Selective removal of creeping bentgrass from Kentucky bluegrass

by

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“The true joy of life is the trip. The station is only a dream. It constantly outdistances us.”

- From “The Station” by Robert Hastings

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GENERAL INTRODUCTION

Creeping bentgrass (*Agrostis stolonifera* L.) is a cool-season, perennial grass native to Eurasia that is used throughout the world in closely-mowed, high-maintenance turf areas (Beard, 1973). Creeping bentgrass was introduced into the United States during the colonial period and is primarily used on high-quality golf course greens, tees, and fairways in the cool-humid regions of the United States (Christians, 2004). Its use on golf course greens in warmer climates is also increasing because it forms a higher quality playing surface compared with bermudagrass (Casler and Duncan, 2003).

Creeping bentgrass possesses vigorous stolons and has a rolled vernation and pointed leaf tips. Other identifiable characteristics include its blue-green color, membranous ligules, and prominent veination on the upper side of the leaf blade. However, creeping bentgrass is best recognized for its fine leaf texture and ability to withstand low mowing heights (Christians, 2004; Casler and Duncan, 2003). Creeping bentgrass is the most tolerant cool-season turfgrass to frequent, close mowing because of its aggressive lateral growth, and newer cultivars can be mowed as low as 2.5 mm (Gray and White, 1999). Although vertical growth is limited at these mowing heights, aggressive horizontal growth allows creeping bentgrass to form a dense, uniform, fine-textured playing surface.

Because of these characteristics, creeping bentgrass is considered ideal for use in areas where close-cut, fine-textured turfs are desirable. However, due to its aggressive growth, it often spreads into surrounding areas of Kentucky bluegrass (*Poa pratensis* L.) (Davis, 1958), and is considered a weed. A particular grass may be desirable in some settings, but can be considered a weed when present in other conditions.

The designation of a weed largely depends upon human attitude, but a plant is usually considered a weed when the uniformity of the turf has been disrupted due to considerable differences in leaf width or shape, growth habit, or color (Beard, 1973).

Weed control in turfgrass settings is mainly achieved using either cultural or chemical management practices. The use of mowing, fertilization, irrigation, cultivation, planting, and turfgrass selection are examples of cultural practices. Cultural weed management practices can be very effective at reducing weed populations (Busey, 2003). Unfortunately, cultural practices provide little control of creeping bentgrass in Kentucky bluegrass. Perennial grasses are often the most difficult weeds to control as they possess characteristics similar to the desired species (Christians, 2004). Currently, the only cultural management option for controlling creeping bentgrass in Kentucky bluegrass is mechanical removal. Isolated patches of creeping bentgrass can be removed by digging 6 to 12 inches outside of the infestation (Dernoeden, 1999). However, mechanical removal is impractical if many patches exist, and is likely a temporary solution as stolons could persist and regrow. Often times chemical methods become necessary for successful weed control when cultural controls are ineffective.

Chemical weed management involves the use of herbicides to suppress weed populations. Chemical weed control has evolved rapidly since the discovery of 2,4-D in the 1940's and more than 750 scientific papers have been published on the subject of chemical weed management in turfgrass (Busey, 2003). Unfortunately, there are only a few examples of chemicals that offer herbicide selectivity between two perennial grasses. Herbicide selectivity is defined as "the use of chemicals to control weeds within a turfgrass community without killing or no more than slightly affecting the desirable turfgrass species" (Beard, 1973).

Chlorsulfuron provides control of tall fescue (*Festuca arundinacea* Schreb.) in mature stands of Kentucky bluegrass (Dernoeden, 1990; Laroque and Christians, 1985; Maloy and Christians, 1986). Ethofumesate is primarily used to selectively control annual bluegrass (*Poa annua* L.) in perennial ryegrass (*Lolium perenne* L.), Kentucky bluegrass, or tall fescue (Dernoeden, 1999; Dernoeden and Turner, 1988), but is also effective at controlling common bermudagrass [*Cynodon dactylon* (L.) Pers.] in St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Ktze.] (McCarty, 1996). Similarly, applications of MSMA selectively control dallisgrass (*Paspalum dilatatum* Poir.) in bermudagrass (Bockholt, 1957), and fenoxaprop is used to control bermudagrass in zoysiagrass (*Zoysia japonica* Steud.) (Johnson, 1992). More recently, Taylorson (1997) and Bhowmik and Drohen (2001) demonstrated that postemergence applications of isoxaflutole control creeping bentgrass in Kentucky bluegrass. Although effective, phytotoxicity was observed on Kentucky bluegrass leaves for 10 to 15 days two weeks after applications (Bhowmik and Drohen, 2001).

Sulfosulfuron and mesotrione are two herbicides that might have the capability to offer selective control of creeping bentgrass in Kentucky bluegrass. Sulfosulfuron is a sulfonylurea herbicide that provides selective control of annual and perennial grass and broadleaf weeds in wheat (*Triticum aestivum* L.), non crop areas, and in highly managed turfgrass areas. The herbicide inhibits the acetolactate synthase (ALS) enzyme which is involved in the synthesis of the branch chain amino acids leucine, isoleucine, and valine (Schloss, 1995).

A number of sulfonylurea herbicides have shown selective herbicidal activity against grassy weeds in grass crops (Bruce and Kells, 1997; Larocque and Christians, 1985; Maloy and Christians, 1986; Rabaey and Harvey, 1997). Recent studies demonstrate that sulfosulfuron exhibits herbicidal activity on annual bluegrass (Lycan and Hart, 2002; Taylor et al., 2002) and tall fescue (Lycan and Hart, 2004), but Kentucky bluegrass and perennial ryegrass are tolerant of the herbicide at low application rates (Lycan and Hart, 2004). Although these reports reveal the differential responses of cool-season grasses to sulfosulfuron, the activity on creeping bentgrass is not understood at this time. In addition, the efficacy of herbicides is often dependent on environmental conditions and target species (Nalewaja and Woznica, 1985; Malefyt and Quakenbush, 1991; Miller et al., 1978). Olson et al. (2000) demonstrated that sulfosulfuron exhibited increased efficacy on jointed goatgrass (*Aegilops cylindrica* Host.), wild oat (*Avena fatua* L.), and downy brome (*Bromus tectorum* L.) when day/night air temperatures after application were 25/23 C compared with 5/3 C.

Mesotrione, an herbicide with the same mode of action as isoxaflutole, provides preemergence and postemergence control of broadleaf and annual grassy weeds in maize (*Zea mays* L.) (Mitchell et al., 2001). The events leading to the discovery of mesotrione started in 1977 when Zeneca scientists in California noticed an unexpectedly small number of plants growing at the base of the bottle brush (*Callistemon citrinus* Stapf.) plant. An allelopathic compound identified as leptospermone was discovered upon investigating soil samples collected from beneath the plants. Leptospermone possessed good foliar and soil activity in addition to controlling a wide spectrum of weeds, but extremely high rates were necessary for control. Mesotrione was eventually produced through synthesis programs and exhibited the same activity on weeds, but was 20 times more active (Mitchell et al., 2001).

