Seedling Tolerance of Cool-season Turfgrasses to Metamifop

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Abstract. Grassy weeds may reduce cool-season turfgrass establishment after seeding and herbicide use is often warranted. Field experiments were conducted to evaluate the tolerance of creeping bentgrass (*Agrostis stolonifera* L.), perennial ryegrass (*Lolium perenne* L.), and tall fescue (*Festuca arundinacea* Schreb.) to fenoxaprop and metamifop applications at 1, 2, 3, or 4 weeks after seeding (WAS). Creeping bentgrass groundcover was reduced from 34% to 71% at 8 WAS from the nontreated by fenoxaprop at 50 g a.i./ha and metamifop at 400 and 800 g a.i./ha at all application timings. Metamifop at 200 g·ha⁻¹ reduced creeping bentgrass cover 10% to 18% from the nontreated at 8 WAS when applied 1, 2, or 3 WAS, but treatments at 4 WAS did not reduce cover. Perennial ryegrass treated with fenoxaprop and metamifop at 800 g·ha⁻¹ at 1 WAS had cover reduced from the nontreated on two and one dates, respectively, whereas tall fescue cover was never reduced greater than 5% from the nontreated. Results suggest applications to creeping bentgrass should be delayed greater than 4 WAS for fenoxaprop at 50 g·ha⁻¹, greater than 4 WAS for metamifop at 400 and 800 g·ha⁻¹, and 3 WAS for metamifop at 200 g·ha⁻¹. Additionally, fenoxaprop applications should be delayed 2 WAS for perennial ryegrass and tall fescue, whereas metamifop could be safely applied at all rates at 1 WAS.

In Georgia, cool-season grasses are primarily seeded in fall, rather than spring, to optimize establishment and minimize competition with warm-season annual grassy weeds. However, soil disruption, fertilization, and regular irrigation during establishment of cool-season grasses may promote crabgrass (*Digitaria* spp.) and goosegrass (*Eleusine indica* Gaertn.) germination in late summer or fall (Peters et al., 1989). Failure to control annual grassy weeds during establishment of cool-season grasses may lead to subsequent emergence of winter annual weeds such as annual bluegrass (*Poa annua* L.) that warrant further herbicide use and intensive management for successful culture.

Quinclorac effectively controls crabgrass and may be applied to seedling tall fescue at reduced labeled rates (less than 0.84 kg a.i./ha) but applications do not control goosegrass

and may cause excessive injury to creeping bentgrass and perennial ryegrass during establishment (Hart et al., 2004; McElroy and Breeden, 2007). Ethofumesate, mesotrione, and siduron are herbicides used during cool-season turf establishment but inconsistent efficacy, cost, and application regimens limit the effectiveness of these herbicides (Johnson, 1983; McElroy and Breeden, 2007; Moshier et al., 1976). Fenoxaprop is an aryloxyphenoxypropionate (AOPP) herbicide used in cool-season turf for controlling bermudagrass [*Cynodon dactylon* (L.) Pers.], crabgrass, and goosegrass but applications may injure perennial ryegrass, tall fescue, and other species during establishment (Dernoeden, 1987; Johnson and Carrow, 1993).

Metamifop is an AOPP herbicide used in rice (*Oryza sativa* L.) for post-control of grassy weeds (Hae-Jin et al., 2002). Compared with AOPP herbicides available in turf, creeping bentgrass has better tolerance to metamifop at rates required for weed control, whereas perennial ryegrass and tall fescue also have acceptable tolerance to applications (Carroll et al., 1992; Dernoeden, 1989; Flessner and McElroy, 2011; McElroy and Rose, 2009; Shim and Johnson, 1992). Metamifop could be useful for controlling annual grassy weeds after seeding cool-season grasses but turf tolerance during establishment has received limited investigation. The objective of this research was to evaluate application timing of metamifop, compared with fenoxaprop, on the establishment of creeping

bentgrass, perennial ryegrass, and tall fescue grown from seed.

