Turfgrass and Environmental Research Online

…Using Science to Benefit Golf

Quinclorac (trade name = Drive®) is labeled for use on creeping bentgrass fairways, and has been shown to effectively control crabgrass in other cool-season turfgrass species. University of Maryland researchers investigated the optimum rate and time of application for postemergence control of crabgrass for the mid-Atlantic region. The objectives of their studies were to assess the effects of several quinclorac rates applied in three timings for postemergence crabgrass control in perennial ryegrass (*Lolium perenne*) and to evaluate creeping bentgrass tolerance to quinclorac.

Volume 2, Number 8
April 15, 2003

PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 215 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

Editor

Jeff Nus, Ph.D.
904 Highland Drive
Lawrence, KS 66044
jnus@usga.org
(785) 832-2300
(785) 832-9265 (fax)

Research Director

Michael P. Kenna, Ph.D.
P.O. Box 2227
Stillwater, OK 74076
mkenna@usga.org
(405) 743-3900
(405) 743-3910 (fax)

Smooth Crabgrass Control and Creeping Bentgrass Tolerance To Quinclorac (Drive®)

Peter Dernoeden, Cale Bigelow, John E. Kaminski and John Krouse

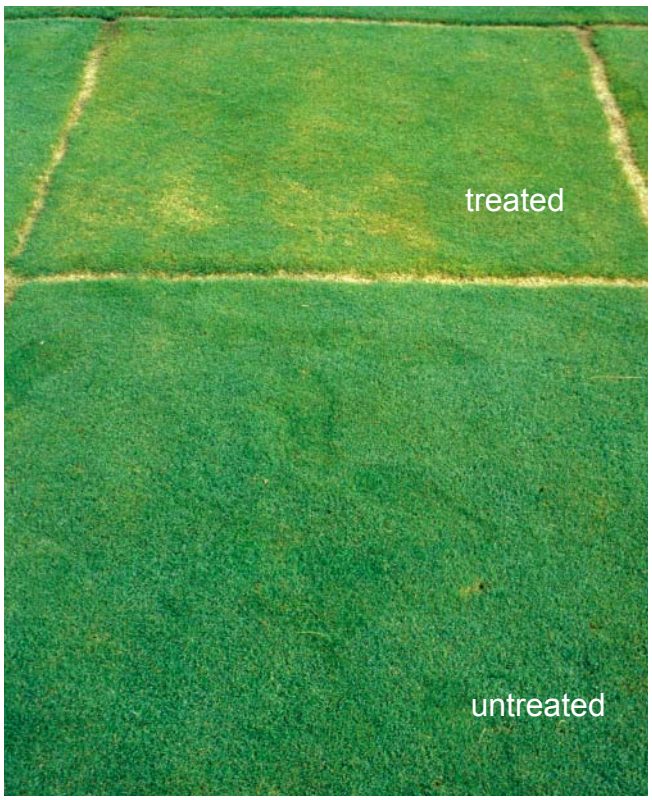
SUMMARY

Creeping bentgrass (*Agrostis stolonifera* L.) is a major turfgrass species grown on fairways in the transition zone and northern regions of the U.S. Crabgrass (*Digitaria spp.*) is among the most common and invasive weeds of turfgrass. There are few herbicides labeled for post-emergence crabgrass control in creeping bentgrass. In 1999, the postemergence herbicide quinclorac was registered for use on bentgrass fairways. Preliminary research conducted in the transitional zone climate of Maryland showed that quinclorac provided erratic levels of crabgrass control and could elicit objectionable levels of discoloration in bentgrass for 50 days or longer. This research was conducted to determine safe and effective use rates for quinclorac on bentgrass fairway turf. Findings include:

- Smooth crabgrass control was best achieved by beginning quinclorac applications in mid-to-late June before tillering of crabgrass.
- A single application (0.75 lb ai/A) effectively controlled crabgrass where weed pressure was low to moderately severe.
- Where dense stands of crabgrass were present, two (0.5 + 0.5 lb ai/A applied on a two week interval) or three (0.33 + 0.33 + 0.33 lb ai/A applied on a two week interval) applications of quinclorac were required to achieve effective crabgrass control.
- A single application of quinclorac (0.75 lb ai/A) discolored bentgrass for 1 to 2 weeks. Two or more applications (0.33 or 0.5 lb ai/A) discolored bentgrass for eight weeks or longer.
- Tank-mixing quinclorac with a chelated iron plus micronutrient product helped to mask quinclorac-induced discoloration, but it did not eliminate discoloration.

Smooth crabgrass (*Digitaria ischaemum* [Schreber] Schreber) is among the most common and invasive weeds in turfgrasses in many regions of the United States. Turfgrass managers commonly apply preemergence herbicides to provide season-long crabgrass control. Poorly timed applications or unseasonably wet weather, however, may reduce the efficacy of these herbicides. When poor crabgrass control occurs, postemergence herbicide applications may be necessary. Previous research has shown that smooth crabgrass can be effectively controlled with several postemergence herbicides, but the efficacy among products can vary from year to year and among regions.

Currently, there are few herbicides that can be safely applied to creeping bentgrass (*Agrostis stolonifera*) to control annual grassy weeds postemergence. Quinclorac (trade name = Drive®) is labeled for use on creeping bentgrass fairways, and has been shown to effectively control crabgrass in other cool-season turfgrass species. In a



The blotchy turf in the plot in the background is one symptom of quinclorac injury.

