Response of Kentucky Bluegrass (*Poa pratensis* L.) Cultivars and Selections to Bispyribac-sodium Herbicide

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Abstract. Annual bluegrass (*Poa annua* L.) is a problematic weed in Kentucky bluegrass (*Poa pratensis* L.). Bispyribac-sodium herbicide can effectively control established annual bluegrass in other cool-season turfgrasses, but unacceptable injury to Kentucky bluegrass has been reported. However, only a few Kentucky bluegrass cultivars have been evaluated. The objective of this study was to determine the extent of intraspecific variability among Kentucky bluegrass cultivars and selections to sequential applications of bispyribac-sodium herbicide. Field experiments were conducted in 2004 and 2005 in New Jersey to determine the response of 55 Kentucky bluegrass cultivars and selections to bispyribac-sodium. The herbicide was applied at 188 g·ha⁻¹ followed 3 weeks later by a second application of 281 g·ha⁻¹. Kentucky bluegrass injury ranged from 8% to 93% 8 weeks after initial treatment (WAIT). ‘Blackstone’, ‘Serene’, and A98-962 were the most tolerant to bispyribac-sodium, exhibiting less than 20% injury 8 WAIT. Conversely, ‘Washington’, 95AN-10, and ‘Avalanche’ were the most susceptible with up to 93% injury 8 WAIT. The range in tolerance to bispyribac-sodium within Kentucky bluegrass indicates the potential for the identification and development of cultivars with improved tolerance to bispyribac-sodium herbicide.

Kentucky bluegrass (*Poa pratensis* L.) is a popular turfgrass species throughout its adaptive range. It typically produces a dense stand of turf with dark green color, high overall turf quality, and a wide range of disease tolerance. This makes it a premier species for lawns, sports fields, and golf courses (Beard, 1973). However, Kentucky bluegrass often becomes infested with annual bluegrass (*P. annua* L.), especially when maintained at low mowing heights and other stressful environments.

Annual bluegrass is a persistent weed, which reduces overall turfgrass usefulness as a result of its light green color, high reproductive capacity, and shallow root system (Lush, 1989; Sprague and Burton, 1937). Annual bluegrass tolerates close mowing and germinates rapidly allowing it to outcompete desirable turfgrass species. This is particularly pronounced in Kentucky bluegrass as a result of its slow establishment rate. It can also encroach into stressed Kentucky bluegrass turfs mown at low cutting heights. The poor disease, drought, and wear tolerance of annual bluegrass compared with Kentucky bluegrass (Beard et al., 1978; Lush, 1989) contribute to its decline in quality. Consequently, Kentucky bluegrass infested with

annual bluegrass requires more water and fungicides, especially in the summer months.

Chemical control options for annual bluegrass in Kentucky bluegrass are limited. Use of pre-emergent herbicides before the annual bluegrass germination cycle can limit infestations from encroaching into Kentucky bluegrass swards but typically have no effect on established annual bluegrass populations. Ethofumesate is a postemergence herbicide that is labeled for annual bluegrass control but often provides inconsistent control with unacceptable Kentucky bluegrass injury (Adams, 1989; Dernoeden and Turner, 1988).

Aside from ethofumesate, there are currently no selective herbicides labeled for control of established annual bluegrass in Kentucky bluegrass. Bispyribac-sodium is a pyrimidinyl carboxy herbicide that controls weeds by inhibiting acetolactate synthase (Shimizu et al., 2002). Bispyribac-sodium has been used for selective postemergence control of barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and other weeds in rice (*Oryza sativa* L.) (Schmidt et al., 1999; Webster et al., 1999; Williams, 1999) and was recently registered for turf (Anonymous, 2004). Research with bispyribac-sodium indicates applications of 60 to 148 g·ha⁻¹ can reduce populations of annual bluegrass without injuring creeping bentgrass (*Agrostis stolonifera* L.) (Askew et al., 2004; Borger and Watschke, 2005; Dernoeden et al., 2004; Lycan et al., 2003; Lycan and Hart, 2005). Additionally, research has found that two applications are needed for complete annual bluegrass control (Lycan and Hart, 2006; McCullough and Hart, 2006; Park et al.,

2002). Limited research with Kentucky bluegrass found a single application of 296 g·ha⁻¹ on ‘Baron’ Kentucky bluegrass resulted in 28% injury 5 weeks after initial treatment (WAIT) (Lycan and Hart, 2005). However, more comprehensive research emphasizing the response of Kentucky bluegrass to multiple applications of bispyribac-sodium is needed.

