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Zoysiagrass Seedhead Suppression with Imidazolinone Herbicides

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Options for suppressing zoysiagrass seedheads in managed turfgrass systems are limited. Experiments were conducted in 2010 and 2011 evaluating the use of imazamox (26, 52, and 70 g ai ha^{-1}) or imazapic (52 g ai ha^{-1}) for 'Zenith' and 'Meyer' zoysiagrass seedhead suppression. Imazamox and imazapic at $\geq$ 52 g ai ha^{-1} suppressed Zenith zoysiagrass seedheads $\geq$ 95% at 2 to 6 wk after initial treatment (WAIT) each year. Slight injury (< 10%) was observed with these treatments; however, effective seedhead suppression resulted in increased (i.e., darker) green color from 8 to 15 WAIT each year. Relative chlorophyll index values for imazamox- and imazapic-treated plots ranged from 100 to 147% of the nontreated control in 2010 and 89 to 125% of the nontreated in 2011. On Meyer zoysiagrass, imazamox and imazapic at $\geq$ 52 g ha^{-1} reduced seedhead counts greater than 90% in both Tennessee and Indiana. However, significant (> 25%) injury was reported with these treatments at one experimental location. Although imazamox and imazapic have efficacy for zoysiagrass seedhead suppression, additional studies are needed to determine factors affecting zoysiagrass injury potential from imazamox and imazapic applications.
Nomenclature: Imazamox; imazapic; zoysiagrass, *Zoysia japonica* Steud. 'Zenith' and 'Meyer'.
Key words: Golf course, Japanese lawngrass, plant growth regulator, seedhead suppression, turf.

Las opciones para suprimir las inflorescencias de *Zoysia japonica* en céspedes manejados son limitadas. En 2010 y 2011 se realizaron experimentos para evaluar el uso de imazamox (26, 52 y 70 g ai ha^{-1}) o imazapic (52 g ai ha^{-1}) para la supresión de inflorescencias de *Z. japonica* 'Zenith' y 'Meyer'. Imazamox e imazapic a 52 g ai ha^{-1} suprimió las inflorescencias de Zenith ≥95% a 2-6 semanas después del tratamiento inicial (WAIT) en cada año. Un ligero daño (<10%) fue observado con estos tratamientos. Sin embargo, la efectiva supresión de inflorescencias resultó en un incremento del color verde (i.e. más oscuro) desde 8 hasta 15 WAIT en cada año. Los valores relativos de índice de clorofila para lotes tratados con imazamox e imazapic variaron de 100 a 147% en comparación con el testigo no-tratado en 2010 y de 89 a 125% en 2011. En Meyer, imazamox e imazapic a ≥52 g ai ha^{-1} redujeron los conteos de inflorescencias en más de 90% en Tennessee e Indiana. Sin embargo, con estos tratamientos se reportó un daño significativo (>25%) en uno de los sitios experimentales. Aunque imazamox e imazapic muestran eficacia para la supresión de inflorescencias de *Z. japonica*, se necesitan estudios adicionales para determinar los factores que afectan el daño potencial de *Z. japonica* con aplicaciones de estos herbicidas.

Zoysiagrasses (*Zoysia* spp. Willd.) are commonly used on golf course fairways throughout the United States transition zone. Lyman et al. (2007) reported that 81% of all zoysiagrasses planted on United States golf courses were found in the transition zone, with 18% found in the southeast. Use of zoysiagrasses has increased in recent years as improved cultivars with high turf quality and resistance to divoting have been developed (Patton 2009; Trappe et al. 2011).

