Tolerance to Quinclorac by Seedling Creeping Bentgrass

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Abstract. Annual grassy weeds often inhibit establishment of spring-seeded creeping bentgrass (*Agrostis palustris* Huds.) on golf courses. The objective of this experiment was to evaluate the safety of the annual grass herbicide quinclorac in spring-seeded creeping bentgrass in varying climatic regions of the United States. Experiments were initiated in Indiana, Iowa, and North Carolina in Spring 2000. Treatments included siduron at 6.72 kg·ha⁻¹ a.i. applied immediately prior to planting (PRE), and quinclorac at 0.84 kg·ha⁻¹ a.i. applied 7 days before seeding (DBS), PRE, and 14 or 28 days after emergence (DAE). Herbicides were applied to three creeping bentgrass cultivars at each location. Siduron reduced establishment of 'Providence', 'L93', and 'Putter' creeping bentgrass in Indiana. Quinclorac applied PRE, 14 DAE, and 28 DAE caused short-term phytotoxicity, primarily in 'Providence' in Indiana. Quinclorac applications did not significantly affect cover of 'Providence', 'L93', or 'Putter' in Indiana or 'L93', 'Pennlinks', or 'Penncross' in Iowa. All applications of quinclorac reduced cover of 'L93', 'Pennlinks', and 'Penncross' in North Carolina. Though quinclorac applications resulted in no long-term damage when applied to creeping bentgrass seedlings in Indiana or Iowa, results from North Carolina indicate that caution should be exercised when using quinclorac on seedlings of creeping bentgrass. Chemical names used: 3,7-dichloro-8-quinolinecarboxylic acid (quinclorac); 1-(2-methylcyclohexyl)-3-phenylurea (siduron).

Creeping bentgrass is often seeded on golf courses during spring and early summer in new construction projects or after winter damage of existing turf. However, crabgrass (*Digitaria* spp.) often outcompetes creeping bentgrass seeded at this time of year. Siduron is labeled for use in creeping bentgrass and can be applied at time of seeding to effectively control crabgrass with little risk of damage to seedlings (Moshier et al., 1976). However, siduron has short residual activity and repeat applications are often needed for season-long crabgrass control. Other preemergence or postemergence herbicides labeled for use in cool-season turf have restrictions limiting use in seedling turf, on creeping bentgrass, or both. Quinclorac was labeled in 1998 for turfgrass use and has both preemergence and postemergence activity on large crabgrass (*Digitaria sanguinalis* L.) (Enache and Ilnicki, 1991) and provides control of a variety of broadleaf weeds including white clover (*Trifolium reptans* L.) (Neal, 1990). Label recommendations allow application of

quinclorac to cool-season turf immediately before seeding, but applications after seeding are restricted to 28 d after emergence (DAE).

Earlier work has shown that quinclorac is safe to use on Kentucky bluegrass (*Poa pratensis* L.) or perennial ryegrass (*Lolium perenne* L.) at emergence and within 14 DAE (Reicher et al., 1999). Since creeping bentgrass is planted on golf courses worldwide, it is important to evaluate the safety of quinclorac on newly seeded creeping bentgrass. The objective of this experiment was to evaluate the safety of quinclorac in spring-seeded creeping bentgrass in varying climatic regions of the United States.

Materials and Methods

Experiments were initiated in Spring 2000 at three sites, including Purdue Univ.'s William H. Daniel Turfgrass Research and Diagnostic Center in West Lafayette, Ind.; Turfgrass Field Laboratory at North Carolina State Univ. in Raleigh; and Iowa State Univ. Horticulture Research Station in Ames. Seedbeds were prepared at each site by controlling vegetation with glyphosate {N-(phosphonomethyl) glycine}, tilling to a depth of 15 cm, smoothing, and applying starter fertilizer. Methyl bromide fumigation was also used following tilling in Indiana to limit weed competition. After seeding creeping bentgrass at 49 kg·ha⁻¹, irrigation was applied as needed to encourage germination and establishment. Plots were mowed at 1.3 cm as needed with clippings returned. Specific details for each site are listed in Table 1.