Materials and Methods

Field experiments were conducted in Griffin, GA, from Sept. 2011 to Mar. 2012 and Sept. 2012 to Feb. 2013. Plots in the second experiment were adjacent to the first experiments. Glyphosate was applied at 2.5 kg a.e./ha to mature tall fescue grown on a Cecil sandy clay loam (fine, kaolinitic, thermic Typic Kanhapludults) with pH 5.9 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 1-cm depth. ‘Penn A-4’ creeping bentgrass, ‘Manhattan V’ perennial ryegrass, and ‘Titan’ tall fescue were seeded in 0.9-m strips at 49, 392, and 392 kg·ha⁻¹ on 17 Oct. 2011 and 8 Oct. 2012. Creeping bentgrass seed was mixed with a 5N–2P₂O₅–0K₂O fertilizer at a 6:1 fertilizer:seed ratio to facilitate accuracy of the targeted seeding rate. Species were randomized in four replications, and fields were irrigated to promote turf establishment. Creeping bentgrass and perennial ryegrass were mowed at 1.3 cm with a reel-mower twice a week and tall fescue was mowed weekly at 6.3 cm with a rotary mower. The initial mowing began at ≈2.5 weeks after seeding and clippings were returned.

Experimental design and treatments. Treatments were applied perpendicular to turf strips in a split-plot design where whole plots were species and subplots were herbicides. Treatments included fenoxaprop-p-ethyl (delineated fenoxaprop) at 50 g a.i./ha and metamifop at 200, 400, or 800 g a.i./ha. Applications were made at 1, 2, 3, or 4 weeks after seeding. Herbicide formulation, application dates, and turfgrass mowing heights during establishment are presented in tables. A nontreated control was included. Fenoxaprop was chosen as a standard comparison with metamifop at a recommended rate for annual weed control in most cool-season grasses (Anonymous, 2004). Applications were made with CO₂-pressured sprayers calibrated to deliver 374 L·ha⁻¹ with a single flat-fan nozzle (9504E flat-fan; TeeJet Spraying Systems) at 222 kPa.

Measurements and data analysis. Turfgrass cover was visually measured on a percent scale where 0 equals no turf cover and 100 equals complete plot cover. Cover was rated weekly from 2 to 8 WAS and at 21 WAS. Grid counts were made for each species by counting the number of 161-cm² squares within a 0.58-m² grid (36 total squares per grid) with shoots present (yes/no) of the desirable turf species at 20 WAS in the 2012–13 experiment. Data were subjected to analysis of variance at the 0.05 *P* level. Species were analyzed separately as randomized complete blocks. Means were separated with Fisher’s protected least significant difference test at $\alpha = 0.05$. Year-by-treatment interactions were not detected, and thus, years were combined.

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Results and Discussion

Creeping bentgrass. Groundcover of nontreated creeping bentgrass increased from 42% at 2 WAS to 83% at 8 WAS (Table 1). All treatments applied 1, 2, or 3 WAS reduced creeping bentgrass cover from the nontreated from 4 to 8 WAS. Although metamifop at 200 g·ha⁻¹ reduced cover at these timings, reductions from the nontreated ranged from 10% to 18% at 8 WAS, whereas 400 to 800 g·ha⁻¹ reduced cover 35% to 71%.

Metamifop treatments were generally less injurious to creeping bentgrass than fenoxaprop when applied 4 WAS (Table 1). Metamifop at 400 and 800 g·ha⁻¹ and fenoxaprop applied 4 WAS reduced creeping bentgrass cover on three dates and measured 33% to 45% by 8 WAS. Creeping bentgrass cover was similar to the nontreated on all dates from metamifop at 200 g·ha⁻¹ applied 4 WAS.

At 21 WAS, creeping bentgrass cover was similar to the nontreated from metamifop at 200 g·ha⁻¹ applied at all timings after seeding, averaging 83% cover (Table 1). However, all other treatments reduced measurements from the nontreated, ranging from 23% to 64% cover. Reductions in creeping bentgrass groundcover were exacerbated by increased metamifop rate from 400 to 800 g·ha⁻¹ at all timings, whereas fenoxaprop reduced cover more when applied 2, 3, and 4 WAS compared with 1 WAS.

Perennial ryegrass. Groundcover of nontreated perennial ryegrass increased from 2 to 8 WAS, ranging from 58% to 85% (Table 2). Fenoxaprop applied 1 WAS reduced perennial ryegrass cover at 2 and 3 WAS but was similar on other evaluation dates. Perennial ryegrass treated with metamifop at 800 g·ha⁻¹ at 1 WAS reduced cover from the nontreated at 2 WAS but 200 and 400 g·ha⁻¹ were similar on all dates. Fenoxaprop and metamifop at all rates applied 2, 3, and 4 WAS did not reduce perennial ryegrass cover from the nontreated on any date. Perennial ryegrass cover was similar to the nontreated at 21 WAS, averaging 88% across all treatments.