Zoysiagrass inflorescence (i.e., seedhead) production on golf courses can reduce turf aesthetic and functional quality, as plants produce short racemes with laterally compressed, dark-colored spikelets (Kane and Miller 2003; Turgeon 1999). Additionally, seedheads cause additional wear on mowing equipment, resulting in increased labor costs associated with more-frequent sharpening of reel mowers. Kaufmann (1989) reported that zoysiagrass seedhead growth is similar to the cool-season grasses, with seedheads predominantly emerging during spring, often before spring green-up is completed. Certain zoysiagrass cultivars ('Cavalier', 'Diamond', 'El Toro') can produce seedheads during fall as well (D. Stone, personal communication). Minimal data have been published on factors affecting zoysiagrass seedhead emergence. Schwartz et al. (2009) reported that seedhead density was a heritable trait, less influenced by the environment than by attributes such as fall dormancy or spring green-up. Seedhead production is more problematic on coarse-textured cultivars of zoysiagrass than on fine-textured Manilagrass [*Zoysia matrella* (L) Merr.]. For example, two zoysiagrass cultivars regularly used in the transition zone for their superior cold tolerance ('Zenith' and 'Meyer') also produce the most seedheads (NTEP 2010; Patton 2009).

Plant growth regulators, such as mefluidide, suppress seedhead production in cool-season grasses (Cooper et al. 1987), but mefluidide has shown minimal efficacy for seedhead suppression in limited research (A. J. Patton, unpublished data). Sublethal rates of herbicides have also been used to suppress seedhead production of desirable turfgrasses. Brosnan et al. (2011) reported that imazapic at 52 g ai ha^{-1} suppressed 'Riviera' bermudagrass [*Cynodon dactylon* (L.) Pers.] seedhead production 80 to 96%. Goatley et al. (1993) also reported effective bermudagrass seedhead suppression with imazapic (evaluated as AC 263,222) at 60 g ha^{-1} and imazapic plus imazaquin (60 plus 420 g ha^{-1}, respectively). Imazapic has been shown to effectively suppress bahiagrass (*Paspalum notatum* Flueggé) and tall fescue [*Lolium*

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arundinaceum (Schreb.) S.J. Darbyshire; synonym, *Festuca arundinacea* Schreb.] seedheads at rates ranging from 36 to 71 g ha^{-1} (Baker et al. 1999; Goatley et al. 1996, 1998; Hixson et al. 2007; Yelverton et al. 1997).

Temporary turfgrass discoloration and injury have been reported following imazapic applications for bahiagrass, bermudagrass, and tall fescue seedhead suppression (Baker et al. 1999; Brosnan et al. 2011; Goatley et al. 1993, 1996, 1998; Hixson et al. 2007; Yelverton et al. 1997). However, turf quality can be improved following imazapic treatment. Brosnan et al. (2011) used relative-chlorophyll index data to illustrate that bermudagrass, injured with imazapic at 52 g ha^{-1}, had increased (i.e., was darker) green color, compared with nontreated bermudagrass, by 35 DAT. Increases in bermudagrass green color with imazapic were similar to those caused by trinexapac-ethyl, a commonly used growth regulator known to increase bermudagrass color (Brosnan et al. 2010). Hixson et al. (2007) reported increased tall fescue quality 1 and 2 mo after treatment with imazapic via spray application, rotary wick, and wet-blade technology.

Imazamox is an imidazolinone herbicide, similar to imazapic, which is used for POST weed control in alfalfa (*Medicago sativa* L.), bean (*Phaseolus* spp. L.), clover (*Trifolium* spp. L.), pea (*Pisum* spp. L.), and soybean [*Glycine max* (L.) Merr.] production at rates of 9 to 70 g ai ha^{-1} (Anonymous 2009b; Senseman 2007). It is also used for aquatic weed control (Anonymous 2009a). There are limited data on the responses of zoysiagrass to imazamox. Research evaluating zoysiagrass safety, seedhead suppression, and growth regulation with imazamox is warranted because imazamox may provide turf managers with a less-injurious option than imazapic. The objective of this research was to compare several rates of imazamox to imazapic for zoysiagrass seedhead suppression.

Materials and Methods

Zenith Zoysiagrass. Field research was conducted in 2010 and 2011 on a mature stand of Zenith zoysiagrass at the East Tennessee Research and Education Center (3215 Alcoa Highway, Knoxville, TN 37996). Soil was a Sequatchie loam (fine-loamy, siliceous, semiactive, thermic humic Hapludult) with a pH of 6.2 and 2.1% organic matter. Turf was mowed twice weekly (1.6 cm ht) with a reel-mower set to return clippings and irrigated as needed to prevent wilt. No fertilizer was applied to the site because low nitrogen fertility has been reported to promote seedhead formation in warm-season grasses (Beard 1973). Plot size was 1.5 by 3 m.