A 3 × 6 factorial in a split plot design was used at each location with three cultivars of creeping bentgrass as main blocks and six herbicide treatments as subplots. Creeping bentgrass cultivars were selected for each location based upon their use in the respective state. 'L93', 'Putter', and 'Providence' were used in Indiana, while 'L93', 'Penncross', and 'Pennlinks' were used in Iowa and North Carolina. Herbicide treatments included an untreated plot (hereafter referred to as the check),

Table 1. Site information for experimental locations in Indiana, Iowa, and North Carolina.

	Indiana	Iowa	North Carolina
Seeding date	12 May 2000	17 May 2000	17 Apr. 2000
Emergence date ^a	19 May 2000	29 May 2000	27 Apr. 2000
Application dates			
7 DBS ^b	3 May 2000	10 May 2000	10 Apr. 2000
PRE ^c	12 May 2000	17 May 2000	17 Apr. 2000
14 DAE ^w	2 June 2000	13 June 2000	11 May 2000
28 DAE	16 June 2000	27 June 2000	25 May 2000
Soil type	Silt loam	Loam	Sandy clay loam
	5.9 pH	7.4 pH	5.8 pH
	P at >224 kg·ha ⁻¹	P at 34 kg·ha ⁻¹	P at 125 kg·ha ⁻¹
	K at 1043 kg·ha ⁻¹	K at 180 kg·ha ⁻¹	K at 53 kg·ha ⁻¹
	7.3% OM	4.1% OM	1.8% OM
Seedbed fertilizer	N at 27 kg·ha ⁻¹	N at 49 kg·ha ⁻¹	N at 13 kg·ha ⁻¹
	P at 32 kg·ha ⁻¹	P at 49 kg·ha ⁻¹	P at 1 kg·ha ⁻¹
	K at 44 kg·ha ⁻¹	K at 0 kg·ha ⁻¹	K at 1 kg·ha ⁻¹
Postseeding fertilizer			
Application date	42 DAE	None	28 and 56 DAE
Application rate	N at 37 kg·ha ⁻¹	None	N at 13 kg·ha ⁻¹
	P at 0 kg·ha ⁻¹	---	P at 1 kg·ha ⁻¹
	K at 0 kg·ha ⁻¹	---	K at 1 kg·ha ⁻¹
Replications of main plots	3	3	4
Subplot size	1.5 × 1.5 m	1.5 × 1.5 m	1.5 × 1.2 m

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^aEmergence was defined as a uniform stand of at least one-leaf seedlings on each untreated plot.

^bDays before seeding.

^cPreemergence application made immediately before planting.

^wDays after emergence.

siduron at 6.72 kg·ha⁻¹ a.i. applied immediately before planting (PRE), and quinclorac at 0.84 kg·ha⁻¹ a.i. applied 7 d before seeding (DBS), PRE, 14, or 28 d after emergence (DAE). Emergence was defined as a uniform stand of at least one-leaf seedlings on each untreated plot. Herbicides were applied with CO₂ powered sprayers in 816 L·ha⁻¹ water and watered-in with at least 0.6 cm water within 2 d of application.

Cover of creeping bentgrass was visually rated weekly as a percentage cover of each plot. Phytotoxicity was rated weekly on a scale of 1 to 9 where 1 = brown turf, 5 = acceptable damage and 9 = no visible phytotoxicity. Visual quality was rated weekly on a scale of 1 to 9 where 1 = dead turf, 5 = acceptable and 9 = excellent quality. Percentage of weed cover was rated weekly in the Iowa study. Data from each site were analyzed in split block designs with PROC ANOVA (SAS Institute, 1989–96). Data recorded before 35 DAE were analyzed as a generalized randomized block with

multiple replications of the untreated check within each block. Fischer's protected LSD was calculated using appropriate error terms according to Steel and Torrie (1980) and were used to separate treatment means.

Results and Discussion

Indiana. Siduron applied PRE caused noticeable phytotoxicity at 7 DAE (Table 2), but phytotoxicity was minimal and lasted less than a week. Quinclorac applied 14 DAE caused phytotoxicity at 21 DAE, but again this phytotoxicity was short-lived and caused no permanent detrimental effects. However, quinclorac applied at 28 DAE caused phytotoxicity lasting from 35 to 49 DAE. Phytotoxicity appeared as a yellowing of older leaf blades and tips. A significant cultivar × herbicide interaction indicated that 'Providence' was slightly more sensitive to quinclorac than either 'L93' or 'Putter'.

