Frequency of Iron Application Influences Bermudagrass Tolerance to Herbicides[1]

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Abstract

Postemergence herbicides used for weed control in bermudagrasses (*Cynodon* spp.) often cause turf injury. A field experiment was initiated to determine the effect of multiple foliar-iron (Fe) applications for reducing injury from postemergence herbicides on 'Tifway' bermudagrass [*C. transvaalensis* Burtt-Davy × *C. dactylon* (L.) Pers.]. Iron was applied at 1 to 4 applications at 1.12 kg Fe/ha (1.0 lb/A) per treatment on a 4-day interval. Herbicides were applied at recommended rates. When bermudagrass was treated with either Image (Imazaquin), {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid}, MSMA (monosodium salt of MAA), and MSMA plus Image or Sencor (Metribuzin), [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one], 2 Fe applications caused only slight turf color improvement compared to 1 Fe. Three Fe applications compared to 1 Fe, however, significantly enhanced turf color by 1 to 10% in combination with all herbicides for 16 to 26 days after initial treatment. The 4 Fe treatment provided only minor improvement in degree of color or duration of color response versus 3 Fe. Iron did not influence any shoot density loss caused by herbicides. On high-maintenance turf where discoloration is objectionable, the use of multiple Fe applications would be feasible for reducing herbicide-induced color loss.

Index words: *Cynodon dactylon* × *C. transvaalensis*, turf quality, turf color

Herbicides used in this study: Image (Imazaquin), {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid}; MSMA (monosodium salt of MAA); Sencor (Metribuzin), [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one].

Significance to the Nursery Industry

On high-quality turfgrass sites, the color loss following many postemergence herbicide applications is objectionable. This paper demonstrates that 3 to 4 applications of foliar-applied Fe reduces the magnitude and duration of color loss induced by Imazaquin, MSMA, Metribuzin, and various combinations on 'Tifway' bermudagrass. Effectiveness of foliar Fe depends upon the number of Fe applications, type of herbicide, and climatic condition.

Introduction

Foliar applied iron (Fe) improves the color and quality of several turfgrass species (1, 5, 6, 7). Iron also may reduce injury by plant growth regulators (2), postemergence herbicides (3), and environmental conditions (6). However, Fe does not prevent all of the turfgrass injury caused by herbicides, but primarily reduces color loss by the turfgrass (3). On high maintenance recreational turf, methods to reduce injury or duration of injury symptoms would be highly desirable.

When herbicides plus Fe were applied to 'Tifway' bermudagrass [*Cynodon transvaalensis* Burtt-Davy × *C. dactylon* (L.) Pers.] twice at a 9 to 10-day interval, herbicide injury was reduced after the second application of MSMA plus Sencor or Image compared to plots treated only with herbicides (3). Initially, Image applied with Fe injured bermudagrass as much as when the chemical was applied alone. However, bermudagrass recovered faster with Fe and Image than with Image alone (3). The use of Fe with herbicides did not prevent bermudagrass injury, but decreased injury during the recovery period, which varied with herbicide treatments. While Fe could reduce injury from certain postemergence herbicides, the best frequency of application was not determined.

Bermudagrass injury from postemergence herbicides is especially serious on high-maintenance recreational sites where optimum quality turf is desired. Thus, an experiment was initiated on Tifway bermudagrass to determine the frequency of Fe applications needed to obtain the optimum reduction of postemergence herbicide injury.

Materials and Methods

A postemergence herbicide and foliage-applied Fe experiment was conducted on established Tifway bermudagrass at Griffin, Georgia during 1989. The experiment was repeated in time in early summer (termed the June study) and in mid-summer (termed the July study) with a separate plot area for each study. Because postemergence herbicides are most often applied in early to mid-summer, the June and July periods were representative of differing climatic conditions when these materials would be used (Table 1).

Herbicide treatments were Image (0.42 kg/ha, 0.38 lb/A), MSMA (2.2 kg/ha, 2.0 lb/A), MSMA plus Image (2.2 + 0.42 kg/ha, 2.0 + 0.38 lb/A), and MSMA plus Sencor (2.2 + 0.14 kg/ha, 2.0 + 0.13 lb/A) and an untreated control. A nonionic surfactant (alkylaryl polyoxyethylene glycols, fatty acid, isopropanol) (X-77 surfactant, Valent U.S.A., Corp., Walnut Creek, CA) was applied with all herbicides at 0.5% (v/v). Iron chelate was used for Fe application treatments at 1.12 kg Fe/ha, (1.0 lb/A) per application. The Fe source was Lawn-Plex (PGB Laboratories, Inc., Kansas City, Mo.) which contains 8% sulfur and 8% chelated Fe derived from ammonium thiosulfate and iron

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Table 1. Climatic conditions for the June and July repetitions of the experiment.