Treatments were imazamox (Raptor herbicide. BASF Corporation. 26 Davis Dr., Research Triangle Park, NC, 27709) at 26, 52, and 70 g ha^{-1}, imazapic (Plateau herbicide; BASF Corporation, 26 Davis Dr., Research Triangle Park, NC 27709) at 52 g ha^{-1} and an nontreated control. Imazamox and imazapic were applied sequentially on a 3-wk interval and included a methylated seed oil surfactant (MSO; Loveland Industries, 14520 County Road 64, Greeley, CO 80631-9317) at 1% v/v. Treatments were applied with a CO_2-powered boom sprayer equipped with four XR8002VS flat-fan nozzles (TeeJet flat fan spray nozzle, P.O. Box 7900, Wheaton, IL 60189) calibrated to deliver 281 L ha^{-1} of spray volume. Fewer than 5 seedheads m^{-2} were present when treatments were initially applied on April 9, 2010, and March 29, 2011. Mowing ceased after treatment application to facilitate visual assessments of seedhead suppression similar to previous experiments (Brosnan et al. 2011; McCullough et al. 2011).

Seedhead suppression and zoysiagrass injury were visually evaluated each week on a 0 (no suppression or turf injury) to 100% (complete seedhead suppression or turf death) scale relative to the nontreated control. Assessments were made to capture treatment responses during the flush of zoysiagrass seedhead emergence in spring with minimal production thereafter (Kaufmann 1989). At 6 wk after initial treatment (WAIT), the number of seedheads present in two 0.09-m^2 sections of each plot were counted and averaged to provide an additional quantitative measure of seedhead suppression. Data for each treatment are presented as the percentage of reduction in seedhead numbers compared with the nontreated control. Zoysiagrass color was visually rated on a 1 (brown) to 9 (dark green) scale from 8 WAIT until the end of the study to assess changes in color due to imazamox or imazapic treatment. Increased (i.e., darker) color following applications of imazapic for seedhead suppression has been reported on bermudagrass (Brosnan et al. 2011). Zoysiagrass color was

Table 1. Effects of imazamox and imazapic on 'Zenith' zoysiagrass seedhead suppression in 2010 and 2011 in Knoxville, TN.[a]

		'Zenith' zoysiagrass seedhead suppression							
		2010				2011			
Treatment[b]	Rate	2 WAIT	4 WAIT	6 WAIT	Seedhead count[c]	2 WAIT	4 WAIT	6 WAIT	Seedhead count
	g ha^{-1}	%			% reduction	%			% reduction
Imazamox	26 fb 26	83	78	70	71	100	90	85	89
	52 fb 52	95	97	96	95	100	95	99	100
	70 fb 70	96	100	97	98	100	100	100	100
Imazapic	52 fb 52	96	95	98	91	100	98	99	99
$LSD_{0.05}$		NS	3	10	14	NS	5	6	4

[a] Abbreviations: WAIT, weeks after initial treatment; fb, followed by; NS, nonsignificant.

[b] All treatments were applied twice, 3 wk apart, and contained a methylated seed oil surfactant at 1% v/v.

[c] Seedhead counts were measured in two 0.09-m^2 locations in the center of each plot and are presented as the percentage of reduction compared with the nontreated control at 6 WAIT. Nontreated control plots averaged 61 and 38 seedheads per 0.09 m^2 in 2010 and 2011, respectively.