Mesotrione acts by suppressing 4-hydroxyphenylpyruvate dioxygenase (HPPD). This leads to a reduction of carotenoids, resulting in the bleaching of plant tissues and subsequent death (Mitchell et al., 2001). Mesotrione controls several grassy and broadleaf weeds including large crabgrass [*Digitaria sanguinalis* (L.) Scop.], goosegrass [*Eleusine indica* (L.) Gaertn.], nimblewill (*Muhlenbergia schreberi* i.F.Gmel.), ground ivy (*Glechoma hederacea* L.), common purslane (*Portulaca oleracea* L.), black medic (*Medicago lupulina* L.), and dandelion (*Taraxacum officinale* Weber in Wiggers) (Giese et al., 2005). In addition, preliminary field trials demonstrate that mesotrione exhibits postemergence herbicidal activity on creeping bentgrass with apparent safety to Kentucky bluegrass (Giese et al., 2005).

Although Kentucky bluegrass appears tolerant of mesotrione applications, the effect on the growth and development is not known. Successful selective removal requires effective control of the unwanted weed while minimizing detrimental effects to the desirable species. Furthermore, because the soil persistence of mesotrione can be relatively short, half-life of 4.5 to 32 days depending on the soil pH (Dyson et al., 2002), the proper application rate and timing is essential for successful weed control.

Therefore, the objectives of this research were to determine the i) effect of sulfosulfuron rate and application timing on creeping bentgrass control, ii) effects of sulfosulfuron applications on Kentucky bluegrass quality, iii) effect of mesotrione applications on the growth and development of creeping bentgrass and Kentucky bluegrass, and iv) effect of mesotrione rate and number of applications on creeping bentgrass control in Kentucky bluegrass.

THESIS ORGANIZATION

This thesis is divided into four chapters. The first chapter identifies the problem and establishes the need for this research. Chapter two is a manuscript to be submitted to *Weed Technology* describing a collaborative field research project with sulfosulfuron established between Iowa State University and Purdue University. Chapter three is a manuscript also to be submitted to *Weed Technology* describing greenhouse and field experiments with mesotrione, and chapter four is a summary of results and overall conclusions from these research projects.

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SELECTIVE REMOVAL OF CREEPING BENTGRASS FROM KENTUCKY BLUEGRASS WITH SULFOSULFURON

A paper to be submitted to *Weed Technology*

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Additional index words: Acetolactate synthase inhibitors, sulfonylurea herbicides, perennial grass control, weed management.

Abbreviations: ALS, acetolactate synthase.

Abstract: Creeping bentgrass is well-adapted to golf course greens, tees, and fairways, but may become a weed in Kentucky bluegrass roughs and lawns. The objective of this study was to determine the effect of sulfosulfuron rate and application timing on control of creeping bentgrass and safety on Kentucky bluegrass. Field experiments were initiated in 2003 and 2004 in Ames, IA and West Lafayette, IN. Single applications of sulfosulfuron at

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11 or 22 g ai/ha were applied over a nine-week period during the fall of each year. Phytotoxicity on Kentucky bluegrass was recorded weekly and control of creeping bentgrass was determined in the spring following fall treatments. No treatment provided greater than 31% control, and there were few differences in control between the two rates of sulfosulfuron. In West Lafayette, late fall applications were the most effective providing up to 31% control of creeping bentgrass. Sulfosulfuron provided less than 18% control in Ames in either year. Kentucky bluegrass was tolerant of all sulfosulfuron applications. Late fall applications of sulfosulfuron may be useful in partially removing creeping bentgrass from a heavily contaminated sward of Kentucky bluegrass.

INTRODUCTION

Creeping bentgrass (*Agrostis stolonifera* L.) is a cool-season grass well-adapted to golf course greens, tees, and fairways and forms a dense, smooth surface ideal for golf when maintained at mowing heights less than 1.25 cm. However, creeping bentgrass is very competitive with other cool-season turfgrasses at higher mowing heights (7.5-10 cm) and often spreads into surrounding areas of Kentucky bluegrass (*Poa pratensis* L.)(Davis 1958). Creeping bentgrass is considered a weed in these situations because it disrupts turfgrass uniformity (Beard 1973). Perennial grasses are often the most difficult weeds to control as they possess characteristics similar to the desired turf species (Christians 2004). Cultural weed management practices are ineffective and herbicides currently labeled to control creeping bentgrass are non-selective (Dernoeden 1999). In addition, the efficacy of herbicides is often dependent on environmental conditions and target species (Nalewaja and Woznica 1985; Malefyt and Quakenbush 1991; Miller et al. 1978). Olson et al. (2000)

demonstrated that sulfosulfuron exhibited increased efficacy on jointed goatgrass (*Aegilops cylindrica* Host.), wild oat (*Avena fatua* L.), and downy brome (*Bromus tectorum* L.) when day/night air temperatures after application were 25/23 C compared with 5/3 C.

Sulfosulfuron is a sulfonylurea herbicide that provides selective control of annual and perennial grassy and broadleaf weeds in wheat (*Triticum aestivum* L.)[2], non crop areas[3], and in highly managed turfgrass areas[4]. The herbicide inhibits the acetolactate synthase (ALS) enzyme, which aids in the synthesis of the branch chain amino acids leucine, isoleucine, and valine (Schloss 1995). A number of sulfonylurea herbicides have shown selective herbicidal activity against grassy weeds in grass crops (Bruce and Kells 1997; Larocque and Christians 1985; Maloy and Christians 1986; Rabaey and Harvey 1997).

Recent studies demonstrate that sulfosulfuron exhibits herbicidal activity on annual bluegrass (*Poa annua* L.) (Lycan and Hart 2002; Taylor et al. 2002) and tall fescue (*Festuca arundinacea* Schreb.)(Lycan and Hart 2004), but Kentucky bluegrass and perennial ryegrass (*Lolium perenne* L.) are tolerant of the herbicide at low application rates (Lycan and Hart 2004). Although these reports reveal the differential responses of cool-season grasses to sulfosulfuron, its activity on creeping bentgrass is not understood at this time. The objective of this study was to determine the effect of sulfosulfuron rate and application timing on control of creeping bentgrass and safety on Kentucky bluegrass.

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[2] Maverick®, 75% a.i., Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[3] Outrider®, 75% a.i., Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[4] Certainty®, 75% a.i., Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

MATERIALS AND METHODS

Experiments were established in 2003 and 2004 in Ames, IA and West Lafayette, IN (Table 1). Research in Ames was conducted at Coldwater Golf Links on a mixed sward of creeping bentgrass and Kentucky bluegrass. Research in West Lafayette was established at the W. H. Daniel Turfgrass Research and Diagnostic Center on adjacent creeping bentgrass and Kentucky bluegrass areas.