PETER DERNOEDEN, Ph.D., Professor; JOHN E. KAMINSKI, PhD. candidate; and JOHN KROUSE, Research Associate; Department of Natural Resource Sciences and Landscape Architecture, University of Maryland; CALE BIGELOW, Ph.D., Asst. Professor of Agronomy at Purdue University.

Chlorosis is a common symptom of quinclorac injury especially during hot weather. The dark green plots in the above photograph have not been treated with quinclorac

Maryland study, quinclorac effectively controlled crabgrass in a single application (0.75 lb ai/A) in two out of three years where crabgrass pressure was moderately severe (2). In another Maryland study, however, multiple applications of quinclorac were required to achieve commercially successful control under high crabgrass pressure (4).

The safety of quinclorac on cool-season grasses has been inconsistent, especially on turf maintained at low mowing heights. Quinclorac (0.50 to 0.75 lb ai/A) was reported to be safe to 'Penncross' creeping bentgrass grown on a Massachussetts nursery green (1). On a 'Penncross' bentgrass green in Georgia, however, quinclorac applied in early-June at 0.5 lb ai/A severely reduced quality and cover for more than eight weeks (5). Similar results were reported on a creeping bentgrass green in New Jersey (7).

Reicher et al. (6), reported that quinclorac (0.75 lb ai/A) applied either pre-plant, or 14 or 28 days after creeping bentgrass seedling emergence caused significant ground cover reductions to spring seeded bentgrass in North Carolina, but not in Indiana or Iowa. It was suggested in this study that caution should be exercised when using quinclorac in regions where elevated temperatures may occur early in the year.

Injury to creeping bentgrass turf sometimes can be ameliorated by tank-mixing herbicides with safeners, such as nitrogen (N) or chelated iron (Fe) + N. For example, slow release liquid N and a Fe + N product helped to mask the injurious effects of fenoxaprop-ethyl (trade name = Acclaim Extra) applied to creeping bentgrass (3). A similar effect was observed with quinclorac applied with Fe + N to creeping bentgrass in New Jersey (7).

Although quinclorac is effective for postemergence crabgrass control in many regions, the optimum rate and time of application have not

Quinclorac rate		Application dates		
(lb ai/A)	Timing	2000	2001	2002
0.75	EPO[z]	June 1	May 31	---
0.5 + 0.5	EPO	June 1, 30	May 31, June 28	---
0.38 + 0.38 + 0.38	EPO	June 1, 13, 30	---	---
0.33 + 0.33 + 0.33	EPO	---[w]	May 31; June 14, 28	---
0.75	MPO[y]	June 30	June 28	June 21
0.5 + 0.5	MPO	June 30, July 27	June 28, July 25	June 21, July 3
0.38 + 0.38 + 0.38	MPO	June 30, July 13, 27	---	---
0.33 + 0.33 + 0.33	MPO	---	June 28, July 11, 25	June 21; July 3,19
0.75	LPO[x]	July 27	July 25	---
0.5 + 0.5	LPO	July 27, Aug. 23	July 25, Aug. 21	---
0.38 + 0.38 + 0.38	LPO	July 27, Aug. 10, 23	---	---
0.33 + 0.33 + 0.33	LPO	---	July 25, Aug. 7, 21	---

[z] Early-postemergence (EPO) applications were initiated when crabgrass was in the 1- to 4- leaf stage.

[y] Mid-postemergence (MPO) applications were initiated when crabgrass was in the 5- leaf to 3- tiller stage in 2000 and 4- leaf to 3- tiller or 2- leaf to 2- tiller stage for the severe and moderately infested sites, respectively in 2001. In 2002, applications were initiated when crabgrass was in the 3- to 5- leaf stage.

[x] Late-postemergence (LPO) applications were initiated when crabgrass was in the 4- to 22- tiller stage in 2000, and 2- to 8- tiller or 2- to 3- tiller stage for the severe and moderately infested sites, respectively in 2001.

[w] Treatment not evaluated.

Table 1. Quinclorac (Drive®) rates and dates of application for smooth crabgrass control in perennial ryegrass.

been well defined for the mid-Atlantic region, and its effects on bentgrass quality have been erratic. Therefore, the objectives of this study were to assess the effects of several quinclorac rates applied in three timings for postemergence crabgrass control in perennial ryegrass (*Lolium perenne*) and to evaluate creeping bentgrass tolerance to quinclorac.

Methods

Crabgrass Control A three-year field study was conducted at University of Maryland turfgrass research facilities in Silver Spring, MD (2000) and College Park, MD (2001 and 2002). Control was assessed in mature stands of perennial ryegrass because our bentgrass study areas contained little or no crabgrass. Smooth crabgrass pressure was severe in the 2000 site. In 2001, efficacy was assessed on two sites that were either moderately infested or severely infested with smooth crabgrass. A moderate infestation of crabgrass was judged to be between 40 and 60% crabgrass cover at the end of the study in untreated control plots; whereas, severe pressure was judged to be approximately 85% or greater crabgrass cover.