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Table 2. Effects of imazamox and imazapic on the color of 'Zenith' zoysiagrass in 2010 and 2011 in Knoxville, TN.[a]

Treatment[b]	Rate	Zenith zoysiagrass color[c]							
		2010				2011			
		8 WAIT	11 WAIT	13 WAIT	15 WAIT	8 WAIT	11 WAIT	13 WAIT	15 WAIT
	g ha^{-1}	1 to 9							
Imazamox	26 fb 26	6.5	6.6	6.8	6.7	6.3	6.5	6.5	6.5
	52 fb 52	6.5	7.0	7.0	6.9	5.6	7.0	6.6	6.3
	70 fb 70	6.6	6.8	6.9	6.9	5.5	7.0	6.8	6.6
Imazapic	52 fb 52	7.0	7.0	7.0	7.0	5.8	6.8	6.5	6.3
Nontreated control	—	6.0	6.0	6.3	6.0	5.6	6.0	6.0	6.0
$LSD_{0.05}$		0.4	0.4	0.3	0.2	0.5	0.2	0.5	NS

[a] Abbreviations: WAIT, weeks after initial treatment; fb, followed by; NS, nonsignificant.

[b] All treatments were applied twice, 3 wk apart, and contained a methylated seed oil surfactant at 1% v/v.

[c] Zoysiagrass color was evaluated on a 1 (brown) to 9 (dark green) scale with a score ≥6 considered acceptable.

also assessed by measuring the relative chlorophyll index (RCI) of each plot with a CM-1000 chlorophyll meter (CM-1000 chlorophyll meter, Spectrum Technologies, 12360 South Industrial Drive E., Plainfield, IL 60585), similar to the methods used by Brosnan et al. (2011), with means expressed as a percentage of the nontreated control. Means represent the average of five RCI measurements per plot.

Meyer Zoysiagrass. In 2011, two separate trials were conducted on mature stands of Meyer zoysiagrass in Tennessee and Indiana. The Tennessee site was located at The Honors Course (9603 Lee Highway, Ooltewah, TN 37363) on a Colbert silt loam soil (fine, smectitic, thermic Vertic Hapludalfs). The Indiana site was located at the W.H. Daniel Turfgrass Research and Diagnostic Center (1340 Cherry Lane, West Lafayette, IN 47996-2285) on a Mahalasville silty clay loam (fine-silty mixed mesic Typic Argiaquoll). Turf was mowed three times per week (to 1.3 cm) with a reel mower with clippings returned at both locations. Similar to the previously described Zenith site in Knoxville, TN, irrigation was applied to prevent wilt, and no supplemental fertilizer applications were made.

Treatments at both locations were imazamox at 26, 52, and 70 g ha^{-1}; imazapic at 52 g ha^{-1}; ethephon (Proxy growth regulator, Bayer CropScience, 2 T.W. Alexander Drive, Durham, NC 27709) at 3,400 g ai ha^{-1}; and a nontreated control. Ethephon is labeled for annual bluegrass (*Poa annua* L.) seedhead suppression at 3,400 g ha^{-1} and been shown to regulate Meyer zoysiagrass growth (Anonymous 2005; Ervin and Ok 2001). All imazamox and imazapic treatments were applied with a methylated seed oil surfactant at 1% v/v. Treatments were applied sequentially on a 3-week interval beginning on March 29, 2011, in Tennessee and April 21, 2011, in Indiana. Sequential applications were made on April 18, 2011, in Tennessee and May 10, 2011, in Indiana. Treatments were applied with a CO_2-powered boom sprayer equipped with four XR8002VS flat-fan nozzles (Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189-7900) calibrated to deliver 281 L ha^{-1} of spray volume in Tennessee and in a similar manner and volume in Indiana using XR80015VS flat-fan nozzles (Spraying Systems Co.). Fewer than 5 seedheads per 0.09 m^2 were present when treatments were initially applied at each location.

Similar to data collected on Zenith zoysiagrass, Meyer zoysiagrass injury and color were visually evaluated. The number of seedheads present in two 0.09-m^2 sections of each plot was counted at 6 WAIT and was expressed as a percentage of reduction compared with the nontreated control. Zoysiagrass RCI data were collected from 8 WAIT until the end of the study. The RCI was measured at five locations in the center of each plot in Tennessee and three locations in Indiana, with means expressed as a percentage of the nontreated control.