Tall fescue. Groundcover of nontreated tall fescue increased from 2 to 8 WAS ranging 39% to 84% (Table 3). Fenoxaprop and metamifop at 400 and 800 g·ha⁻¹ applied 1 WAS reduced turf cover from the nontreated on one date but tall fescue recovered and was similar to the nontreated from 5 to 8 WAS. Treatments applied 2 WAS did not reduce turf cover from the nontreated except metamifop at 800 g·ha⁻¹, which reduced cover ≈5% from the nontreated at 5 and 6 WAS. Tall fescue cover was similar to the nontreated at all evaluations from metamifop at all rates when applied 3 and 4 WAS. Fenoxaprop applied 3 WAS reduced tall fescue cover 5% from the nontreated at 5 WAS. Cover was also reduced on all evaluation dates from metamifop applied at 4 WAS. However, reductions from the nontreated never exceeded 7% and would likely be considered acceptable in weed control programs during tall fescue establishment. There were no meaningful differences detected among treatments for tall fescue cover at 21 WAS, because all

Table 1. Groundcover of 'Penn A-4' creeping bentgrass treated with herbicides after seeding in two combined field experiments, 2011–13, Griffin, GA.

			Creeping bentgrass cover (WAS) ^z							
Timing ^y		Rate	2	3	4	5	6	7	8	21
WAS	Treatment	(g a.i./ha)	----- (%) -----							
1	Fenoxaprop	50	7	9	20	26	38	43	49	61
	Metamifop	200	17	25	41	58	65	68	73	83
		400	12	15	22	31	38	43	48	62
		800	6	7	10	14	19	22	24	44
2	Fenoxaprop	50		31	28	19	19	21	20	30
	Metamifop	200		43	47	53	59	62	66	79
		400		33	31	25	26	28	31	48
		800		29	22	14	11	12	13	23
3	Fenoxaprop	50			61	59	47	29	22	27
	Metamifop	200			58	66	66	64	65	79
		400			62	60	43	35	35	62
		800			58	50	29	16	12	31
4	Fenoxaprop	50				68	59	49	36	26
	Metamifop	200				78	77	75	75	88
		400				74	69	59	45	64
		800				74	67	53	33	30
—	Nontreated	0	42	56	71	78	80	81	83	88
		LSD _{0.05}	7	8	9	10	11	10	8	12

^zWAS = week after seeding. Seeding dates were 17 Oct. 2011 and 8 Oct. 2012. Creeping bentgrass was mowed at 1.3-cm height with a reel mower 2 d/week.

^yFenoxaprop (0.57 EC) and metamifop (10% EC) were applied on 24 Oct., 31 Oct., 7 Nov. 7, and 14 Nov. in 2011 and 16 Oct., 23 Oct., 30 Oct., and 5 Nov. in 2012.

LSD = least significant difference; EC = electrical conductivity.

Table 2. Groundcover of 'Manhattan V' perennial ryegrass treated with herbicides after seeding in two combined field experiments, 2011–13, Griffin, GA.

			Perennial ryegrass cover (WAS) ^z							
Timing ^y		Rate	2	3	4	5	6	7	8	21
WAS	Treatment	(g a.i./ha)	----- (%) -----							
1	Fenoxaprop	50	49	61	73	79	78	79	81	88
	Metamifop	200	56	68	76	81	82	83	85	88
		400	55	67	78	81	81	83	85	89
		800	49	64	75	80	80	81	84	89
2	Fenoxaprop	50		63	74	77	79	81	83	87
	Metamifop	200		72	81	84	84	84	86	91
		400		68	76	82	81	83	86	90
		800		65	74	77	77	80	81	88
3	Fenoxaprop	50			78	81	81	83	86	89
	Metamifop	200			74	79	78	81	83	87
		400			77	81	81	81	83	91
		800			77	79	80	80	82	89
4	Fenoxaprop	50				78	78	79	80	86
	Metamifop	200				83	83	83	85	88
		400				83	82	82	84	89
		800				80	83	80	81	86
	Nontreated	0	58	68	77	81	80	83	85	89
		LSD _{0.05}	7	6	5	5	4	5	6	5

^zWAS = week after seeding. Seeding dates were 17 Oct. 2011 and 8 Oct. 2012. Perennial ryegrass was mowed at 1.3-cm height with a reel mower 2 d/week.