In 2002, a site adjacent to the 2001 study area was utilized and crabgrass pressure was severe. There were three application timings in 2000 and 2001: early-postemergence (EPO), mid-postemergence (MPO) and late-postemergence, (LPO); and three quinclorac rates: 0.75 lb ai/A applied once, 0.5 + 0.5 lb ai/A applied twice on a four week interval and 0.38 + 0.38 + 0.38 (2000) or 0.33 + 0.33 + 0.33 (2001) lb ai/A applied three

Quinclorac rate (lb ai/A)	Timing[y]	Crabgrass cover[z] 2000	2001 Moderate site	2001 Severe site	2002
		%			
0.75	EPO	69 bc[x]	5 c	51 b	---
0.5 + 0.5	EPO	26 f	1 c	8 c	---
0.38 + 0.38 + 0.38	EPO	1 g	---	---	---
0.33 + 0.33 + 0.33	EPO	---[w]	1 c	9 c	---
0.75	MPO	78 b	3 c	53 b	10 b
0.5 + 0.5	MPO	44 de	4 c	49 b	<1 c
0.38 + 0.38 + 0.38	MPO	4 g	---	---	---
0.33+0.33+0.33	MPO	---	3 c	16 c	1 c
0.75	LPO	58 cd	20 b	71 b	---
0.5 + 0.5	LPO	32 ef	4 c	1 b	---
0.38 + 0.38 + 0.38	LPO	8 g	---	---	---
0.33 + 0.33 + 0.33	LPO	---	3 c	16 c	---
Untreated control		99 a	57 a	97 a	85 a

[z] Early postemergence = EPO; mid-postemergence = MPO; and late postemergence = LPO.

[y] Crabgrass cover was assessed visually on a linear 0 to 100 % scale where 0 = no crabgrass and 100 = entire plot area covered on 8 Sept, and 17 Sept, and 9 Aug. in 2000, and 2001 and 2002, respectively.

[x] Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD (P = < 0.05).

[w] Treatment not evaluated.

Table 2. Smooth crabgrass cover in perennial ryegrass as influenced by various quinclorac (Drive®) rates and application timings.

times on two-week intervals. The 0.38 lb ai/A sequential rate was reduced to 0.33 lb ai/A in 2001 to meet label restrictions requiring no more than 1.0 lb ai/A of quinclorac be applied per year.

In 2002, all treatments were applied MPO at the following rates: 0.75 lb ai/A applied once; 0.5 + 0.5 lb ai/A applied twice on a two-week interval; and 0.33 + 0.33 + 0.33 lb ai/A applied three times on two-week intervals. Application dates are shown in Table 1. The percent of plot area covered by smooth crabgrass was assessed visually on a 0 to 100 % scale where 0 = no crabgrass and 100 = entire plot area covered with crabgrass. Treatments with mean smooth crabgrass cover ratings exceeding 5 % of plot area covered were considered to be unacceptable levels of control for most golf course fairways.

Bentgrass Tolerance Treatments were applied to either a mature stand of 'Penncross', 'Crenshaw', or 'L-93' creeping bentgrass in 2000, 2001, and 2002, respectively. All bentgrass sites were mowed to a fairway height three times per week and clippings were removed. In 2000, quinclorac treatments were identical to those used in the aforementioned perennial ryegrass area. In 2001 and 2002, however, treatments were initiated only in the mid-postemergence timing.

In 2001, quinclorac was applied alone or tank-mixed with either urea (N at 0.125 lb/1000 ft^2) or Lesco's 12-0-0 Chelated Fe Plus Micronutients® (Fe + N at 4.0 fl. oz/1000 ft^2). In 2002, only Fe + N was used as a safener. An additional urea or Fe + N application was made two weeks following the last application and again on

Aug.31, 2001, except for plots treated with quinclorac alone. In 2002, an additional Fe + N application without quinclorac was made on July 19. For comparison, urea and Fe + N were applied alone to separate plots in 2001, but not in 2002. The dates of all treatment applications appear in the data tables. Turf color and quality were rated visually on a 0 to 10 scale where 0 = turf brown; 7.5 = minimum acceptable discoloration; and 10 = optimum green color and density.

All treatments were applied in 50 gallons of water per acre using a CO_2 pressurized (35 psi) sprayer equipped with an 8004E flat-fan nozzle. All quinclorac treatments involved the 75 DG formulation and were tank-mixed with methylated seed oil (MSO, 1% v/v) and the study sites were irrigated with at least 0.3 inch of water within 24 hours of each application.

Results

Crabgrass Control All quinclorac rates and timings reduced crabgrass cover in 2000 (Table 2). All EPO treatments appeared to pro-