Treatments at both locations were arranged in a 2 by 9 factorial with two application rates and nine application timings. Application rates were 11 or 22 g ai/ha of sulfosulfuron. In 2003, sulfosulfuron was applied weekly beginning the fourth week of August and concluding the fourth week of October. Since early applications of sulfosulfuron had little effect in 2003, applications in 2004 started the third week of September and ended the third week of November. Sulfosulfuron was mixed with a non-ionic surfactant[5] at 0.25% (v/v) for all applications.

Visual quality ratings of Kentucky bluegrass were assessed weekly on a scale of 1 to 9 with 1 = poorest, 6 = acceptable, and 9 = best. In Ames, percentage creeping bentgrass control was determined by using a grid described by Patton et al. (2004) modified from Tinney et al. (1937). A 1.5 by 1.5 m PVC frame with an internal filament grid of 81 intersections was placed over each plot. The total number of times creeping bentgrass was present under each intersection was recorded for each plot. Percentage cover was calculated by dividing the number of times creeping bentgrass occurred under a filament intersection by 81. Initial creeping bentgrass coverage was determined before initiation of fall treatments. Percentage

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[5] MON 0818, Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

creeping bentgrass coverage was again determined the following spring and compared to initial coverage to quantify changes in creeping bentgrass populations. Percentage control of creeping bentgrass was calculated by subtracting changes in creeping bentgrass populations in untreated control plots from population changes in treated plots.

Since solid and separate stands of creeping bentgrass and Kentucky bluegrass was used in West Lafayette, creeping bentgrass coverage was visually estimated on a 0 to 100% linear scale the spring following fall applications. Coverage of creeping bentgrass was calculated by subtracting cover of live creeping bentgrass from 100. Percentage control of creeping bentgrass was calculated by subtracting spring populations of creeping bentgrass in untreated control plots from population changes in treated plots.

Experiments at both locations were arranged in a randomized complete block and all data were analyzed using the MIXED models procedure of SAS[6]. Years and locations were considered fixed, because trends in the efficacy of the herbicide were expected to vary with environmental conditions between years and locations. Means of Kentucky bluegrass quality and percentage creeping bentgrass control were compared by using an *F*-protected least significant difference test. All tests of significance were made at $P \leq 0.05$.

RESULTS AND DISCUSSION

Kentucky Bluegrass Quality. Kentucky bluegrass quality remained above acceptable levels throughout the duration of each experiment (data not shown), and quality ratings of Kentucky bluegrass were similar in treated plots as in the untreated plots ($P \geq 0.2235$). These results

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[6] SAS software 8.02, SAS Institute Inc., 100 SAS Campus Drive, Cary NC 27513.

agree with Lycan and Hart (2004) who demonstrated that Kentucky bluegrass was tolerant to sulfosulfuron and exhibited only temporary discolorations at application rates ≤ 34 g/ha.

Application Rate and Date. Applications of sulfosulfuron at 11 g/ha were equally as effective at controlling creeping bentgrass compared with the 22 g/ha rate except the third and fourth weeks of October in 2003 in West Lafayette (Table 2). Sulfosulfuron applied at 22 g/ha the third and fourth weeks of October reduced creeping bentgrass up to 16% more than 11 g/ha. Similarly, Lycan and Hart (2004) found that turfgrass injury of tall fescue increased as sulfosulfuron rates increased from 6 to 67 g/ha. With the exception of West Lafayette in 2003, sulfosulfuron's poor control is likely a result of the rates in this study being too low. Preliminary data indicates that single applications of sulfosulfuron at rates of 35 to 105 g/ha controlled 37 to 80% of creeping bentgrass during the fall (Reicher and Weisenberger 2004).

Applications of sulfosulfuron later in the fall were more effective at controlling creeping bentgrass compared with earlier applications. Sulfosulfuron applied at either rate during the fourth week of August through the second week of October 2003 resulted in ≤ 8% creeping bentgrass control in West Lafayette, but provided an average of 20 and 17% control when applied in the third or fourth week of October, respectively (Table 2). In 2004, creeping bentgrass control increased with later applications, and applications made the first week of November provided an average of 30% control of creeping bentgrass in West Lafayette (Table 3). Sulfosulfuron applications occurring after the first week of November in 2004 provided 18% or less control of creeping bentgrass in West Lafayette regardless of rate.

The inconsistent efficacy of sulfosulfuron is likely due to variations in environmental conditions. Soil moisture levels and air temperatures can alter herbicide efficacy by influencing absorption, translocation, or metabolism. Malefyt and Quakenbush (1991) found that greater soil moisture levels increased control of slender meadow foxtail (*Alopecurus myosuroides* Huds.) receiving applications of imazamethabenz-methyl. Similarly, Nalewaja and Woznica (1985) reported green foxtail (*Setaria viridis* L.) susceptibility to chlorsulfuron increased as air temperatures decreased. Increased efficacy of sulfosulfuron applications later in fall might be due to creeping bentgrass's inability to metabolize the herbicide. The rate at which plants metabolize sulfonylurea herbicides has been cited as the major selectivity mechanism between species (Gallaher et al. 1999). In addition, Olsen et al. (2000) found that cooler air temperatures decreased the metabolism rate of sulfosulfuron in jointed goatgrass (*Aegilops cylindrical* Host.), wild oat (*Avena fatua* L.), and downy brome (*Bromus tectorum* L.). An attempt was made to relate soil moisture levels and air temperature to sulfosulfuron efficacy, but trends were not apparent.

Sulfosulfuron provided ≤ 17% control of creeping bentgrass in Ames in either year (Tables 2 and 3). The ineffectiveness of sulfosulfuron in Ames and the discrepancies between the two locations in 2004 may be related to the general inconsistent performance of sulfosulfuron. Other research with sulfosulfuron indicates variable results in different years (Lycan and Hart 2004) and between locations (Taylor et al. 2002).

Control of creeping bentgrass in this study was dependent on proper application timing. Late fall applications were the most effective providing up to 31% control of creeping bentgrass. Single applications of sulfosulfuron late in the fall may be useful in partially removing creeping bentgrass in a heavily contaminated sward of Kentucky bluegrass.

However, the capability of sulfosulfuron at completely removing creeping bentgrass is questionable unless greater control can be achieved. Preliminary data indicates that three fall applications of sulfosulfuron at 53 g/ha provided 93% control of creeping bentgrass (Reicher and Weisenberger 2004). Future research examining the effect of increased rates and multiple applications in addition to investigating how environmental factors affect the herbicidal efficacy on different turfgrass cultivars will be needed to determine the future application of sulfosulfuron for turfgrass managers.