A significant amount of genetic diversity exists within Kentucky bluegrass. This is attributable in part to the variable ploidy levels and the unique apomictic breeding behavior of the species (Raggi et al., 2006). This reproductive breeding behavior results in many distinct phenotypes and preserves genomic complexity through the inhibition of outcrossing. Many examples of this complexity can be found in the literature, including differences in agronomic and morphological traits (Bonos et al., 2000; Shortell et al., 2006), summer stress tolerance (Bonos and Murphy, 1999), both drought and heat tolerance (Wang and Huang, 2004), and disease tolerance (Bonos et al., 2000, 2006; Czembor, 2003; Czembor et al., 2001). The objective of this study was to determine the amount of intraspecific variability of Kentucky bluegrass cultivars and experimental selections to sequential applications of bispyribac-sodium herbicide.

Materials and Methods

This experiment was conducted in 2004 and 2005 at the Rutgers Plant Biology and Pathology Research and Extension Farm in Adelphia, NJ. The soil type was a Freehold sandy-loam (fine-loamy, mixed, active, mesic Aquic Hapludult) with a pH of 6.4 and 2.0% organic matter. Separate Kentucky bluegrass cultivar trials were established in the fall of 2000 and 2001. Entries in each test were sown by hand using a maximum of 15 g of seed per 0.9 × 1.5-m plot (10 g·m⁻²). An unplanted 15-cm border was left around each plot. Kentucky bluegrass cultivars and selections were arranged in a randomized complete block design with three replications in each trial. Fifty-five cultivars or experimental selections were replicated in both trials. These entries represent a broad range of diversity within Kentucky bluegrass and contain cultivars within the major classification types (Bonos et al., 2000). The trials were maintained at 3.8 cm and mowed twice weekly with a reel mower (Toro, Bloomington, MN) with clippings returned. The turf trials received 98 kg·ha⁻¹ N per year applied in four applications of 25 kg·ha⁻¹ N. The plots were irrigated only to prevent drought stress.

Bispyribac-sodium treatments (Velocity®, 80WP herbicide; Valent U.S.A. Corp., Walnut Creek, CA) were applied in the early summer of 2004 and 2005 to mimic the conditions of highest annual bluegrass activity seen in previous studies (Lycan and Hart, 2006). Half of each plot was treated with bispyribac-sodium and the other half was left untreated as a control. The Kentucky bluegrass trial seeded in 2001 was treated with

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188 g·ha⁻¹ on 14 June 2004 followed by 281 g·ha⁻¹ on 7 July 2004 (3 WAIT). The Kentucky bluegrass trial seeded in 2000 was treated with 188 g·ha⁻¹ on 9 June 2005 followed by 281 g·ha⁻¹ on 30 June 2005 (3 WAIT). Although lower rates do provide adequate annual bluegrass control, higher rates were used in this study to help achieve maximum cultivar differentiation to bispyribac-sodium and to determine maximum cultivar susceptibilities. Treatments were applied with a single-nozzle CO₂ backpack sprayer equipped with a 9504E nozzle tip (Tee Jet® flat fan nozzles; Spraying Systems Co., Wheaton, IL), which delivered 374 L·ha⁻¹ of spray solution at 221 kPa. Turfgrass injury was visually assessed as the amount of injury observed on the treated half of each plot directly compared with its adjacent untreated control and reported on a 0% to 100% scale with 0 representing no injury and 100 representing complete necrosis. Cultivars and selections were evaluated at 2, 4, and 8 WAIT.

Data were tested for normality using the univariate procedure of the Statistical Analysis System (SAS) V.8.2 (SAS Institute, Cary, NC). These data did not show significant deviation from normality and were therefore directly subjected to the analysis of variance for a randomized complete block design. Differences in mean visual injury between cultivars were determined using Fisher's protected least significant difference test at the *P* = 0.05 level.

Results and Discussion

The analysis of variance for injury ratings taken at 2, 4, and 8 WAIT are presented in Table 1. There was no significant cultivar-by-year interaction for any of the rating dates; therefore, results from 2004 and 2005 were combined (Table 2). The fact that there was no interaction between years and relatively similar results were observed for each cultivar in each year indicates that this trait is under strong genetic control and not highly affected by the fluctuating environmental conditions. Significant differences in injury to bispyribac-sodium between cultivars and selections were observed at 4 and 8 WAIT (Table 1).