The experimental design for studies conducted on Zenith and Meyer zoysiagrass was a randomized complete block with

Table 3. Effects of imazamox and imazapic on 'Zenith' zoysiagrass relative chlorophyll index in 2010 and 2011 in Knoxville, TN.[a]

Treatment[b]	Rate	Zenith zoysiagrass RCI							
		2010				2011			
		8 WAIT	11 WAIT	13 WAIT	15 WAIT	8 WAIT	11 WAIT	13 WAIT	15 WAIT
	g ha^{-1}	% of nontreated control							
Imazamox	26 fb 26	117	119	112	106	89	108	115	115
	52 fb 52	111	131	117	114	95	107	118	121
	70 fb 70	100	132	126	103	97	110	125	131
Imazapic	52 fb 52	137	145	141	134	97	109	113	109
$LSD_{0.05}$		12	NS	16	12	NS	NS	NS	NS

[a] Abbreviation: RCI, relative chlorophyll index; WAIT, weeks after initial treatment; fb, followed by; NS, nonsignificant.

[b] All treatments were applied with a methylated seed oil surfactant at 1% v/v on a 3 wk interval with a total of two applications.

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Table 4. Effects of imazamox and imazapic on 'Meyer' zoysiagrass seedhead counts 6 wks after initial treatment in Knoxville, TN, and West Lafayette, IN, in 2011.[a]

		'Meyer' zoysiagrass seedhead suppression	
		Tennessee	Indiana
Treatment[b]	Rate	Seedhead count[c]	Seedhead count
	g ha^{-1}	% reduction	
Imazamox	26 fb 26	78	78
	52 fb 52	95	99
	70 fb 70	98	100
Imazapic	52 fb 52	93	91
Ethephon	3,400 fb 3,400	89	60
$LSD_{0.05}$		8	28

[a] Abbreviation: fb, followed by.

[b] All treatments were applied twice, 3 wk apart; imazamox and imazapic treatments contained a methylated seed oil surfactant at 1% v/v.

[c] Seedhead counts were measured in two 0.09-m^2 locations in the center of each plot and are presented as the percentage of reduction compared with the nontreated control. nontreated control plots averaged 50 seedheads per 0.09 m^2 in Tennessee and Indiana.

three replications. However, data collected from Zenith and Meyer zoysiagrass were analyzed separately. All data were subjected to ANOVA in SAS software (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414), with main effects and all possible interactions tested using the appropriate expected mean-square values described by McIntosh (1983). Fisher's Protected LSD test values were calculated when the *F* ratio was significant at the 0.05 level.

Results and Discussion

Zenith Zoysiagrass. Significant year-by-treatment interactions were detected in Zenith zoysiagrass data. Therefore, data for each year were analyzed and are presented separately.

Imazamox effectively suppressed Zenith zoysiagrass seedheads in this study. Imazamox at $\geq$ 52 g ha^{-1} resulted in $\geq$ 95% seedhead suppression at 2 to 6 WAIT each year (Table 1). Seedhead suppression with imazamox at 26 g ha^{-1} ranged from 70 to 83% from 2 to 6 WAIT in 2010 and from 85 to 100% in 2011. Imazapic produced results similar to imazamox with seedhead suppression exceeding 94% from 2 to 6 WAIT each year. Similar levels of seedhead suppression with imazapic applications at 52 g ha^{-1} were found with other turfgrass species (Brosnan et al. 2011; Hixson et al. 2007; Yelverton et al. 1997). Seedhead count data supported visual assessments of seedhead suppression. Nontreated control plots averaged 61 and 38 seedheads per 0.09 m^2 in 2010 and 2011, respectively. Imazamox (52 and 70 g ha^{-1}) and imazapic reduced seedhead counts more than 90% each year, with treated plots having fewer than 6 seedheads per 0.09 m^2.