Date	Average temperature (°C) Max.	Min.	Avg. evaporation[y] (mm d^{-1})	Total precipitation (mm)	Irrigation applied (mm)
June Study (1 to 29 June)					
0 to 12 DAI[z]	28.6	18.1	5.87	60.4	0
13 to 17 DAI	27.4	18.6	3.93	42.6	0
18 to 23 DAI	27.5	17.2	3.65	57.4	0
24 to 29 DAI	30.9	19.4	5.99	7.7	0
	28.6	18.3		168.1 (6.59 in)	0
July Study (28 June to 26 July)					
0 to 12 DAI	29.2	20.1	4.41	66.6	0
13 to 17 DAI	31.8	19.7	5.97	0	25
18 to 23 DAI	29.1	19.6	4.64	27.0	0
24 to 29 DAI	29.3	20.4	5.28	12.1	12
	29.6	20.0		105.8 (4.15 in)	37 (1.45 in)

[z]DAI = days after initiation of the study.

[y]Evaporation from U.S. Weather Bureau weather pan.

phosphate-citrate in a liquid formulation. This was the same Fe source used by Johnson et al., (3).

Herbicides were applied to the same plots on June 1 and June 9 for the June study, and to the same plots on June 28 and July 6 for the July study. Herbicide treatments were repeated to be representative of the 7 to 14-day reapplication schedule recommended for most postemergence herbicides. Iron frequency consisted of one to four applications to the June herbicide treatments on 1, 5, 9, and 13 June, and to the July herbicide treatments on June 28, and July 3, 6 and 10. Although the first application of herbicides and Fe treatments was made June 28 and the remainder of treatments were made in July, this series of treatments will be referred to as the July study throughout the paper. When Fe was applied once (1 Fe), it was at the first date, when applied twice (2 Fe), it was at the first and second dates, when applied three times (3 Fe), it was at the first three dates, and when applied four times (4 Fe), it was applied at all four dates. The Fe treatments applied at 4-day interval in one to four applications differed from Johnson et al. (3) where Fe was applied once or twice (10-day interval). Herbicides and Fe treatments were applied in separate applications within 15 min. of each other with Fe applied first. In a previous study, similar results occurred whether herbicide and Fe were tank-mixed or applied separately within 15 minutes of each other (3). The broadcast spray water volume was 375 l/ha for the herbicides and 1600 l/ha for the Fe. Water pH was 8.5 and treatments were applied within 30 min. of mixing. After the addition of Lawn-Plex to the water, pH was 6.2 and no problem with Fe precipitation was noted.

Tifway bermudagrass was mowed with a reel mower three times per week at 2 to 3 cm height. Grass clippings were returned before treatments were applied and removed thereafter. The turfgrass was fertilized with 50N-22P-42K kg/ha (45N-20P-38K lb/A) in mid-April and 50 kg N/ha (45 lb/A) in late May. No additional N was applied to plots. Rainfall was supplemented with irrigation as needed to maintain optimum turfgrass growth (Table 1).

The soil type at both study sites was an Appling sandy clay loam (clayey kaolinitic, thermic Typic Hapludult) with 1.7% organic matter, 55% sand, 22% silt, and 23% clay. Soil tests were: pH 6.5, 30 mg P/kg (high), and 58 mg K/kg (medium) based on Georgia soil test recommendations.

Visual ratings for turfgrass color, shoot density, and quality were made. The color rating was 1 to 9 where 1 = no green color (all brown or yellow) and 9 = dark green color. Shoot density ratings were 100% = no loss of shoot density and 0 = total turf loss. Turfgrass quality ratings were 1 to 9 where 1 = no live turf and 9 = ideal shoot density, color, and uniformity. Color and shoot density are components of turfgrass quality so overall turf quality ratings were also conducted. Ratings for color, shoot density, and quality were made at various times from 2 to 26 days after the initial treatment.

The experimental design was a split-plot randomized complete block design with four replications (blocks). Herbicides were main plots (1.5 by 6.0 m, 4.9 by 20 ft) and Fe treatments were sub-plots (1.5 by 1.5 m, 4.9 by 4.9 ft). Analysis of variance was performed and revealed significant time by herbicide and by Fe interactions; thus, data are presented separately for each date (4).

While the experimental design allowed herbicide (main plot) and Fe application (sub-plot) comparisons to be investigated, the primary objective was to determine the influence of repeated Fe applications on each herbicide (i.e., herbicide × Fe interaction). Comparisons of the herbicides were of no practical interest since each herbicide or combination of herbicides is currently used for specific situations and are not necessarily choices for the same weed problem. Thus, each herbicide was analyzed separately from the others for influence of Fe applications by use of single degree of freedom paired comparisons. The herbicide by Fe application interaction was significant on all dates of measurement.