Quinclorac rate	Turfgrass color, 2000[z]										
(lb ai/A)	June 6	June 20	July 6	July 13	July 27	Aug. 2	Aug. 9	Aug.17	Aug. 23	Aug. 30	Sept.8
	(0-10 scale)										
Early-postemergence timing											
0.75 [y]	8.9 b[x]	8.6 c	8.0 b	8.8 a	9.0 ab	9.5 a	9.0 a	8.8 a	8.3 a	9.3 a	9.3 a
0.5 + 0.5 [w]	8.9 b	9.1 b	6.2 c	6.8 b	7.5 c	8.5 a	7.7 b	7.6 a	8.2 a	8.3 b	8.5 b
0.38+0.38+0.38[v]	9.0 b	8.1 d	6.5 c	7.0 b	7.8 bc	8.6 a	8.1 ab	7.5 a	8.1 a	8.4 b	8.4 b
Untreated	10.0 a	10.0 a	9.7 a	9.8 a	9.6 a	9.6 a	9.0 a	7.9 a	8.1 a	9.0 a	9.3 a
Mid-postemergence timing											
0.75 u	---	---	6.1 c	6.8 c	7.8 b	8.7 b	8.1 a	7.6 ab	8.0 a	8.6 ab	8.6 ab
0.5 + 0.5[t]	---	---	6.7 c	8.5 b	8.4 b	6.5 c	6.9 b	7.0 ab	7.4 ab	7.7 c	8.0 b
0.38+0.38+0.38[s]	---	---	7.5 b	8.5 b	8.3 b	6.8 c	7.0 b	6.7 b	7.1 b	8.0 bc	8.1 b
Untreated	---	---	9.7 a	9.8 a	9.6 a	9.6 a	9.0 a	7.9 a	8.1 a	9.0 a	9.3 a
Late-postemergence timing											
0.75[r]	---	---	---	---	---	6.9 c	7.0 c	6.5 bc	7.0 bc	8.1 b	8.3 b
0.5 + 0.5[q]	---	---	---	---	---	7.1 bc	7.7 bc	5.9 c	6.7 c	6.8 c	7.1 c
0.38+0.38+0.38[p]	---	---	---	---	---	7.7 b	8.1 b	6.8 b	7.0 bc	6.8 c	7.0 c
Untreated	---	---	---	---	---	9.6 a	9.0 a	7.9 a	8.1 a	9.0 a	9.3 a

[z] Color was assessed visually on a 0-10 scale, where 0 = brown turf, 7.5 = minimum acceptable level of color for golf fairway turf and 10=optimum greenness.

[y] Treatment was applied 1 June 2000.

[x] Means in the same column within the same application timing followed by the same letter are not significantly different according to Fisher's protected LSD (P = < 0.05).

[w] Treatment was applied June 1 and 30, 2000.

[v] Treatment was applied June 1, 13 and 30, 2000.

[u] Treatment was applied June 30, 2000.

[t] Treatment was applied June 30 and July 27, 2000.

[s] Treatment was applied June 30, July 13 and 27, 2000.

[r] Treatment was applied July 27, 2000.

[q] Treatment was applied July 27 and Aug. 10, 2000.

[p] Treatment was applied July 27, Aug.10 and 23, 2000.

Table 3. Fairway height 'Penncross' creeping bentgrass color ratings as influenced by various quinclorac (Drive®) rates and three application timings, 2000.

Quinclorac rate	Color, 2001[z]										
(lb ai/A)	July 3	July 10	July 13	July 21	July 24	July 30	Aug. 3	Aug. 8	Aug. 13	Aug. 20	Aug. 27
	(0-10 scale)										
0.75[y]	6.3 f x	7.5 e	7.8 c	7.8 bc	7.4 ef	8.2 cd	7.8 de	8.2 bcd	7.9 cde	8.3 cde	7.8 de
0.75 + urea[w]	6.8 ef	7.5 e	7.8 c	8.0 bc	7.8 de	8.3 cd	8.1 bcd	7.9 cde	7.8 def	8.4 cd	8.0 cd
0.75 + Fe + N[w]	7.7 cd	8.5 abc	9.4 ab	9.1 a	8.9 abc	9.0 bc	8.5 bcd	8.6 b	8.5 bc	9.0 bc	7.4 def
0.5 + 0.5[v]	6.6 ef	7.8 de	7.5 c	7.0 d	6.6 f	6.8 e	7.3 ef	7.2 e	7.3 efg	7.7 de	7.7 def
0.5 + 0.5 + urea	7.1 de	7.5 e	8.0 c	7.3 cd	7.5 e	8.0 d	7.9 de	7.9 cde	7.1 g	7.7 de	7.2 ef
0.5 + 0.5 + Fe + N	8.1 bc	8.7 abc	8.8 b	7.8 bc	7.8 de	9.5 ab	8.6 b	9.4 a	8.2 cd	9.1 b	8.0 cd
0.33+0.33+0.33[u]	7.1 de	8.1 cd	7.9 c	7.8 bc	7.3 ef	6.4 e	6.9 f	7.3 e	7.3 fg	7.6 e	7.2 ef
0.33+0.33+0.33 + urea	8.1 bc	8.4 abc	8.0 c	7.6 cd	7.5 de	7.9 d	7.9 cde	7.6 de	7.5 efg	7.8 de	7.0 f
0.33+0.33+0.33+ Fe + N	8.2 bc	8.3 bcd	8.8 b	8.4 b	8.3 cd	9.3 ab	8.6 bc	8.1 bcd	8.4 c	9.4 ab	7.8 de
Urea[t]	8.5 ab	8.8 ab	9.9 a	9.6 a	9.2 ab	10.0 a	9.4 a	9.6 a	9.6 a	9.9 a	9.1 b
Fe + N[t]	8.9 a	8.8 ab	10.0 a	9.4 a	9.5 a	10.0 a	9.5 a	9.6 a	9.8 a	9.9 a	9.9 a
Untreated	8.5 ab	9.0 a	9.1 b	9.2 a	8.6 bc	8.6 bcd	8.5 bcd	8.5 bc	9.0 b	8.8 bc	8.7 bc

[z] Color was assessed visually on a 0-10 scale where 0=brown turf, 7.5 = minimum acceptable level of color for golf fairway turf and 10=optimum greenness.