Bispyribac-sodium typically causes a transitory chlorosis that starts in tolerant grasses such as creeping bentgrass (*Agrostis*

stolonifera L.) and perennial ryegrass (*Lolium perenne* L.) 1 WAIT and lasts for ≈3 weeks (Anonymous, 2004). This transitory chlorosis is represented in the first rating taken 2 WAIT. All Kentucky bluegrass cultivars and selections evaluated in this study were initially injured by bispyribac-sodium and there were no significant differences between entries 2 WAIT (Tables 1 and 2).

After the second application of bispyribac-sodium made 3 WAIT in 2004 and 2005, visual injury increased (Table 2). This response is represented by the visual injury rating taken 4 WAIT. The injury rating at this time represented the initial transitory chlorosis from the second application of bispyribac-sodium and permanent damage caused by the first application. 'Blackstone', 'Lakeshore', 'Kingfisher', and A98-877 exhibited the least injury with 42%, 43%, 45%, and 45% visual injury, respectively, 4 WAIT, although 95AN-10, 'SR 2100', NB67-6, 'North Star', 'Champagne', and 'Avalanche' exhibited injury greater than 70% 4 WAIT (Table 2).

Overall, this injury is higher than previous reports within Kentucky bluegrass. Lycan and Hart (2005) found 28% injury on 'Baron' Kentucky bluegrass after a single application of bispyribac-sodium at 296 g·ha⁻¹ 5 WAIT. In the current study, 'Baron' was injured 63% after the sequential application of 188 g·ha⁻¹ followed by 281 g·ha⁻¹ of bispyribac-sodium. The differences between the two studies were likely the result of the increased efficacy (and subsequent injury) of bispyribac-sodium when applied sequentially (Lycan and Hart, 2006) compared with a single application.

The most striking cultivar differences in visual injury were observed 8 WAIT. This injury rating represented cumulative and permanent effects of the two bispyribac-sodium applications. Injury at this time was primarily in the form of necrosis of the leaf tissue and stand reduction. Blackstone exhibited the least injury (8%) followed by 'Serene' (15%), A98-962 (18%), A98-1025 (20%), A98-877 (25%), 'Cabernet' (25%), and 'Unique' (25%). 'Avalanche' exhibited the most injury (93%). 95AN-10 (88%), 'Washington' (78%), 'North Star' (77%), SR 2100 (73%), and NB67-6 (73%) were statistically similar to 'Avalanche' and exhibited high levels of injury to bispyribac-sodium (Table 2). These cultivars and selections did not recover from bispyribac-sodium applications.

The majority of the cultivars evaluated in this study displayed intermediate tolerance to bispyribac-sodium with injury levels ranging from 30% to 70% 8 WAIT. Kentucky bluegrass cultivars Livingston and Midnight are good examples of this level of tolerance with 'Livingston' exhibiting 52% injury 8 WAIT, and 'Midnight' showing 35% injury 8 WAIT. Other cultivars exhibiting an intermediate level of injury, included 'SR 2284' and 'Liberator' with 35 and 38% injury 8 WAIT, respectively.

In both years, Kentucky bluegrass cultivars responded to bispyribac-sodium in three relatively distinct consistent patterns. Although all of the cultivars were initially injured, some such as Blackstone and Serene recovered rapidly from initial chlorosis and suffered little to no decline in turfgrass stand. The majority of the cultivars such as Midnight and Livingston did not recover rapidly from initial chlorosis exhibited some necrosis of the leaf tissue and slight thinning of the turfgrass stand. Lastly, several cultivars such as Avalanche, Washington, North Star, and Champagne did not recover from chlorosis, exhibited significant desiccation of the leaf tissue, and suffered nearly complete turfgrass stand loss at 8 WAIT.

Bispyribac-sodium herbicide has been shown to be highly effective at removing populations of annual bluegrass from agricultural commodities, including rice (*Oryza sativa*), and some cool-season turfgrasses (Lycan and Hart, 2006; Schmidt et al., 1999; Webster et al., 1999; Williams, 1999). As hypothesized, a wide range of injury in response to bispyribac-sodium was observed in this study. Although injury levels observed in this study on most Kentucky bluegrass cultivars may be considered unacceptable to turfgrass managers, some tolerant Kentucky bluegrass cultivars and experimental selections had the ability to recover from multiple applications of bispyribac-sodium at higher than labeled use rates for annual bluegrass control and showed acceptable turf quality within 8 weeks. Thus, tolerant cultivars should be evaluated for tolerance to bispyribac-sodium applied at lower rates that are effective for annual bluegrass control. The consistent results between years and large variation between entries provide evidence that this trait is genetically controlled. This indicates that the relative response of these cultivars and selections to bispyribac-sodium should be consistent over multiple locations with different environments (Poehlman and Sleper, 1995). These results indicate the potential to identify current cultivars and develop new cultivars of Kentucky bluegrass with acceptable tolerance to bispyribac-sodium.