^yFenoxaprop (0.57 EC) and metamifop (10% EC) were applied on 24 Oct., 31 Oct., 7 Nov., and 14 Nov. in 2011 and 16 Oct., 23 Oct., 30 Oct., and 5 Nov. in 2012.

LSD = least significant difference; EC = electrical conductivity.

plots had 8% or less difference from the nontreated.

Grid counts. Treatment-by-application-timing interaction was not detected for grid count measurements for any species, and thus, main effects are presented separately. For nontreated creeping bentgrass, 100% of grids had turf present at 20 WAS, whereas plots treated with metamifop at 200 and 400 g·ha⁻¹ were similar (Table 4). However, fenoxaprop and metamifop at 800 g·ha⁻¹ reduced the presence of creeping bentgrass in grid counts to 68% and 71%, respectively. Treatments applied 2, 3, and 4 WAS reduced the presence

of creeping bentgrass to 72% to 86% cover in grid counts but treatments 1 WAS were similar to the nontreated. Perennial ryegrass and tall fescue were present in all sampling grids across all treatments and application timings at 20 WAS.

Metamifop may have potential for use on perennial ryegrass and tall fescue seedlings, but reductions in creeping bentgrass cover may limit use to established turf only at rates tested. Although turf seedling tolerance to metamifop has received limited investigation, researchers have reported tolerance to other AOPP herbicides. For example, Dernoeden

Table 3. Groundcover of 'Titan' tall fescue treated with herbicides after seeding in two combined field experiments, 2011–13, Griffin, GA.

			Tall fescue cover (WAS) ^z							
Timing		Rate	2	3	4	5	6	7	8	21
WAS	Treatment ^y	(g a.i./ha)	----- (%) -----							
1	Fenoxaprop	50	32	48	65	76	78	82	85	88
	Metamifop	200	41	56	69	79	81	83	85	86
		400	34	52	63	75	77	79	83	81
		800	36	51	68	77	79	83	85	89
2	Fenoxaprop	50		50	66	76	78	81	83	88
	Metamifop	200		58	71	81	84	86	87	91
		400		53	67	75	79	81	83	88
		800		54	64	73	74	79	81	86
3	Fenoxaprop	50			66	74	76	79	82	87
	Metamifop	200			66	76	78	79	82	86
		400			68	76	78	80	83	88
		800			70	78	78	79	81	87
4	Fenoxaprop	50				74	74	76	78	83
	Metamifop	200				80	83	84	86	91
		400				79	81	81	83	84
		800				78	79	80	80	82
	Nontreated	0	39	54	69	79	80	83	84	89
	LSD _{0.05}		5	6	6	5	5	5	4	5

^zWAS = week after seeding. Seeding dates were 17 Oct. 2011 and 8 Oct. 2012. Tall fescue was mowed weekly at 6.3-cm height with a rotary mower.

^yFenoxaprop (0.57 EC) and metamifop (10% EC) were applied on 24 Oct., 31 Oct., 7 Nov., and 14 Nov. in 2011 and 16 Oct., 23 Oct., 30 Oct., and 5 Nov. in 2012.

LSD = least significant difference; EC = electrical conductivity.

Table 4. Grid counts for turfgrass presence at 20 weeks after seeding 'Penn A-4' creeping bentgrass, 'Manhattan V' perennial ryegrass, and 'Titan' tall fescue treated with herbicides in a field experiment, Griffin, GA.

Herbicide	Rate (g a.i./ha)	Turfgrass presence ^z		
		Creeping bentgrass	Perennial ryegrass	Tall fescue
		----- (% of total grids) -----		
Fenoxaprop	50	68	100	100
Metamifop	200	100	100	100
	400	87	100	100
	800	71	100	100
Nontreated	0	100	100	100
	LSD _{0.05}	14	NS	NS
Application timing ^y (WAS) ^x				
	0	100	100	100
	1	96	100	100
	2	72	100	100
	3	86	100	100
	4	73	100	100
	LSD _{0.05}	14	NS	NS

^zCreeping bentgrass and perennial ryegrass were mowed at 1.3-cm height with a reel mower 2 d/week. Tall fescue was mowed weekly at 6.3-cm height with a rotary mower.

^yFenoxaprop (0.57 EC) and metamifop (10% EC) were applied on 24 Oct., 31 Oct., 7 Nov., and 14 Nov. in 2011 and 16 Oct., 23 Oct., 30 Oct., and 5 Nov. in 2012.