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Table 1. Site, application, and management information of two locations used to determine the effect of sulfosulfuron rate and timing on creeping bentgrass control in Kentucky bluegrass turf.

	Location	
Site information	Ames, IA	W. Lafayette, IN
Replications	3	4
Plot size (m)	1.5	1.5
Kentucky bluegrass variety	Sure shot[a]	Columbia
Creeping bentgrass variety	L-93	L-93
Mowing height (cm)	2.54	6.35/3.81[b]
Mowing frequency	1x/week	2x/week
Irrigation frequency	to prevent drought stress	to prevent drought stress
Soil texture	silty clay loam	silt loam
Soil series	Zook	Stark
Soil family	fine montmorillonitic mesic Cumulic Haplaquolls	fine-silty mixed mesic Aeric Ochraqualfs
Soil pH	7.2	6.9
Soil $mg \cdot kg^{-1}$ P	5	112
Soil $mg \cdot kg^{-1}$ K	143	303
Soil organic matter (%)	4.0	5.7
Spray volume (L/ha)	1218	824
Spray pressure (kPa)	262	241
Nozzle Type	#8002	#80015

[a] Sure shot is a Kentucky bluegrass blend containing Nuglade, Bluemoon, Award, Rugby II, and Rambo cultivars.

[b] Adjacent areas of Kentucky bluegrass and creeping bentgrass were mowed at 6.35 and 3.81 cm, respectively.

Table 2. Sulfosulfuron application timing and rate affects creeping bentgrass populations. All treatments were mixed and applied with the non-ionic surfactant MON 0818 at 0.25% v/v. Percentage creeping bentgrass coverage was determined the spring of 2004 following treatments applied during the fall of 2003.

	Ames, IA[a]			West Lafayette, IN		
Timing	11 g ai/ha	22 g ai/ha	Mean	11 g ai/ha	22 g ai/ha	Mean
	% control of creeping bentgrass compared with untreated plot					
Aug. wk 4	-2[b]	4	1	3	2	3
Sept. wk 1	-5	-12	-9	-5	-5	-5
Sept. wk 2	7	12	10	-3	-5	-4
Sept. wk 3	-9	-17	-13	-2	-6	-4
Sept. wk 4	-14	0	-7	-4	-2	-3
Oct. wk 1	8	1	5	-4	-4	-4
Oct. wk 2	1	5	3	2	8	5
Oct. wk 3	11	16	14	12	28	20
Oct. wk 4	17	7	12	13	20	17
Mean	2	2		1	4	
ANOVA[c]						
Rate		0.00^{NS}			7.56^{**e}	
Date		3.37^{**d}			43.33^{**}	
Rate × Date		0.63^{NS}			4.74^{**}	

[a] Values presented for Ames, IA and W. Lafayette, IN represent means of three and four replications, respectively.

[b] Negative values represent an increase in creeping bentgrass cover.

[c] *, **, and NS indicate differences at $P = 0.05$, $P = 0.01$, and not significant, respectively.

[d] LSD for date is 22.

[e] LSD's for rate, date, and rate × date are 6, 7, and 5, respectively.

Table 3. Sulfosulfuron application timing and rate affects creeping bentgrass populations. All treatments were mixed and applied with the non-ionic surfactant MON 0818 at 0.25% v/v. Percentage creeping bentgrass coverage was determined the spring of 2005 following treatments applied during the fall of 2004.

	Ames, IA[a]			West Lafayette, IN		
Timing	11 g ai/ha	22 g ai/ha	Mean	11 g ai/ha	22 g ai/ha	Mean
	% control of creeping bentgrass compared with untreated plot					
Sept. wk 4	9	0	5	-9	-9	-9
Sept. wk 5	-1[b]	5	2	-4	-2	-3
Oct. wk 1	-16	2	-7	-14	-10	-12
Oct. wk 2	11	2	7	-8	10	1
Oct. wk 3	-15	-10	-13	7	5	6
Oct. wk 4	-14	1	-7	11	7	9
Nov. wk 1	-1	-13	-7	28	31	30
Nov. wk 2	-9	-12	-11	12	8	10
Nov. wk 3	-15	-13	-14	0	18	9
Mean	-6	-4		3	6	
ANOVA[c]						
Rate		0.11^{NS}			1.72^{NS}	
Date		1.26^{NS}			7.37^{**d}	
Rate × Date		2.24^{NS}			0.86^{NS}	

[a] Values presented for Ames, IA and W. Lafayette, IN represent means of three and four replications, respectively.

[b] Negative values represent an increase in creeping bentgrass cover.

[c] *, **, and NS indicate differences at $P = 0.05$, $P = 0.01$, and not significant, respectively.

[d] LSD for date is 21

MESOTRIONE CONTROLS CREEPING BENTGRASS IN KENTUCKY BLUEGRASS

A paper to be submitted to *Weed Technology*

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Additional Index Words: HPPD inhibitor, triketones, carotenoid biosynthesis inhibition, perennial grass control, weed management.

Abbreviations: HPPD, hydroxyphenylpyruvate dioxygenase; WAT, weeks after treatment.

Abstract: Creeping bentgrass creates a dense, high-quality playing surface on golf courses but it often encroaches adjacent areas of Kentucky bluegrass. Mesotrione can control creeping bentgrass in Kentucky bluegrass, but more information is needed regarding the effect of herbicide rate and number of applications on creeping bentgrass control and the impact to Kentucky bluegrass. Greenhouse experiments were conducted to determine the effect of mesotrione on the growth and development of creeping bentgrass and Kentucky bluegrass. In the greenhouse experiment, applications of mesotrione caused phtotoxicity of creeping bentgrass and reduced turfgrass quality 13 to 56% two weeks after treatment

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(WAT). Despite the observed phtotoxicity, mesotrione applications did not reduce clipping yield or root production, and creeping bentgrass was not completely controlled in the greenhouse. Kentucky bluegrass proved tolerant to all mesotrione applications. Shoot and root production were unaffected and remained similar to untreated controls. Field experiments were conducted to determine the effect of application rate and number of applications on creeping bentgrass control. One application of mesotrione controlled 16 to 60% of creeping bentgrass in Kentucky bluegrass and two applications of mesotrione controlled 26 to 96% as rates increased from 70 to 1120 g ai/ha. Gaps present in the canopy after the creeping bentgrass died reduced overall turfgrass quality 2 to 6 WAT before recovering. These data indicate the capability of mesotrione to selectively control creeping bentgrass while providing excellent safety to Kentucky bluegrass.