[y] Treatment was applied on June 28, 2001.

[x] Means in the same column followed by the same letter are not significantly different according to Fisher's protected LSD (P = 0.05).

[w] When a treatment specified tank-mixing with either urea or Fe + N an additional urea or Fe + N application without quinclorac was made two weeks following the last application and again on Aug. 31, 2001.

[v] Treatment was applied on June 28 and July 11, 2001.

[u] Treatment was applied on June 28, and July 11 and 25, 2001.

[t] Treatments were applied on June 28 and July 11 and 25, and Aug. 7 and 31, 2001.

Table 4. The influence of urea or chelated iron (Fe) plus nitrogen (N) tank-mixed with quinclorac (Drive®) on the color of fairway height 'Crenshaw' creeping bentgrass in 2001.

vide excellent postemergence crabgrass control 20 days after initial treatment on June 21 (data not shown). By July 21, however, recovery of herbicide injured crabgrass and subsequent germination of new crabgrass seedlings were observed in plots treated with 0.75 or 0.5 + 0.5 lb ai/A of quinclorac. The 0.38 + 0.38 + 0.38 lb ai/A quinclorac treatment in the EPO timing provided excellent control. Commercially unacceptable (more than 5 %) crabgrass cover, however, resulted from quinclorac applied at 0.75 and 0.5 + 0.5 lb ai/A in the EPO timing.

For the MPO treatments, poor crabgrass control again was observed with either the 0.75 and 0.5 + 0.5 lb ai/A rates. The 0.38 + 0.38 + 0.38 lb ai/A sequential applications again provided commercially acceptable crabgrass control. For the LPO treatments, all quinclorac rates appeared to severely injure the crabgrass for several weeks following application and provided a reduction in crabgrass cover. Many injured crabgrass plants recovered, particularly in plots treated with the 0.75 and 0.5 + 0.5 lb/A rates. On the final rating date (i.e., Sept. 8), data showed that quinclorac applied at 0.38 + 0.38 + 0.38 lb ai/A in the LPO timing provided good control (8 % crabgrass cover) and data were similar to those of the same rate applied in the EPO and MPO timings (Table 2).

In 2001, crabgrass control was evaluated at two sites containing either moderate or severe crabgrass levels. The severe site was overseeded with crabgrass in Oct., 1999, and allowed to reseed in 2000; whereas, the moderate site was overseeded in 2000. Hence, the severe site had a larger reservoir of seed, which likely germinated

over a longer period of time. The density of crabgrass plants also was extremely high and plants matured (i.e. tillered) more rapidly.

Crabgrass cover was rated initially in the severe site on Aug. 22. At this time, commercially acceptable control was observed in the plots treated with 0.5 + 0.5 (EPO) and 0.33 + 0.33 + 0.33 lb ai/A (EPO) rates (data not shown). By Sept. 17, crabgrass plants had tillered extensively and produced seedheads, and the percent crabgrass cover generally doubled in EPO, MPO, and selected LPO (0.75 and 0.5 + 0.5 lb/A)-treated plots. Hence, by Sept. 17 the level of crabgrass control was unacceptable in all plots in the severe pressure site as a result of the increasing size of plants that had survived injury from quinclorac. Relatively good control (8 to 9 % crabgrass cover), however, was associated with the 0.5 + 0.5 lb ai/A (EPO), and 0.33 + 0.33 + 0.33 lb ai/A (EPO) rates. In the moderate pressure site, all treatments except 0.75 lb ai/A (LPO), provided acceptable control (Table 2).

The relatively poor level of crabgrass control in the severe site was attributed to a large seed reservoir, more rapid tillering, and the extremely high density of crabgrass plants. It is likely that the greater density of crabgrass plants in the severe site protected the lower canopy shoots, resulting in less contact with quinclorac. Tillering also was more aggressive in the severe site, and these larger plants likely were more resistant to the herbicide. Thus, the reduced density of the crabgrass (i.e., better quinclorac coverage) and smaller plants in the moderate site were effectively controlled. The only exception was the 0.75 lb ai/A rate in the moderate site, which failed to provide acceptable control in the LPO timing when crabgrass plants had a two to three tillers at the time the application was made.

In 2002, treatments only were applied MPO to a site with severe crabgrass pressure. The single quinclorac application at 0.75 lb/A greatly reduced crabgrass cover, but the level of control was not within the acceptable threshold (less than 5% crabgrass cover) (Table 2). Unlike 2000 and 2001, the 0.5 + 0.5 lb ai/A rate provided excellent control. In 2002, however, the aforementioned sequential rate was applied on a two-week rather than the four-week interval used in 2000 and 2001. The 0.33 + 0.33 + 0.33 lb ai/A sequential treatment again provided excellent control. No phytotoxicity was observed in the perennial rye-

Quinclorac rate	Quality, 2002 [z]							
(lb ai/A)	June 17	June 25	July 2	July 10	July 19	July 31	Aug.9	Aug.16
	(0-10 scale)							
0.5 + 0.5 [y]	6.3 bc[x]	6.3 d	5.1 d	5.0 c	6.0 b	6.8 c	6.5 c	6.5 bc
0.5 + 0.5 + Fe + N [w]	6.5 abc	7.1 bc	5.8 bc	5.9 b	6.8 a	7.3 ab	7.1 ab	7.1 a
0.33+0.33+0.33 [v]	6.1 c	6.9 c	5.5 cd	5.6 b	6.8 a	6.9 bc	6.6 bc	6.4 c
0.33+0.33+0.33+ Fe + N[w]	6.8 ab	7.5 ab	6.3 b	6.1 b	6.5 ab	7.0 bc	6.9 abc	7.0 ab
Untreated	6.9 a	7.9 a	7.1 a	7.1 a	6.5 ab	7.5 a	7.3 a	7.2 a

[z] Quality was visually assessed on a 0-10 scale where 0 = brown or dead turf and 10 = uniform, optimum green color and density.

