodiamine at 0.36 kg ai ha^{-1} applied at 2 wk after creeping bentgrass emergence caused unacceptable injury, but treatments applied at 4 wk after emergence were less injurious (Kaminski at al. 2004). In other experiments, Reicher et al. (2002) reported that quinclorac at 0.84 kg ha^{-1} applied 14 d after emergence caused temporary quality reductions at 28 d after emergence in Indiana and Iowa. Topramezone at all rates and timings caused less stand thinning to creeping bentgrass than levels reported in these previous experiments. Results suggest that topramezone could provide an alternative herbicide to fenoxaprop, quinclorac, or siduron during creeping bentgrass establishment. Further research is needed to evaluate cultural practices and the differential tolerance levels of various creeping bentgrass cultivars to topramezone application rates and regimens during establishment.

Perennial Ryegrass. Treatment-by-application timing interactions were not detected ($P > 0.05$) for injury, ground cover, or grid counts for perennial ryegrass throughout the experiment. Herbicides applied at 4 WAS injured perennial ryegrass 7% at 2 WAT, but injury declined to < 2% at 4 and 6 WAT (data not shown). Perennial ryegrass was injured < 5% from treatments applied at 0, 2, and 6 WAS at all evaluations. Ground cover of nontreated perennial ryegrass ranged 70 to 77% throughout the experiment (Table 2). All herbicide treatments increased ground cover approximately 10% from that of the nontreated control at 16 to 20 WAS. Treatments did not reduce the presence of perennial ryegrass from the nontreated check in grid count measurements.

Perennial ryegrass tolerance to topramezone during establishment was consistent with previous research with mesotrione. Beam et al. (2006) reported that sequential applications of mesotrione resulted in ≤ 2% injury to perennial ryegrass by 6 wk after initial treatment. Similarly, Willis et al. (2007) noted that mesotrione at 280 g ha^{-1} injured a blend of perennial ryegrass and Kentucky bluegrass (*Poa pratensis* L.) by < 10%. Topramezone could also control weeds during overseeding of perennial ryegrass in bermudagrass [*Cynodon dactylon* (L.) Pers.) or Kentucky bluegrass turf and warrants further investigation.

Table 3. Ground cover and grid counts following mesotrione and topramezone applications during establishment of 'Titan' tall fescue in two field experiments, 2013–2015, Griffin, GA. Results were pooled over years.[a]

Herbicide	Rate[c]	Ground cover (WAS)[b] 4	8	12	16	20	Grid counts 20 WAS
	g ha^{-1}			%			% of nontreated
Mesotrione	175	61	74	80	87	86	100
Topramezone	18.5	59	69	71	71	72	100
	37	61	73	75	75	76	100
	74	58	72	75	77	77	100
Nontreated	0	63	68	65	65	66	100
	$LSD_{0.05}$	NS	4	4	6	6	NS
Application timing (was)[d]							
0		61	78	80	85	86	100
2		59	72	74	73	73	100
4			74	77	79	79	100
6			65	70	73	73	100
Nontreated		66	65	65	65	66	100
	$LSD_{0.05}$	NS	4	4	6	5	NS

[a] Abbreviations: WAS, wk after seeding; NS, not significant.

[b] Tall fescue was seeded at 392 kg ha^{-1} on September 30, 2013, and September 30, 2014.

[c] Rate for mesotrione is active ingredient, and rate for topramezone is in acid equivalent.

[d] Application dates were September 30, October 14, October 28, and November 11 in 2013 and September 30, October 13, October 28, and November 10 in 2014.

Turf managers could potentially use topramezone in sequential applications with other herbicides during perennial ryegrass establishment. Researchers have noted that perennial ryegrass seedlings have excellent tolerance to siduron and ethofumesate (Bingham and Schmidt 1983; Coats and Krans 1986). Reicher et al. (1999) reported no injury from quinclorac applications during perennial ryegrass emergence. The species is susceptible to injury from other herbicide mechanisms of action, such as acetyl-coenzyme A carboxylase inhibitors, used for controlling crabgrass and goosegrass. Dernoeden (1987) noted that fenoxaprop caused yellowing of perennial ryegrass seedlings but did not result in stand reductions. Similar injury to perennial ryegrass seedlings from fenoxaprop was reported by Neal et al. (1990). Topramezone could provide turfgrass managers a safer alternative to fenoxaprop for goosegrass control during perennial ryegrass establishment and a more efficacious herbicide than ethofumesate, quinclorac, or siduron.

Tall Fescue. Treatment-by-application timing interactions were not detected ($P > 0.05$) for tall fescue injury, ground cover, or grid counts. Ground cover of nontreated tall fescue ranged 63 to 68% (Table 3). All herbicides and application timings resulted in greater or equal ground cover than that of the nontreated check at 8 to 20 WAS. There was no meaningful injury (< 2%) detected on tall fescue from any treatment at any application timing (data not shown). The presence of tall fescue was not reduced from the nontreated control in grid count evaluations from any treatment.