INTRODUCTION

Creeping bentgrass (*Agrostis stolonifera* L.) is a stoloniferous, cool-season, perennial grass used predominately on golf course putting greens in temperate regions of the United States. Its use on golf course fairways is increasing steadily (Christians 2004) as new cultivars possess improved shoot density and disease tolerance. However, due to the aggressive growth habit of bentgrass, it often spreads into surrounding areas of Kentucky bluegrass (*Poa pratensis* L.) (Davis 1958) forming unsightly, scattered patches. This occurs most frequently while seeding, but also can result from scalping Kentucky bluegrass adjacent to creeping bentgrass, therefore, affecting new and established golf courses. Creeping bentgrass is a weed in stands of Kentucky bluegrass because it disrupts turfgrass uniformity, a fundamental component of turfgrass quality (Beard 1973).

Isolated bentgrass patches can be removed by digging or by treating each patch with a nonselective herbicide. However, mechanical removal is impractical if many patches are present, and spraying a nonselective herbicide also will kill the desirable species. Cultural practices such as mowing, fertilization, and irrigation can affect weed populations adversely (Bussey 2003). Unfortunately, these practices provide little control of creeping bentgrass in Kentucky bluegrass because of the similar characteristics shared between species.

Researchers seeking herbicides that provide selective control between two perennial grasses have been successful (Dernoeden 1990; McCarty 1996). Haley and Turgeon (1976) demonstrated that endothall in combination with silvex can selectively control creeping bentgrass in Kentucky bluegrass, but these products are no longer available for use on golf courses. More recently, Taylorson (1997), and Bhowmik and Drohen (2001) demonstrated that postemergence applications of isoxaflutole control creeping bentgrass in Kentucky bluegrass. Although effective, phytotoxicity was observed on Kentucky bluegrass leaves for 10 to 15 d two wks after application (Bhowmik and Drohen 2001).

Mesotrione, an herbicide with the same mode of action as isoxaflutole, provides preemergence and postemergence control of broadleaf and annual grassy weeds in maize (*Zea mays* L.) (Mitchell et al. 2001). The herbicides act by suppressing 4-hydroxyphenylpyruvate dioxygenase (HPPD). This leads to a reduction of carotenoids, resulting in the bleaching of plant tissues and subsequent death (Mitchell et al. 2001). Mesotrione controls several grassy and broadleaf weeds including large crabgrass [*Digitaria sanguinalis* (L.) Scop.], goosegrass [*Eleusine indica* (L.) Gaertn.], nimblewill (*Muhlenbergia schreberi* i.F.Gmel.), ground ivy (*Glechoma hederacea* L.), common purslane (*Portulaca oleracea* L.), black medic (*Medicago lupulina* L.), and dandelion (*Taraxacum officinale*

Weber in Wiggers) (Giese et al. 2005). In addition, preliminary field trials demonstrate that mesotrione exhibits postemergence herbicidal activity on creeping bentgrass with apparent safety to Kentucky bluegrass (Giese et al. 2005).

Although appearing tolerant of mesotrione applications, the effect on the growth and development of Kentucky bluegrass is not known. Successful selective removal requires effective control of the unwanted weed, while minimizing detrimental effects to the desirable species. Furthermore, because the soil persistence of mesotrione can be relatively short, half-life of 4.5 to 32 d depending on the soil pH (Dyson et al. 2002), the proper application protocol is essential for successful weed control.

Therefore, the objectives of this research were to evaluate the 1) effect of mesotrione applications on the growth and development of creeping bentgrass and Kentucky bluegrass, and 2) effect of mesotrione rate and number of applications on creeping bentgrass control in Kentucky bluegrass.

MATERIALS AND METHODS

Greenhouse Experiments. On 21 Oct. 2003, 28 sod plugs each of ‘L-93’ creeping bentgrass and ‘Sure Shot’ Kentucky bluegrass were removed from field plots. All sod plugs were reestablished in 12 by 11.5 cm plastic pots filled with Nicollet soil (fine-loamy, mixed, mesic-Aquic Hapludolls) containing 122 kg/ha P, 850 kg/ha K, 3.2 % organic matter, and a pH of 6.5. The pots were placed in the greenhouse and were allowed to acclimate for two months before application of treatments. All pots were fertilized with urea (46N-0P-0K) at 49 kg/ha N one wk before initiation of treatments. On 23 Dec. 2003, mesotrione was applied at 0, 140, 280, 420, 560, 700, and 840 g ai/ha. A spray-mist atomizer attached to an air pressure pump pressurized to 262 kPa was used to apply all treatments.

The experiment was completely randomized and contained four replications. Natural sunlight was supplemented with 400-W high pressure sodium lamps[2] supplying 100 $\mu mol/m^2/s$ and a 16-h photoperiod, and air temperatures were maintained at 21 ± 1 C. Pots were maintained at a height of 5 cm and were uniformly surface irrigated to avoid drought.

Weekly evaluations of turfgrass quality based on color, uniformity, and plant density were assessed visually on a scale of 1 to 9 with 1 = poorest, 6 = acceptable, and 9 = best. Clipping yield was determined every 10 d by oven-drying fresh clippings taken at 5 cm above the soil surface. Root production was measured at the conclusion of the experiment by subtracting ashed root weight from oven-dry weight.

The experiment was repeated in Oct. 2004 using identical procedures. Treatments were applied on 17 Oct. 2004. Management practices were consistent throughout both experiments except that a nonionic surfactant[3] was mixed and applied with mesotrione at 0.25% v/v in the second experiment.

All data were analyzed by using the General Linear Models procedure of SAS[4]. Regression analysis was performed by using PROC REG to test linear and quadratic effects of mesotrione rate on control of creeping bentgrass. All tests of significance were made at $P \leq 0.05$.

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[2] Sun System III, Sunlight Supply Inc., Vancouver, WA 98665.

[3] MON 0818, Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[4] SAS Institute v. 8.02, Cary, NC 27513.

Field Experiments. Experiments were established at the Iowa State University Horticulture Research Station near Gilbert, IA. Turfgrass was a 20-year-old mixed sward of 'Pencross' creeping bentgrass and an unknown cultivar of Kentucky bluegrass adjacent to two established putting greens. Experimental design was a randomized complete block with three replications. Each plot measured 1.5 by 1.5 m. Plots were irrigated daily and mowed to 3.8 cm three times per wk. Soil type was a Nicollet (fine-loamy, mixed, mesic-Aquic Hapludolls) with 70 kg/ha P, 530 kg/ha K, 3.7% organic matter, and a pH of 8.0.

On 5 May 2004, mesotrione was applied at 0, 70, 140, 280, 560, 840, and 1120 g ai/ha. On 17 June, six plots in each block received a second application at the same rate used in the first application. Mesotrione was mixed with a nonionic surfactant[3] at 0.25% v/v, and total spray volume was 1218 L/ha. A carbon dioxide powered backpack sprayer pressurized to 262 kPa and equipped with flat fan nozzles[5] was used to make all applications. On 24 May 2004, all plots were fertilized with urea (46N-0P-0K) at 49 kg/ha N.