In conclusion, high rates of bispyribac-sodium were able to significantly differentiate Kentucky bluegrass cultivars and selections for tolerance to bispyribac-sodium. Kentucky bluegrass cultivars and selections were identified that exhibited very little injury in response to bispyribac-sodium. The apomictic breeding behavior of Kentucky bluegrass allows for the ability to fix traits

Table 1. Calculated mean squares of percent injury ratings at 2, 4, and 8 weeks after initial treatment from analysis of variance of bispyribac-sodium tolerance of 55 Kentucky bluegrass cultivars and selections.^z

Source of variance	df	Week 2	Week 4	Week 8
		Percent injury		
Year	1	1,905*	5,424***	13,822**
Cultivar	54	586	473**	1,885*
Rep (year)	4	700	1,544**	3,938*
Cultivar × year	54	232	141	615
Cultivar × rep	108	119	86	283
Error	216	101	72	280

^zBispyribac-sodium treatments were applied as 188 g·ha⁻¹ on either 14 June 2004 or 9 June 2005 followed by a sequential application of 281 g·ha⁻¹ 3 weeks after the initial treatment (7 July 2004 or 30 June 2005, respectively).

*, **, ***Significant F tests at *P* = 0.05, 0.01, and 0.001, respectively.

Table 2. Percent injury of 55 Kentucky bluegrass cultivars and selections evaluated in 2004 and 2005 at Adelphia, NJ.^{z,y}

	Cultivar or selection	Visual injury		
		2 WAIT ^x	4 WAIT (%)	8 WAIT
1	Blackstone	17	42	8
2	Serene	22	47	15
3	A98-962	32	53	18
4	A98-1025	33	48	20
5	A98-877	28	45	25
6	Cabernet	35	52	25
7	Unique	53	58	25
8	A98-363	38	55	27
9	PST-C-74	48	52	27
10	Rita	32	50	28
11	A97-1560	50	52	30
12	A98-283	40	53	30
13	Showcase	53	57	30
14	Lakeshore	25	43	32
15	Sonoma	35	53	32
16	Kingfisher	28	45	35
17	Midnight	30	53	35
18	SR 2284	38	50	35
19	A98-344	57	50	37
20	Arcadia	30	60	37
21	Arrow	45	58	37
22	A98-290	35	57	38
23	Award	30	55	38
24	Bariris	33	60	38
25	Baronette	23	53	38
26	Liberator	37	60	38
27	A96-1201	48	68	42
28	Fairfax	35	52	43
29	NuGlade	23	58	43
30	Eagleton	37	63	45
31	A98-516	33	60	47
32	America	52	60	48
33	Baronie	30	58	48
34	Freedom II	43	63	50
35	Livingston	33	58	52
36	Rambo	43	65	52
37	A98-890	32	48	53
38	Baritone	45	63	53
39	Parade	40	62	53
40	Odyssey	40	62	55
41	RSP	48	65	57
42	SRX 27753	45	67	57
43	Boutique	30	55	60
44	Canon	55	70	62
45	Cynthia	37	70	62
46	Bordeaux	47	57	63
47	F-124	45	67	63
48	Baron	47	63	67
49	Champagne	55	78	67
50	NB67-6	50	73	73
51	SR 2100	48	75	73
52	North Star	22	72	77
53	Washington	42	68	78
54	95AN-10	45	73	88
55	Avalanche	48	77	93
LSD (0.05) ^w		NS	17.5	23.6

^zEntries are ranked by order of tolerance to bispyribac-sodium^y herbicide 8 weeks after initial treatment.

^yBispyribac-sodium was applied at 188 followed by 281 g·ha⁻¹ 3 WAIT. Application dates were 14 June and 7 July 2004 and 9 June and 30 June 2005.

^xWAIT = weeks after initial treatment.

^wLSD (0.05) = Fisher's protected least significant difference at a 5% probability level.

^{ns}Nonsignificant.

within a cultivar and provides stable inheritance through successive generations. This suggests that the identification and development of Kentucky bluegrass cultivars with improved tolerance to bispyribac-sodium is possible. Within these tolerant cultivars and selections, bispyribac-sodium could be used as a new tool for annual bluegrass control

provided a period of aesthetic turfgrass injury can be tolerated.

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