[y] Treatment was applied on June 12 and 27, 2002.

[x] Means in the same column followed by the same letter are not significantly different according to Fisher's protect ed LSD (P = 0.05).

[w] An additional Fe + N application without quinclorac was made on July 19, 2002.

[v] Treatment was applied on June 12 and 27, and July 8, 2002.

Table 5. The influence of chelated iron (Fe) plus nitrogen (N) tank-mixed with quinclorac (Drive® 75DG) on the quality of fairway height 'L-93' creeping bentgrass in 2002.

grass, regardless of year or site.

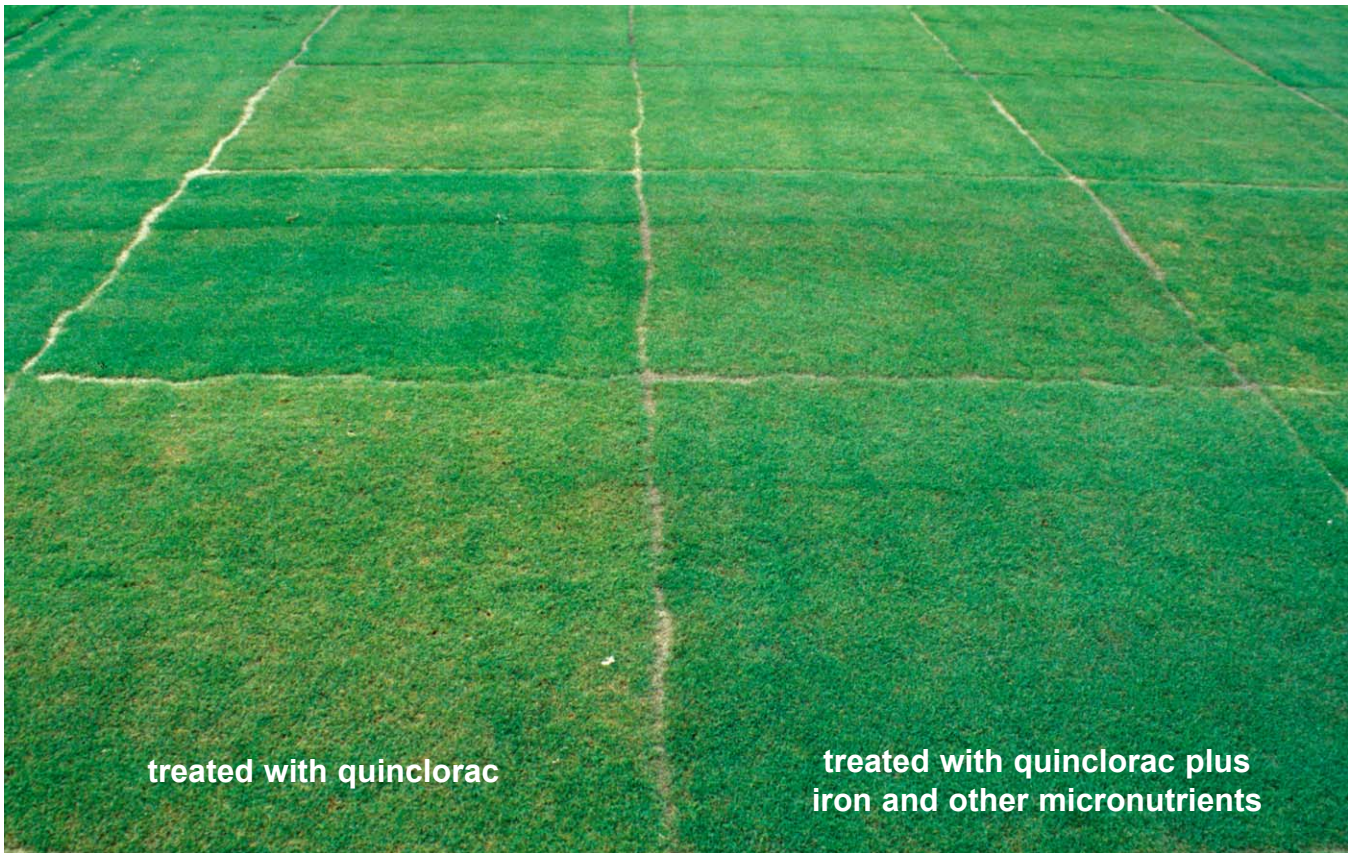
Bentgrass Tolerance to Quinclorac 2000

All quinclorac treatments in 2000 discolored the 'Penncross' creeping bentgrass (Table 3). Quinclorac injury appeared as a foliar chlorosis, but there was no loss of turf density. The 0.75 lb ai/A rate applied EPO was the only treatment associated with acceptable color (greater than 7.5 rating) on all dates. 'Penncross' treated with quinclorac sequentially at 0.5 + 0.5 lb ai/A and 0.38 + 0.38 + 0.38 lb ai/A rates in the EPO timing had unacceptable yellowing for two weeks (July 6 and 13). All treated plots in the EPO timing generally recovered by August 2. A reduction in color, however, was observed in 'Penncross' treated with the 0.5 + 0.5 or 0.38 + 0.38 + 0.38 lb ai/A rates as late as the final rating date (i.e., Sept. 8).