Results and Discussion

All herbicides caused a significant loss of green color on at least 5 out of 8 ratings over both study periods (Table 2).

Table 2. Herbicide (main plot) and iron application (sub-plot) treatment effects on turf color at Griffin, GA in June and July 1989.

Paired comparisons	Rate		Turf color							
			June 1–27, 1989				June 28–July 23, 1989			
	kg/ha	lb/A	12[x] DAT	16 DAT	21 DAT	26 DAT	12 DAT	16 DAT	21 DAT	26 DAT
			9 = dark green; 1 = no green, all brown							
Herbicide[z]										
Untreated *versus*	0	0	8.3[w]	8.1	7.5	7.7	7.8	8.0	8.0	7.9
Image	.42	.38	7.0*	6.8*	7.5	7.8	6.9*	6.9*	6.7*	7.5*
MSMA	2.2	2.0	7.7*	8.0	7.3*	7.7	6.6*	7.1*	7.8*	7.9
MSMA + Image	2.2 + .42	2.0 + .38	6.7*	6.8*	7.5	7.8	6.2*	6.4*	7.1*	8.2*
MSMA + Sencor	2.2 + .14	2.0 + .13	6.8*	8.1	6.6*	7.3*	5.8*	7.3*	8.2*	7.5*
Iron Applications[y]										
1 *versus*	1.12	1.00	7.0[w]	7.3	7.1	7.6	6.3	6.9	7.4	7.7
2	2.24	2.00	7.2*	7.4	7.2	7.6	6.4	6.9	7.4	7.7
3	3.36	3.00	7.6*	7.7*	7.4*	7.7	7.3*	7.3*	7.6*	7.8
4	4.48	4.00	—	7.8*	7.4*	7.8*	—	7.4*	7.7*	7.8
CV (%)			3.2	3.6	3.0	3.0	4.6	3.7	2.2	3.1

[z]Herbicides were applied 1 and 9 June for the first study and 28 June and 6 July for the second.

[y]Fe was applied on 1, 5, 9 and 13 June for the first study and 28 June, 3, 6, and 10 July for the second. Each application was at 1.12 kg/ha (1.0 lb/A) of Fe.

[x]DAT = days after treatment with initial herbicide and Fe applications.

[w]Paired comparisons within a column are with the untreated control for herbicide main effect and with one Fe application for Fe application main effect. Significant differences at the $P < 0.05$ are denoted with an *.

Combinations of MSMA with Image or Sencor caused the greatest color decline of up to 19 to 26%. Color loss was temporary for all herbicides and most plots exhibited recovery by 26 DAT (days after initial herbicide and Fe application).

The color of Tifway bermudagrass treated or not treated with herbicide was not influenced by 2 Fe applications at anytime from 2 to 8 days after initial treatment (DAT) in either study (data not given). After 8 DAT, 2 Fe applications differed from 1 Fe on only one date (12 DAT, June study) when averaged over all herbicides (Table 2). Significant color improvement was apparent at 3 and 4 Fe applications compared to 1 or 2 Fe applications on all periods between 12 to 21 DAT when averaged over herbicide main plots.

Two Fe applications decreased Image induced turfgrass discoloration relative to 1 Fe by 3 to 4% in June at 12 to 21 DAT but not July (Table 3). In an earlier study, Johnson et al. (3) reported that 2 Fe applications would improve color of bermudagrass treated with Image for 9 to 18 DAT under August conditions. With 3 Fe applications, color was significantly better by 3 to 6% compared to 1 Fe for 16 to 21 DAT in June and 12 to 26 DAT in July. Increasing the Fe applications to four, resulted in better color than 3 Fe but the magnitude was small (i.e., < 3%).

The use of 2 Fe treatments compared to 1 Fe in conjunction with MSMA improved turf color at 21 DAT in June and between 21 and 26 DAT in July. Applying 3 or 4 Fe applications substantially decreased MSMA induced discoloration for the duration of both studies with 3 Fe providing very similar degree of greening as 4 Fe.

For MSMA plus Image, 2 Fe treatments reduced discoloration relative to 1 Fe for most periods between 12 to 21 DAT. Increasing Fe applications to 3 or 4 Fe provided better color of longer duration. The primary benefit of 4 Fe versus 3 Fe was a somewhat longer duration color response in June.

Comparing 2 Fe versus 1 Fe for the MSMA and Sencor revealed only minor differences in turf color at 12 DAT (June) and 21 DAT (July). When Fe application was increased to 3 Fe, however, a substantial greening response occurred for 12 to 26 DAT duration in June and 12 to 21 DAT duration in July.