^xWAS = week after seeding. Seeding dates were 17 Oct. 2011 and 8 Oct. 2012.

LSD = least significant difference; NS = nonsignificant; EC = electrical conductivity.

(1987) noted perennial ryegrass and tall fescue seedlings were tolerant to fenoxaprop from 90 to 280 g·ha⁻¹, and treatments effectively controlled smooth crabgrass (*Digitaria ischaemum* Schreb. Muhl.). In Georgia, Johnson and Carrow (1993) reported fenoxaprop temporarily injured tall fescue, but treatments did not reduce turfgrass density from the nontreated. In Virginia, Beam et al. (2005) noted fluzafop plus fenoxaprop treatments injured newly seeded tall fescue less than 5% at 5 weeks after initial treatment, suggesting applications have potential for grassy weed control during turf establishment.

Although AOPP herbicides are efficacious for grassy weed control, turf managers may also apply other chemistries in newly seeded

cool-season grasses. McElroy and Breeden (2007) reported mesotrione at 280 g·ha⁻¹ applied sequentially at 28 and 42 d after emergence reduced tall fescue cover less than 5% from the nontreated. Hart et al. (2004) noted quinclorac at 400, 600, and 800 g·ha⁻¹ caused chlorosis to creeping bentgrass, but applications did not reduce establishment from the nontreated. Despite injury from these herbicides to seedling turfgrass, practitioners should consider the benefits of controlling summer annual grasses with herbicides and the potential for enhancing turfgrass competition with other weeds in subsequent growing seasons.

Perennial ryegrass and tall fescue generally have greater tolerance to fenoxaprop than

creeping bentgrass, but metamifop may have comparable safety across these species. Flessner and McElroy (2011) reported singly or sequentially applied metamifop from 100 to 800 g·ha⁻¹ caused minimal injury to established creeping bentgrass, kentucky bluegrass (*Poa pratensis* L.), and tall fescue. Fenoxaprop may be safely applied to mature perennial ryegrass and tall fescue at rates up to 200 g·ha⁻¹, but researchers have reported significant injury (greater than 20%) to established creeping bentgrass at lower rates (Carroll et al., 1992; Dernoeden, 1987, 1989; Johnson and Carrow, 1995; Neal et al., 1990). Shim and Johnson (1992) noted sequential applications of fenoxaprop at 70 to 200 kg·ha⁻¹ caused unacceptable injury to creeping bentgrass, and turf did not fully recover after 3 months compared with nontreated. Henry and Hart (2004) reported creeping bentgrass density was reduced up to 33% from the nontreated after sequential applications of fenoxaprop at 40 or 70 g·ha⁻¹, respectively.

Growth stage of grasses influences efficacy of AOPP herbicides, and treatments are often more phytotoxic when applied before tillering (Anderson, 1976; Derr et al., 1985; Wu and Santelman, 1976). Derr et al. (1985) reported goosegrass, large crabgrass (*Digitaria sanguinalis* L.), and giant foxtail (*Setaria faberi* Herrm.) control from fluzafop was substantially reduced when treatments were made at late tillering stages. Neal et al. (1990) noted fenoxaprop was less effective on tillered smooth crabgrass and large crabgrass compared with two to five leaf growth stages. Efficacy of AOPP herbicides may have important implications for cool-season turfgrass seedling tolerance, and further investigation is warranted to determine metamifop rates that are comparable to mesotrione, quinclorac, and other chemistries during establishment.

Overall, results suggest applications to creeping bentgrass should be delayed greater than 4 WAS for fenoxaprop at 50 g·ha⁻¹, greater than 4 WAS for metamifop at 400 and 800 g·ha⁻¹, and 3 WAS for metamifop at 200 g·ha⁻¹. Additionally, fenoxaprop applications should be delayed 2 WAS for perennial ryegrass and tall fescue, whereas metamifop could be safely applied at all rates at 1 WAS. These recommendations are based on turfgrass maintained at mowing heights evaluated. Physiological effects of lower mowing height could potentially exacerbate turfgrass injury to these herbicides during establishment. Contrarily, higher mowing heights for grasses such as perennial ryegrass could increase seedling turfgrass tolerance to herbicides and warrant further investigation. Research is also needed to evaluate cool-season turfgrass seedling tolerance to multiple applications of metamifop alone and with other herbicides during establishment.

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