Quinclorac treatments applied in the MPO timing significantly reduced 'Penncross' color on most dates between July 6 and August 2 (Table 3). Turf treated with 0.75 lb ai/A rate, however, was associated with unacceptable color for only a two-weeks period immediately following application. Unacceptable discoloration was associated with sequential quinclorac applications in the MPO timing for three weeks between August 2 and 23. All herbicide-treated plots had acceptable color by September 8.

All LPO treatments caused an unacceptable chlorosis for several weeks following application (Table 3). Quinclorac applied once at 0.75 lb ai/A discolored the 'Penncross' unacceptably for nearly four weeks (August 2 to 23). All sequentially-treated 'Penncross' plots had unacceptable color between August 17 and Septemeber 8. On the final rating date, turf in all quinclorac-treated plots had reduced color ratings, when compared to the untreated control, especially the sequentially-treated 'Penncross' plots.

In a separate study, quinclorac (0.75 lb ai/A) and MSO were applied alone or in combination on July 6, 2000. Quality ratings revealed that the chlorosis was not influenced significantly by



Plot in the foreground left is quinclorac treated without iron plus other micronutrients. The plot in the foreground right was treated with the same rate of quinclorac and the addition of iron and other micronutrients.

the MSO (data not shown). Hence, this study demonstrated that quinclorac alone was the primary source of discoloration in creeping bentgrass. Therefore, safeners (i.e. urea-N or Fe + N) were investigated to determine if they would minimize or mask bentgrass injury induced by quinclorac.

Safeners and Quinclorac 2001 and 2002

This study was initiated in the MPO timing on June 28, 2001. This timing was selected for two reasons: 1) it coincides with the time when crabgrass infestations are most often first discerned by turf managers in the region; and 2) previous results showed quinclorac to be most effective in controlling crabgrass when application(s) was initiated in June prior to crabgrass tillering.

In 2000, quinclorac elicited a brilliant foliar chlorosis in 'Penncross'. By contrast, in 2001 'Crenshaw' did not develop a chlorotic appearance, but injury was detectable for ten or more weeks in response to selected sequential quinclorac treatments (Table 4). Between July 3 and August 8, the discoloration was uniform and foliage was light-green or slightly yellow, but there was no loss of turf density at this time. Multiple applications of quinclorac alone (i.e. without safeners) often resulted in color ratings below the 7.5 minimum acceptable level.

Herbicide injury became most pronounced following a period of high temperature stress (average daily high 92^{o}F and low 70^{o}F) and 2.5 inches of rain between August 7 and 12. These stressful environmental conditions apparently enhanced injury and turf appeared mottled and blotched with a mix of green, yellow, tan and reddish-brown discolored foliage. While some thinning and loss of shoot density (less than 2% thinning) occurred, there was no exposure of bare ground.

Plots treated once with quinclorac (0.75 lb ai/A) were discolored unacceptably for one week after treatment (July 3), but thereafter color ratings were generally above the minimum acceptable level (Table 4). Color ratings, however, were worse than the untreated control for three weeks (July 3 to 24) following the quinclorac application. Except for the August 27 rating, plots treated with the 0.75 lb ai/A rate tank-mixed with Fe + N exhibited acceptable color and quality on all dates. Plots treated once with quinclorac (0.75 lb ai/A) on June 28 appeared to recover by July 30.

Following the aforementioned period of environmental stress, however, the bentgrass in these same plots, as well as others, exhibited a reduction in color (August 13 to 27), which probably can be attributed to the herbicide. The nature and mechanism of this delayed negative effect due to quinclorac in response to environmental stress is unknown. It seems likely, however, that creeping bentgrass plants may be physiologically stressed by the herbicide for long periods of time.

'Crenshaw' treated with 0.5 + 0.5 lb ai/A quinclorac had color ratings similar to turf treated with the 0.75 lb ai/A rate between July 3 and 13 (Table 4). Following the second quinclorac application on July 11, however, turf color was reduced and was below the acceptable threshold on most dates between July 3 and August 13. 'Crenshaw' treated with the 0.5 + 0.5 lb ai/A rate plus urea had unacceptable color or quality on several dates, especially between August 13 and 2. Conversely, plots treated at this rate with Fe + N had acceptable color on nearly all dates between July 3 and September 10. (Table 4).

'Crenshaw' color was reduced in plots treated with 0.33 + 0.33 + 0.33 lb ai/A of quinclorac alone on all rating dates (Table 4). 'Crenshaw' treated with the 0.33 + 0.33 + 0.33 lb ai/A and Fe + N, however, had color ratings greater than 8.1 on all dates between July 3 and August 20, and color ratings often were similar to the untreated control.