Overall turfgrass quality was assessed visually with the rating system previously described. Percentage creeping bentgrass control was determined by using a grid described by Patton et al. (2004) modified from Tinney et al. (1937). A 1.5 by 1.5 m PVC frame with an internal filament grid of 81 intersections was placed over each plot. The total number of times creeping bentgrass was present under each intersection was recorded for each plot. Percentage cover was calculated by dividing the number of times creeping bentgrass occurred under a filament intersection by 81. Initial creeping bentgrass coverage was determined on 4 May 2004 before application of treatments. Percentage creeping bentgrass

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[5] TeeJet #8002 flat fan nozzles, TeeJet Agricultural Spray Products, Wheaton, IL 60189

coverage was determined again on 4 Aug. 2004 and compared with initial coverage to quantify creeping bentgrass control. The experiment was repeated in May 2005 using identical procedures and management practices.

All data were analyzed by using the General Linear Models procedure of SAS[4]. Turfgrass quality means were compared by using an *F*-protected least significant difference test. Regression analysis was performed by using PROC REG to test linear and quadratic effects of mesotrione rate on percentage control of creeping bentgrass. All tests of significance were made at $P \leq 0.05$.

RESULTS AND DISCUSSION

Turfgrass quality data were analyzed and presented separately for each experiment because of significant experiment by treatment interactions. The effect of mesotrione rate on clipping yield and root production was not significant on either species at any time (data not shown).

Greenhouse Experiments. Turfgrass quality of creeping bentgrass decreased as mesotrione rates increased (Figure 1). In both experiments, creeping bentgrass injury symptoms, appearing as bleached plant tissue, occurred approximately 1 wk after treatment (WAT). These symptoms continued to progress and creeping bentgrass displayed the greatest phytotoxicity 2 WAT. Other research also indicates herbicide injury from mesotrione applications commonly appearing between 1 and 2 WAT (Young et al. 2003; Johnson et al. 2002; Armel et al. 2003). We found that increasing mesotrione rates from 140 to 840 g/ha reduced turfgrass quality 13 to 56% and 44 to 56% compared with untreated creeping bentgrass controls in experiments one and two, respectively (Figure 1). Phytotoxicity from mesotrione applied at 140, 280, and 420 g/ha was more severe in experiment two, reducing quality 36, 34, and 43% greater compared with experiment one. The increased efficacy of mesotrione at the lower application rates in experiment two is likely due to the addition of a non-ionic surfactant applied with mesotrione (Wichert and Pastushok 2000).

Although creeping bentgrass displayed severe phytotoxicity 2 WAT, mesotrione applications did not result in reduced clipping yield ($P \geq 0.1856$), or reduced root mass ($P \geq 0.1452$) in either experiment. In addition, mesotrione applications did not completely control creeping bentgrass in either study. The lack of complete creeping bentgrass control was likely influenced by air temperature and light intensity. Johnson and Young (2002) demonstrated that the efficacy of mesotrione on velvetleaf (*Abutilon theophrasti* L.) and common cocklebur (*Xanthium strumarium* L.) increased when air temperatures after application were maintained at 32 C compared with 18 C. Air temperatures in our experiments were maintained at 21 ± 1 C. In addition, light intensity is known to influence the efficacy of herbicides inhibiting carotenoid biosynthesis (G. Hall, personal communication 2004; Hess 2000). Mesotrione acts by competitive inhibition of the HPPD enzyme, which is involved in the pathway that converts the amino acid tyrosine to plastoquinone (Mitchell et al. 2001). This competitive inhibition results in the blockage of carotenoid synthesis, bleaching of plant tissues, and eventual death. Because experiment one was conducted in midwinter and experiment two in late fall, it is likely that the low light intensities inside the greenhouse contributed to the lack of creeping bentgrass control.

Kentucky bluegrass was tolerant of all mesotrione applications and shoot ($P \geq 0.9184$) and root production ($P \geq 0.0992$) remained similar to untreated controls in both experiments (data not shown). Although creeping bentgrass displayed severe phytotoxicity 2 WAT, phytotoxicity was not observed on Kentucky bluegrass (Figure 1). Similarly, Giese et al. (2005) also found that Kentucky bluegrass was tolerant of mesotrione applications. In contrast, Bhowmik and Drohen (2001) observed phytotoxicity on Kentucky bluegrass for a period of one to two wks after applications of isoxaflutole. The tolerance of Kentucky bluegrass to mesotrione is likely a result of rapid metabolism. The rate at which plants metabolize mesotrione has been cited as the basis for species selectivity (Wichert et al. 1999). Other research also demonstrates the selectivity of mesotrione between two or more species (Johnson et al. 2002; Young et al. 1999). Mitchell et al. (2001) demonstrated more rapid metabolism of mesotrione in maize compared to common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and ivyleaf morning glory (*Ipomoea hederacea* (L.) Jacq.). Although creeping bentgrass was not completely controlled in this study, our data demonstrates the susceptibility of creeping bentgrass to mesotrione, while Kentucky bluegrass appears tolerant of mesotrione applications.

Field Studies. There was no interaction between years for creeping bentgrass control (P = 0.1849) and quality ($P \geq 0.2138$). Therefore, data were pooled over 2004 and 2005 for presentation. Percentage control of creeping bentgrass receiving one application of mesotrione increased linearly with increasing mesotrione rates (Figure 2). One application of mesotrione controlled 16 to 60% of creeping bentgrass in Kentucky bluegrass as rates increased from 70 to 1120 g/ha. Applications of mesotrione at 70, 140, 280, and 560 g/ha provided < 50% control of creeping bentgrass. Single applications of mesotrione at 840 and 1120 g/ha resulted in 55 and 60% control of creeping bentgrass, respectively (Figure 2).

Percentage control of creeping bentgrass receiving two applications of mesotrione increased nonlinearly with increasing mesotrione rates (Figure 2). Two applications of mesotrione at increasing rates of 70 to 1120 g/ha each, controlled 26 to 96% creeping bentgrass in Kentucky bluegrass. Two applications of mesotrione at 70 and 140 g/ha each, provided 26 and 44% creeping bentgrass control. However, two applications of mesotrione ≥ 280 g/ha, provided ≥ 69% control of creeping bentgrass with the highest rate resulting in 96% control (Figure 2).

These data show that mesotrione effectively provided postemergence control of creeping bentgrass in Kentucky bluegrass. Giese et al. (2005) also found that mesotrione exhibited herbicidal activity on creeping bentgrass, controlling 50% to 80% in swards of Kentucky bluegrass. However, the label rate for maximum single applications of mesotrione in maize is 336 g/ha, and the yearly maximum is 560 g/ha. These rates are unlikely to change when mesotrione is labeled for use on turfgrass (M.S. Giese, personal communication 2004). Therefore, a single application of mesotrione at 336 g/ha or two applications at 280 g/ha would control 32 and 69% creeping bentgrass in Kentucky bluegrass based upon the data presented (Fig. 2).