Tall fescue tolerance to topramezone was similar to that in previous research with mesotrione during establishment. Venner (2011) reported mesotrione applied at 0.14 to 0.58 kg ha^{-1} at establishment plus 4 wk after emergence did not reduce tall fescue cover from the nontreated control. McElroy and Breeden (2007) reported mesotrione at 280 g ha^{-1} reduced tall fescue cover ≤ 6% at 63 d after emergence when applied 14 d after emergence. It was also noted that tall fescue recovered to ≤ 8% injury by 56 d after seedling emergence from mesotrione at 280 g ha^{-1}.

Herbicide selection for weed control in tall fescue is often similar to perennial ryegrass during establishment. Willis et al. (2006) reported no injury to tall fescue with sequential quinclorac applications during establishment. Fenoxaprop has been reported to cause temporary chlorosis on tall

Table 4. Lesser swinecress control in ‘Penn A-4’ creeping bentgrass following mesotrione and topramezone treatments during establishment in two experiments, 2013–2015, Griffin, GA.[a]

			Lesser swinecress control[b] (WAS)[c]				
Application Timing	Herbicide	Rate[d]	4	8	12	16	20
		g ha^{-1}			%		
WAS							
0	Mesotrione	175	80	86	77	71	71
	Topramezone	18.5	30	31	24	23	23
		37	57	41	37	36	36
		74	75	87	73	72	67
2	Mesotrione	175	68	100	100	100	99
	Topramezone	18.5	8	18	15	15	15
		37	13	21	16	14	14
		74	32	46	36	34	32
4	Mesotrione	175		70	100	100	100
	Topramezone	18.5		31	26	24	24
		37		54	49	50	50
		74		58	63	60	60
6	Mesotrione	175		32	100	100	100
	Topramezone	18.5		4	8	9	9
		37		16	24	23	23
		74		9	23	22	24
		LSD$_{0.05}$	25	27	24	22	21

[a] Abbreviations: WAS, weeks after seeding.

[b] Lesser swinecress control was calculated by dividing the reduction in ground cover per plot from the cover in the nontreated control per block with the following equation: Control $= 100 \times [(A - B)/A]$, where A equals the treated plot, and B equals the nontreated plot by replication. Lesser swinecress cover in the nontreated plots was 36 (±4 SE), 42 (±8), 42 (±8), 40 (±7), and 42% (±7) at 4, 8, 12, 16, and 20 WAS, respectively

[c] Creeping bentgrass was seeded at 49 kg ha^{-1} on September 30, 2013, and September 30, 2014. Application dates were September 30, October 14, October 28, and November 11 in 2013 and September 30, October 13, October 28, and November 10 in 2014.

[d] Rate for mesotrione is active ingredient, and rate for topramezone is in acid equivalent.

fescue seedlings without reducing stand density (Dernoeden 1987; Johnson and Carrow 1995). Dernoeden (2000) reported minimal to no reduction in turf quality with single applications of ethofumesate from 0.56 to 2.24 kg ha^{-1} and sequential applications at 0.56 kg ha^{-1}. However, reductions in turf quality and stand thinning were noted with sequential applications at higher rates. Overall, topramezone at rates and timings evaluated appeared to have minimal injury potential to tall fescue during establishment.

Lesser Swinecress Control. Treatment-by-application timing interaction was detected ($P < 0.05$) for lesser swinecress control in creeping bentgrass, and thus, results are presented across all combinations. Lesser swinecress ground cover in the nontreated plots ranged from 36 (±4 SE) to 45% (±7) at 4 to 20 WAS (Table 4). Mesotrione applied the day of seeding controlled lesser swinecress 86% at 8 WAS but declined to 71% at 20 WAS. However, mesotrione applied at 2, 4, and 6 WAS provided $\geq$ 99% control from 12 to 20 WAS. These levels of lesser swinecress control are similar to previous reports with POST applications of synthetic auxins in established tall fescue (Reed and McCullough 2012).

Topramezone at 74 g ha^{-1} applied the day of seeding controlled lesser swinecress 87% at 4 WAS (Table 4). This treatment was similar to mesotrione applied the day of seeding, but control declined to 67% at 20 WAS. Reductions in control resulted from lesser swinecress regrowth after initial injury from treatments. All other topramezone rates and application timings provided <64% lesser swinecress control throughout the experiment. Lesser swinecress cover was insufficient to evaluate control in perennial ryegrass and tall fescue strips. Overall, mesotrione appeared to be more efficacious than topramezone was for controlling lesser swinecress at the rates and timings evaluated.

Implications from This Research. Topramezone was safe at rates evaluated for use during perennial ryegrass and tall fescue establishment. Importantly, creeping bentgrass was tolerant to most rates and timings of topramezone applied. Creeping bentgrass injury was transient, and turf recovered within 4 wk to acceptable levels. Topramezone was less effective than mesotrione was for lesser swinecress control, suggesting control of certain broadleaf weeds may be a limitation to using this herbicide. However, topramezone could provide creeping bentgrass managers an opportunity to incorporate an HPPD inhibitor in weed control programs. This herbicide will also be important for managing resistance in crabgrass, goosegrass, and other annual grassy weeds that emerge during establishment (Kuk et al. 1999; Yang et al. 2007). Further research is needed to investigate topramezone rates and regimens that optimize weed control and establishment of cool-season grasses in spring.

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