Siduron applied PRE reduced creeping

bentgrass cover from 7 to 35 DAE in Indiana (Table 3). This is in contrast to a study that showed siduron to be safe on seedlings of 'Penncross' and 'Seaside' creeping bentgrass (Moshier et al., 1976). Any possible negative effects of siduron may be compensated for by improved annual grass control in the majority of uses, but fumigation at the Indiana site removed all weed competition. A significant cultivar × herbicide interaction revealed that siduron decreased cover of 'Putter' and 'L93' at 21 DAE, but it had no effect on cover of 'Providence'. 'Providence' seedlings were more aggressive, establishing faster than 'L93' and 'Putter', and outgrowing any potential damaging effects of siduron. Negative effects of quinclorac on creeping bentgrass cover were minimal in Indiana. Only quinclorac applied PRE reduced bentgrass cover compared to the check at 35 DAE by 2%.

Iowa. Unlike the Indiana study, there was no cultivar × herbicide interaction at any time during the study and means of herbicide treat-

Table 2. Phytotoxicity^a ratings on 'L93', 'Providence' (Prov), and 'Putter' creeping bentgrass treated with siduron or quinclorac either before or after seeding in Indiana.

Herbicide	Application timing	7 DAE ^b				21 DAE				35 DAE				49 DAE			
		L93	Prov	Putter	Mean	L93	Prov	Putter	Mean	L93	Prov	Putter	Mean	L93	Prov	Putter	Mean
Check	---	7.4 ^x	7.3	7.6	7.4	9.0	9.0	9.0	9.0	9.0	8.7	9.0	8.9	9.0	9.0	9.0	9.0
Quinclorac	7 DBS ^w	7.3	7.7	7.7	7.6	9.0	9.0	9.0	9.0	9.0	8.7	9.0	8.9	9.0	9.0	9.0	9.0
Siduron	PRE ^v	7.0	6.0	6.7	6.6	9.0	9.0	9.0	9.0	9.0	8.7	9.0	8.9	9.0	9.0	9.0	9.0
Quinclorac	PRE	7.0	7.0	7.3	7.1	9.0	9.0	9.0	9.0	9.0	8.7	9.0	8.9	9.0	9.0	9.0	9.0
Quinclorac	14 DAE					7.7	5.3	6.7	6.6	9.0	8.7	9.0	8.9	9.0	9.0	9.0	9.0
Quinclorac	28 DAE									7.3	4.7	5.0	5.7	8.3	7.3	8.3	8.0
Cultivar mean		7.2	7.0	7.3		8.7	8.3	8.5		8.7	8.0	8.3		8.9	8.7	8.9	
<i>Analysis of variance</i>																	
Cultivar (C)			*				NS				NS						
Herbicide (H)			**				**				**					**	
C × H			NS				**				**					**	
LSD _{0.05} for comparing C means			NS				0.3				NS					NS	
LSD _{0.05} for comparing H means			0.4				0.4				0.5					0.2	
LSD _{0.05} for comparing C × H means			NS				0.7				0.9					0.4	

^aPhytotoxicity rated on a scale of 1 to 9 where 1 = brown turf, 5 = acceptable damage and 9 = no visible phytotoxicity.

^bDays after emergence.

^cMeans of 3 replications.

^wDays before seeding.

^vPreemergence application made immediately before planting.

NS, *, **Nonsignificant or significant at $P = 0.05$ or $P = 0.01$, respectively.

Table 3. Percent cover of 'L93', 'Providence', and 'Putter' creeping bentgrass treated with siduron or quinclorac either before or after seeding in Indiana.