While our research demonstrates the capability of mesotrione to control creeping bentgrass, the effectiveness of mesotrione may be increased while still complying with label rates by evaluating different interval timings. We used a six wk interval between applications to ensure the second application would be applied to fully recovered creeping bentgrass tissue in anticipation that mesotrione absorption would increase. Preliminary data at Iowa State University indicates two applications of mesotrione at 140 or 210 g/ha at two week intervals provides ≥ 93% control of creeping bentgrass without harming Kentucky bluegrass.

Two WAT, one and two applications of mesotrione reduced overall turfgrass quality from 11 to 56% before recovering later in the season (Table 1). Similarly, Taylorson (1997) found that postemergence applications of isoxaflutole affected turfgrass quality four to eight wks after application. Reductions in overall turfgrass quality during this study resulted from the lack of plant density after creeping bentgrass died. In areas where creeping bentgrass comprises a large percentage of swards, removal would create gaps in the canopy, inviting weeds to colonize. Seeding Kentucky bluegrass, fescue species (*Festuca* L.), or perennial ryegrass (*Lolium perenne* L.) may improve overall turfgrass quality faster, rather than simply allowing the established Kentucky bluegrass to fill this void. Future work is required to determine if mesotrione possesses preemergence activity on cool-season turfgrass seedlings.

Successful postemergence control of creeping bentgrass in Kentucky bluegrass depends on effective creeping bentgrass control while minimizing effects on overall turfgrass quality. The capacity of mesotrione to control creeping bentgrass is contingent upon the proper rate, number of applications, and application interval. Two applications of mesotrione, six wks apart, at 280 g/ha each, provided 69% control of creeping bentgrass while resulting in minimal effects to overall turfgrass quality. In addition, preliminary data indicates that ≥ 93% control of creeping bentgrass may be obtained at rates of 140 or 210 g/ha if multiple applications are made at two wk intervals. These data demonstrate the capability of mesotrione to provide effective postemergence control of creeping bentgrass. Mesotrione presents turfgrass managers the opportunity for selective removal of creeping bentgrass in Kentucky bluegrass.

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Table 1. Mesotrione rate and number of applications affect turfgrass quality in the field. The first application occurred 5 May 2004, and plots that received two applications were treated again on 17 June 2004. Plots were irrigated daily and fertilized with urea (46N-0P-0K) at 49 kg/ha N on 24 May 2004. Values represent means of three replications.

	One application						Two applications			
	Time after application (wks)						Time after final application (wks)			
	2	3	4	5	6	7	2	4	6	8
Mesotrione (g ai/ha)	Overall quality[a]						Overall quality			
0	9a[b]	9a	9a	9a	9a	9a	9a	9a	9a	9a
70	9a	9a	9a	9a	9a	9a	7b	9a	9a	9a
140	8b	9a	9a	9a	9a	9a	6c	9a	9a	9a
280	6c	7b	8b	9a	9a	9a	5d	8b	9a	9a
560	6c	6c	7c	8b	9a	9a	4e	7c	9a	9a
840	5d	5d	6d	8b	9a	9a	4e	7c	9a	9a
1120	4e	4e	5e	7c	8b	9a	4e	6d	8b	9a

[a] Overall quality based on color, uniformity, and plant density was assessed visually on a scale of 1 to 9 with 1 = poorest, 6 = least acceptable, and 9 = best.

[b] Means within columns followed by the same letter are not different according to Fisher's $LSD_{0.05}$.

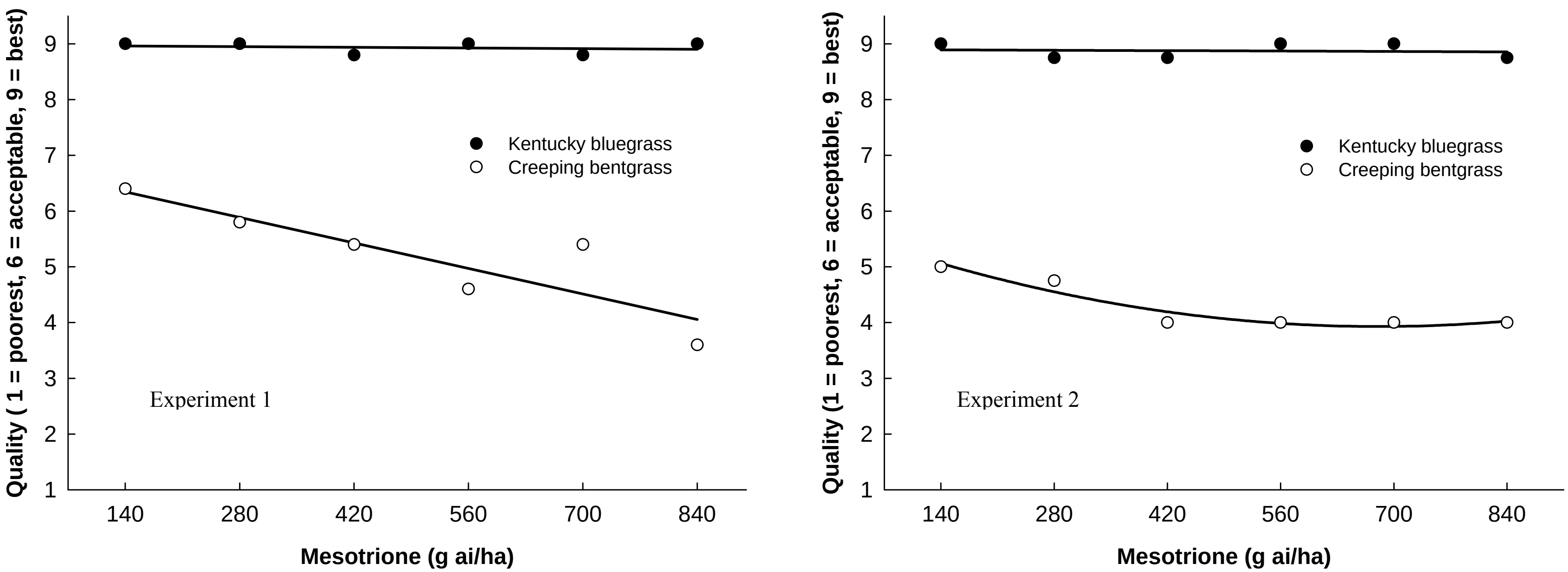

Figure 1. Turfgrass quality of creeping bentgrass and Kentucky bluegrass 2 wks after treatment in greenhouse experiment one and two, respectively. Mesotrione was applied at 140, 280, 420, 560, 700, and 840 g/ha. Regression equations and coefficients of determination in experiment one were: creeping bentgrass $y = -0.00326x + 6.8$, $R^2 = 0.76$; Kentucky bluegrass $y = -0.00008163x + 8.97$, $R^2 = 0.04$. Regression equations and coefficients of determination in experiment two were: creeping bentgrass $y = 5.725 + -0.005274x + 0.000003872x^2$, $R^2 = 0.92$; Kentucky bluegrass $y = -0.0071x + 8.89$, $R^2 = 0.0095$.