In 2002, selected quinclorac treatments again were assessed in tank-mixes with Fe + N to corroborate 2001 findings. Because most discoloration elicited by quinclorac occurred with two or more herbicide applications, only two sequential treatments were assessed. It should be noted that during the study period air temperature exceeded 90^{o}F on most days, and turf quality was generally poor and below the acceptable quality level (7.5) for fairways due to heat stress.

As was observed in 2000, quinclorac-

treated 'L-93' turf developed a brillant chlorosis within one week of application. Between June 17 and July 10, the addition of Fe + N generally improved quality, when compared to plots treated with the same rate of quinclorac alone (Table 5). The second quinclorac application on June 27 resulted in some reddening and thinning of the turf (less than 2%; data not shown) between July 2 and 10, and all herbicide-treated plots exhibited reduced quality, when compared to the untreated control.

Between July 19 and August 16, plots treated with 0.5 + 0.5 lb ai/A rate with Fe + N had quality equivalent to the untreated control. Tank-mixing Fe + N with the 0.33 lb ai/A rate improved quality, when compared to plots treated with the same rate without the safener between June 17 and July 2. Following the third application of the 0.33 lb ai/A rate on July 8, however, no improvement in quality was provided by Fe + N until August 9.

On the final rating date (August 16), plots receiving both herbicide treatments tank-mixed with Fe + N had quality equivalent to the untreated control. Conversely, plots treated with quinclorac alone exhibited quality inferior to both the untreated control and their counterpart Fe + N treatments. For both sequential rates, tank-mixing quinclorac with Fe + N resulted in a level of quality equivalent to the untreated control during five of the eight weeks of the 2002 study.

Conclusions

Data showed that the best timing to initiate quinclorac applications to effectively control smooth crabgrass in the mid-Atlantic region was in June (EPO and MPO) prior to crabgrass tillering. Multiple quinclorac applications at 0.33 lb ai/A rates provided better crabgrass control than a single application (0.75 lb ai/A) of quinclorac where crabgrass pressure was severe. In the moderately infested site in 2001, however, effective crabgrass control was achieved with 0.75 lb ai/A rate in the EPO and MPO timings, but not the LPO timing. It should be noted that in 2000 and 2001, the 0.5 + 0.5 lb ai/A treatment was applied on a four-week interval. When the 0.5 + 0.5 lb ai/A rate was applied on a two-week interval in 2002, excellent crabgrass control was achieved.

Sequential quinclorac applications extended the period of creeping bentgrass discoloration, which apparently was enhanced by heat stress. In 2000, bentgrass injury was least severe in the EPO timing and most severe in the LPO timing, indicating that increasing temperature contributed to more discoloration. In 2001, injury was best minimized by tank-mixing quinclorac with Fe + N. While urea generally improved color and quality, it was not as effective as Fe + N in masking the discoloration and injury elicited by quinclorac.

In 2002, the level of discoloration induced by quinclorac was more severe than in 2001, which was likely due to a prolonged period of high temperature stress. Tank-mixing quinclorac with Fe + N ameliorated the discoloration on five of eight rating weeks in 2002. Furthermore, tank-mixing quinclorac with Fe + N in 2002 resulted in complete recovery of the turf by August 9, whereas turf treated with quinclorac alone continued to exhibit lower quality for an additional three weeks. Therefore, regardless of how often quinclorac is applied to creeping bentgrass, it is advisable to tank-mix Fe + N with quinclorac and subsequently apply Fe + N approximately every two weeks following quinclorac application until the turf has recovered.

Acknowledgements

We are grateful for the financial support of this study provided by the United States Golf Association and the BASF Corp.

Literature Cited

1. Bhowmik, P. C., and B.M. O'Toole. 1991. New tools for selective control of crabgrass in cool-season turfgrass. Proc. Northeastern Weed Sci. Soc. 45:116. (Abstr.) (TGIF Record 20124)

2. Dernoeden, P. H. 2001. Reduced herbicide

rates for smooth crabgrass control in the mid-Atlantic region. *Intl. Turfgrass Soc. Res. J.* 9:1005-1008. (TGIF Record 7447)

3. Dernoeden, P. H. 1989. Mature creeping bentgrass and seedling Kentucky bluegrass tolerance to fenoxaprop. *Intl. Turfgrass Soc. Res. J.* 6:279-283. (TGIF Record 17104)

4. Dernoeden, P. H. and J. M. Krouse. 1990. Maryland smooth crabgrass control evaluations for 1989. Proc. Northeastern Weed Sci. Soc. 44:141-142. (Abstr.) (TGIF Record 18125)

5. Johnson, B. J. 1994. Creeping bentgrass quality following preemergence and postemergence herbicide applications. *HortScience* 29:880-883. (TGIF Record 3115)

6. Reicher, Z. J., G. A. Hardebeck, F. F. Yelverton, N. E. Christians, B. Bingaman, and J.Turner. 2002. Tolerance to quinclorac by seedling creeping bentgrass. *HortScience* 37:210-213. (TGIF Record 7934)

7. Sciarappa, W. 1991. BAS 514 Approaches to selectivity and efficacy in bentgrass and bluegrass. Proc. Northeastern Weed Sci. Soc. 45:144. (Abstr.) (TGIF Record 2013)