Herbicide	Application timing	7 DAE ^a				21 DAE				35 DAE				49 DAE			
		L93	Prov	Putter	Mean	L93	Prov	Putter	Mean	L93	Prov	Putter	Mean	L93	Prov	Putter	Mean
Check	---	18 ^y	73	15	35	86	99	82	89	98	100	99	99	99	100	100	100
Quinclorac	7 DBS ^x	22	77	20	39	86	98	90	91	99	100	98	99	100	100	98	99
Siduron	PRE ^w	13	68	7	29	73	96	60	76	94	100	94	96	97	100	97	98
Quinclorac	PRE	20	67	20	36	83	97	78	86	96	99	97	97	98	99	97	98
Quinclorac	14 DAE					82	99	83	88	96	100	98	98	98	100	99	99
Quinclorac	28 DAE									99	100	97	98	100	99	98	99
Cultivar mean		18	71	15		82	98	79		97	100	97		99	100	98	
<i>Analysis of variance</i>																	
Cultivar (C)			**				NS				NS					NS	
Herbicide (H)			**				**				*					NS	
C × H			NS				**				NS					NS	
LSD _{0.05} for comparing C means			4				NS				NS					NS	
LSD _{0.05} for comparing H means			5				5				2					NS	
LSD _{0.05} for comparing C × H means			NS				8				NS					NS	

^aDays after emergence.

^xMeans of 3 replications.

^wDays before seeding.

^vPreemergence application made immediately before planting.

NS, *, **Nonsignificant or significant at $P = 0.05$ or $P = 0.01$, respectively.

ments over all three cultivars are presented. None of the herbicide treatments reduced bentgrass cover compared to the check (Table 4). However, siduron-treated plots had greater bentgrass cover compared with the check and quinclorac applied PRE, 14 DAE, and 28 DAE when rated at 35 DAE (Table 4). This was primarily due to siduron controlling purslane (*Portulaca oleracea* L.) and prostrate pigweed (*Amaranthus blitoides* S.). Siduron reduced cover of these weed species by up to 21% compared with the check at 49 DAE, whereas quinclorac treatments did not reduce weed cover. Others have found quinclorac applied preemergence and postemergence to be effective on broadleaf weeds such as dandelion (*Taraxacum officinale* Weber) (Enache and Ilnicki, 1991) and effective on white clover (*Trifolium repens* L.) when applied postemergence (Neal, 1990). Quinclorac had little effect on purslane and prostrate pigweed in IA either preemergence or postemergence. Quinclorac applied 7 DBS, PRE, and 14 DAE provided slightly better weed control than quinclorac applied 28 DAE. Similar to the Indiana study, quinclorac applied 14 DAE caused slight

discoloration and reduced visual quality at 28 DAE, but this effect was short-lived lasting less than 7 d (data not shown). Quinclorac applied at 28 DAE caused no phytotoxicity as it did in Indiana.

North Carolina. Unlike Indiana and Iowa, quinclorac applications caused significant negative effects on creeping bentgrass. As was observed in Iowa, the effects were consistent across all cultivars and no cultivar $\times$ herbicide interaction occurred. All quinclorac treatments reduced turf cover rated from 21 through 64 DAE (Table 5). Quinclorac applied at 28 DAE caused the least damage reducing bentgrass cover by 17% at 64 DAE, while quinclorac applied PRE was the most damaging reducing bentgrass cover 46% at 64 DAE. Quinclorac applied 7 DBS had the least effect on visual quality, producing acceptable quality ratings throughout the study. However, quinclorac applied PRE, and 14 and 28 DAE reduced visual quality to unacceptable levels at 36, 50, and 64 DAE. Siduron had no negative effects on bentgrass in North Carolina.

Others have reported excellent tolerance of cool-season turfgrasses to quinclorac, especially in the cooler areas of the country includ-

ing Indiana (Reicher et al., 1999); western Virginia (Chism and Bingham, 1991); and New Jersey (Enache and Ilnicki, 1991). However, Georgia studies report quinclorac to be damaging to cool-season turf when exposed to heat stress (Johnson, 1994a). Further Georgia studies show quinclorac to be safe to creeping bentgrass when applied in February, but was damaging when applied in June (Johnson, 1994b). This could explain the marked differences in quinclorac effects in North Carolina, when compared to Indiana and Iowa. Air temperatures between 0 and 49 DAE in Indiana never exceeded 32 °C and rarely exceeded 29 °C, while air temperatures in Iowa exceeded 32 °C on only 4 d during this period. Air temperature in North Carolina exceeded 32 °C on 22 d between 0 and 49 DAE. However, this may not explain the immediate reduction in creeping bentgrass cover caused by the 7 DBS and PRE applications of quinclorac in North Carolina. Evans et al. (1992) reported that quinclorac can be more damaging to cool-season turfgrasses when applied to soils with low organic matter. This may help to explain the damage caused by quinclorac applied 7 DBS and PRE in North Carolina. Organic matter content in the soils of Indiana and Iowa was 7.3% and 4.1%, respectively, whereas organic matter content of the North Carolina soil was 1.8%.