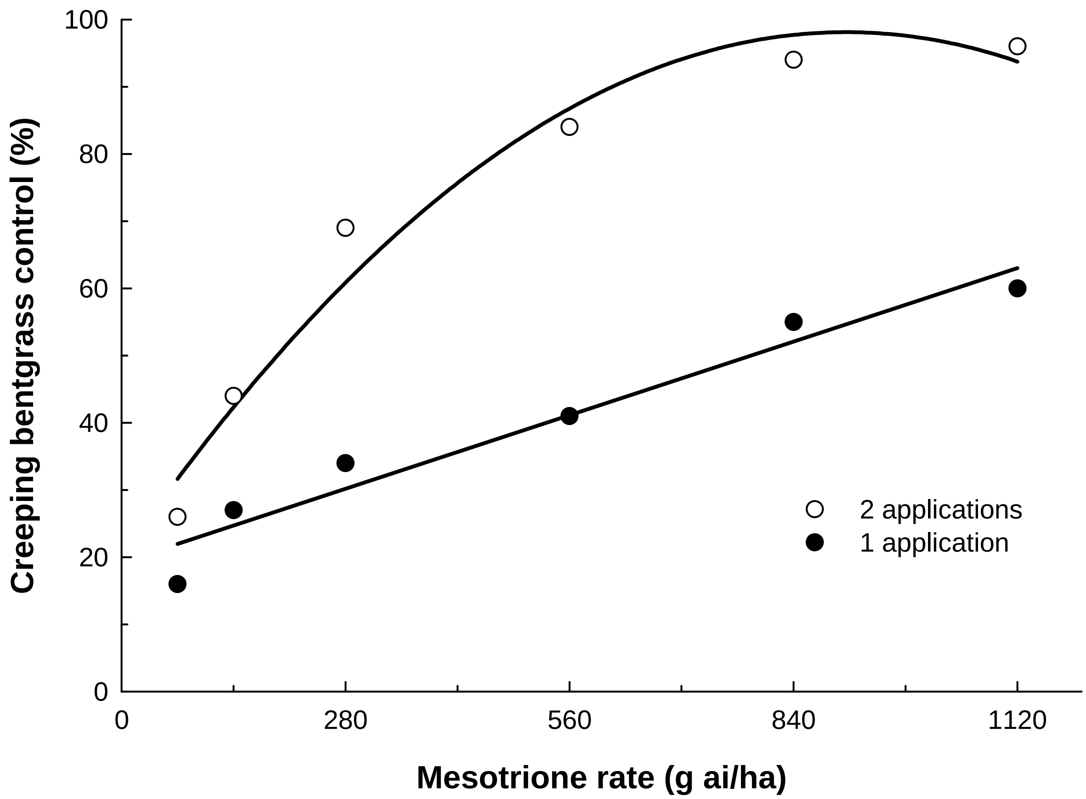

Figure 2. Percentage control of creeping bentgrass in Kentucky bluegrass in field plots receiving one or two applications of mesotrione at 70, 140, 280, 560, 840, and 1120 g/ha. The first application occurred on 5 May, and plots that received a second application were treated again on 17 June. Regression equations and coefficients of determination were: one application y = 19.2 + 0.0391x, R^2 = 0.95; two applications y = 20.035 + 0.1724x + -0.000095x^2, R^2 = 0.97.

GENERAL CONCLUSION

Sulfosulfuron field studies. Control of creeping bentgrass with sulfosulfuron was dependent on proper application timing and less dependent on application rate. Applications of sulfosulfuron later in the fall were more effective at controlling creeping bentgrass compared with earlier applications, although no treatment provided > 31% control. Increased efficacy of sulfosulfuron applications later in the fall is likely due to creeping bentgrass's inability to metabolize the herbicide (Gallaher et al., 1999). Sulfosulfuron's activity on creeping bentgrass can be increased with greater application rates. Preliminary data indicates that single applications of sulfosulfuron at rates of 35 to 105 g/ha controlled 37 to 80% of creeping bentgrass (Reicher and Weisenberger, 2004). Sulfosulfuron caused minor discoloration to Kentucky bluegrass but quality ratings stayed above acceptable levels throughout the duration of the experiment. These results agree with Lycan and Hart (2004) who demonstrated that Kentucky bluegrass was tolerant of sulfosulfuron and exhibited only slight, temporary discolorations at application rates ≤ 34 g/ha. These studies suggest that Kentucky bluegrass is more tolerant than creeping bentgrass to applications of sulfosulfuron. Late fall applications of sulfosulfuron may be useful in partially removing creeping bentgrass from a heavily contaminated sward of Kentucky bluegrass.

Mesotrione greenhouse experiments. Kentucky bluegrass displayed a greater tolerance to applications of mesotrione than creeping bentgrass. Turfgrass quality of creeping bentgrass was reduced 13 to 56% and 44 to 56% 2 WAT in experiments one and two, respectively, while Kentucky bluegrass quality remained similar to untreated controls. In addition, clipping yield and root production of Kentucky bluegrass was not affected by mesotrione applications. Similarly, Giese et al. (2005) found that Kentucky bluegrass was tolerant of mesotrione applications. Although the quality of creeping bentgrass was effected, clipping yield and root production was not reduced by mesotrione applications and was likely influenced by air temperature and light intensity (Johnson and Young, 2002; G. Hall, personal communication, 2004; Hess, 2000). The addition of a non-ionic surfactant appeared to increase the efficacy of mesotrione at low application rates. These studies demonstrate the susceptibility of creeping bentgrass to mesotrione while Kentucky bluegrass appears tolerant.

Mesotrione field studies. Successful postemergence control of creeping bentgrass depends on the proper rate, number of applications, and application timing. Two applications of mesotrione, six weeks apart, at 280 g/ha each, provided 69% control of creeping bentgrass while minimizing effects to overall turfgrass quality. Similarly, Giese et al. (2005) found that mesotrione exhibited herbicidal activity on creeping bentgrass, controlling 50% to 80% in swards of Kentucky bluegrass. In addition greater percentages of creeping bentgrass control may be obtained at lower rates by shortening the application interval. Greater than 93% control of creeping bentgrass was achieved at rates of 140 or 210 g/ha when multiple applications were made at two week intervals. Mesotrione applications reduced overall turfgrass quality by creating gaps in the canopy where creeping bentgrass died. Overseeding various cool-season grasses may help fill these voids and future work is required to determine if mesotrione possesses preemergence activity on cool-season turfgrass seeds. These studies demonstrate the capability of mesotrione to provide effective postemergence control of creeping bentgrass in Kentucky bluegrass.

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