In a study involving only one or two Fe applications, Johnson et al. (1990) demonstrated that 1 or 2 Fe treatments had only minor effect on bermudagrass color when in conjunction with MSMA plus Image or Sencor. In the current study, our results were similar for MSMA and Sencor but better Fe response was observed for 1 or 2 Fe treatments with the MSMA and Sencor than reported by Johnson et al. (3).

Turfgrass shoot density and overall visual quality ratings were taken at the same time as color. Iron treatments had no effect on shoot density loss due to postemergence herbicide application (data not presented) which was consistent with results in a previous study (3). Iron did influence visual quality but this was a reflection of improved turf color, a component of quality. Since quality ratings only reflected the color response of Fe treatments, these data were not presented.

These results indicate that response to Fe of bermudagrass treated with herbicides will vary with type of herbicide, number of Fe applications, and may be influenced by climatic conditions. While 2 Fe applications will improve turf color compared to 1 Fe, more consistent and better color enhancement resulted from 3 Fe treatments for all herbicides. The 4 Fe treatments provided some minor color responses compared to 3 Fe, especially for Image. Relative to 1 Fe treatment, 3 Fe enhances turf color in combination with all herbicides by 1 to 22% for at least 21 to 26 DAT. On high-maintenance turf sites with emphasis on optimum visual quality, the use of multiple applications of Fe would

Table 3. **Influence of frequency of iron application on color of Tifway bermudagrass within a herbicide treatment at Griffin, Ga. in June and July 1989.**

Paired comparison		Turf color							
		June 1–27, 1989				June 28–July 23, 1989			
Herbicide[z] (rate)	Fe[y] applic.	12[x] DAT	16 DAT	21 DAT	26 DAT	12 DAT	16 DAT	21 DAT	26 DAT
		9 = dark green; 1 = no green, all brown							
Untreated	1 vs.	8.2[w]	8.0	7.3	7.6	7.6	7.9	7.9	7.9
	2	8.3	8.1	7.5*	7.7	7.9*	7.9	7.8*	7.8
	3	8.4*	8.1	7.6*	7.6	8.0*	8.1*	8.0*	7.8
	4	—	8.3*	7.6*	7.8*	—	8.2*	8.1*	7.9
Image	1 vs.	6.8	6.5	7.2	7.8	6.8	6.6	6.5	7.3
(0.42 kg/ha)	2	7.1*	6.7*	7.4*	7.8	6.9	6.7	6.5	7.4
(0.38 lb/A)	3	7.2*	6.9*	7.6*	7.9	7.1*	6.9*	6.7*	7.6*
	4	—	7.1*	7.7*	7.9	—	7.2*	6.9*	7.7*
MSMA	1 vs.	7.5	7.8	7.1	7.5	6.1	6.7	7.6	7.7
(2.2 kg/ha)	2	7.6	7.8	7.3*	7.6	6.1	6.7	7.7*	7.9*
(2.0 lb/A)	3	8.0*	8.1*	7.4*	7.8*	7.7*	7.4*	7.9*	8.0*
	4	—	8.1*	7.5*	7.8*	—	7.5*	7.9*	7.9*
MSMA + Image	1 vs.	6.3	6.4	7.3	7.8	5.7	6.2	7.0	8.2
(2.2 + 0.42 kg/ha)	2	6.5*	6.6*	7.5*	7.7	5.9*	6.1	7.1*	8.2
(2.0 + 0.38 lb/A)	3	7.2*	7.0*	7.6*	7.8	6.9*	6.7*	7.1*	8.2
	4	—	7.0*	7.7*	7.9*	—	6.7*	7.2*	8.2
MSMA + Sencor	1 vs.	6.4	7.9	6.4	7.1	5.4	7.0	8.0	7.5
(2.2 + 0.14 kg/ha)	2	6.6*	8.0	6.4	7.1	5.5	7.1	8.1*	7.4
(2.0 + 0.13 lb/A)	3	7.4*	8.3*	6.7*	7.4*	6.6*	7.5*	8.2*	7.4
	4	—	8.3*	6.7*	7.4*	—	7.6*	8.3*	7.5

[z]Herbicides were applied 1 and 9 June for the first study and 28 June and 6 July for the second.

[y]Fe was applied on 1, 5, 9 and 13 June for the first study and 28 June, 3, 6, and 10 July for the second. Each application was at 1.12 kg/ha Fe (1.0 lb/A).

[x]DAT = days after treatment with initial herbicide and Fe applications.

[w]Paired comparison in a column is with each iron application treatment versus one Fe application within each herbicide. Significant differences at $P < 0.05$ are denoted with an *.

be feasible as a means of reducing the degree of herbicide injury when the injury is expressed as discoloration.

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