Quinclorac effects were fairly consistent among cultivars within each location, with only 'Providence' being slightly more sensitive to quinclorac resulting in phytotoxicity in Indiana. This agrees with Tapp and Powell (1992) who reported that quinclorac caused no injury when applied to 18 cultivars of 5 year-old creeping bentgrass.

Quinclorac applications resulted in no long-term damage when applied to 'L93', 'Pennlinks', and 'Pennncross' in Iowa and to 'L93', 'Putter', and 'Providence' in Indiana. However, results from North Carolina where quinclorac damaged creeping bentgrass seedlings indicate that caution should be exercised when using quinclorac on seedlings of creeping bentgrass.

Table 4. Percent cover of creeping bentgrass and weeds treated with siduron or quinclorac either before or after seeding in Iowa.

Herbicide	Application timing	Creeping bentgrass cover				Weed cover ^a		
		7 DAE ^z	21 DAE	35 DAE	49 DAE	21 DAE	35 DAE	49 DAE
		%				%		
Check	---	25 ^y	43	62	75	5	13	28
Quinclorac	7 DBS ^x	26	47	67	74	4	13	21
Siduron	PRE ^w	24	39	69	78	1	3	7
Quinclorac	PRE	25	43	60	74	6	14	21
Quinclorac	14 DAE	46	59	69	4	13	21	
Quinclorac	28 DAE	58	67	19	34			
<i>Analysis of variance</i>								
Cultivar (C)		NS	NS	NS	NS	NS	NS	NS
Herbicide (H)		NS	NS	*	NS	*	*	*
C $\times$ H		NS	NS	NS	NS	NS	NS	NS
LSD _{0.05} for comparing H means		NS	NS	6	NS	3	6	9

^zDays after emergence.

^yMeans over 3 replications and 3 cultivars of creeping bentgrass ('L93', 'Pennncross,' and 'Pennlinks').

^xDays before seeding.

^wPreemergence application made immediately before planting.

NS, *, ** Nonsignificant or significant at $P = 0.05$ or $P = 0.01$, respectively.

Table 5. Percent cover and visual quality of creeping bentgrass with siduron or quinclorac before or after seeding in North Carolina.

Herbicide	Application timing	Percent cover				Visual quality ^z			
		21 DAE ^y	36 DAE	50 DAE	64 DAE	21 DAE	36 DAE	50 DAE	64 DAE
		%							
Check	---	43 ^x	76	83	91	6.9	6.9	6.9	7.0
Quinclorac	7 DBS ^w	31	50	61	69	5.8	5.8	5.7	5.7
Siduron	PRE ^y	44	86	88	93	7.0	6.9	6.7	6.9
Quinclorac	PRE	18	28	40	45	5.0	4.5	4.4	4.3
Quinclorac	14 DAE	44	53	59	64	5.8	4.4	4.5	4.6
Quinclorac	28 DAE	80	72	74	4.8	4.3	4.9		
<i>Analysis of variance</i>									
Cultivar (C)		NS	NS	NS	NS	NS	NS	NS	NS
Herbicide (H)		**	**	**	**	**	**	**	**
C $\times$ H		NS	NS	NS	NS	NS	NS	NS	NS
LSD _{0.05} for comparing H means		8	12	11	11	0.6	0.8	0.7	0.5

^zVisual quality rated on a scale of 1 to 9 where 1 = dead turf, 5 = acceptable and 9 = excellent turf quality.

^yDays after emergence.

^x Means over 4 replications and 3 cultivars of creeping bentgrass ('L93', 'Pennncross,' and 'Pennlinks').

^wDays before seeding.

^yPreemergence application made immediately before planting.

NS, *, ** Nonsignificant or significant at $P = 0.05$ or $P = 0.01$, respectively.

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