Slight injury was observed each year with imazamox and imazapic applications for seedhead suppression (data not presented). In 2010, injury (7%) was only observed on a single evaluation date (4 WAIT) with the highest rate of imazamox (70 g ha^{-1}). In 2011, significant injury was detected on one date (6 WAIT); however, injury measured $<$ 10% for all treatments. These results differ from those found by Brosnan et al. (2011), who observed greater bermudagrass injury (12 to 17%) with imazapic applications at 52 g ha^{-1} for seedhead suppression. Hixson et al. (2007) reported $\leq$ 20% injury following imazapic applications to tall fescue, as well.

Imazamox and imazapic affected Zenith zoysiagrass color from 8 to 13 WAIT each year (Table 2). In 2010, all imazamox and imazapic treatments resulted in higher color scores (i.e., leaf tissues were darker green) than the nontreated control on each evaluation date. In 2011, this response was less pronounced. Zenith zoysiagrass treated with imazamox at 26 g ha^{-1} had darker color than other herbicide treatments 8 WAIT but was not significantly different from the nontreated control by 13 WAIT. At 52 and 70 g ha^{-1}, imazamox-treated zoysiagrass did not have increased (i.e., darker) green color until 11 WAIT, and the effect dissipated by 15 WAIT. A similar response was observed with imazapic as well. The RCI data supported visual assessments of turfgrass color. Zoysiagrass treated with imazamox and imazapic yielded RCI values ranging from 100 to 145% of the nontreated control in 2010 and 89 to 125% of the nontreated control in 2011 (Table 3). However, no significant differences in RCI were detected between treatments in 2011.

Meyer Zoysiagrass. Significant treatment-by-location interactions were detected in seedhead count and injury data; therefore, data from each location were analyzed and are presented separately.

Table 5. 'Meyer' zoysiagrass injury from imazamox and imazapic in Knoxville, TN, and West Lafayette, IN, in 2011.[a]

		'Meyer' zoysiagrass injury									
		TN					IN				
Treatment[b]	Rate	2 WAIT	3 WAIT	4 WAIT	5 WAIT	6 WAIT	2 WAIT	3 WAIT	4 WAIT	5 WAIT	6 WAIT
	g ha^{-1}	%									
Imazamox	26 fb 26	0	0	2	5	0	0	4	25	38	38
	52 fb 52	2	2	6	18	8	0	8	25	42	46
	70 fb 70	3	3	10	17	13	0	21	42	50	50
Imazapic	52 fb 52	0	0	5	10	0	0	21	46	46	50
Ethephon	3,400 fb 3,400	0	0	2	2	0	0	0	0	0	0
$LSD_{0.05}$		NS	NS	4	5	5	NS	NS	16	10	6

[a] Abbreviations: WAIT, weeks after initial treatment; fb, followed by; NS, nonsignificant.

[b] All treatments were applied twice, 3 wk apart; imazamox and imazapic treatments contained a methylated seed oil surfactant at 1% v/v.

Table 6. Effects of imazamox and imazapic on the color of 'Meyer' zoysiagrass in Knoxville, TN, and West Lafayette, IN, in 2011.[a]

		'Meyer' zoysiagrass color[c]							
		TN				IN			
Treatment[b]	Rate	7 WAIT	8 WAIT	9 WAIT	12 WAIT	6 WAIT	8 WAIT	9 WAIT	10 WAIT
	g ha^{-1}	1 to 9							
Imazamox	26 fb 26	6.8	6.8	7.3	7.3	4.3	8.3	7.7	7.3
	52 fb 52	6.2	6.2	6.5	7.5	4.3	8.7	8.3	7.0
	70 fb 70	6.0	5.5	6.7	6.8	3.7	8.0	8.7	7.3
Imazapic	52 fb 52	6.5	6.3	7.3	7.0	3.7	9.0	8.3	7.3
Ethephon	3,400 fb 3,400	6.8	6.7	7.0	6.7	6.7	7.3	7.0	6.7
Nontreated control	—	6.8	6.7	7.2	7.0	6.7	7.3	7.3	7.0
$LSD_{0.05}$		0.3	0.5	NS	0.5	1.0	0.8	1.0	NS

[a] Abbreviations: WAIT, weeks after initial treatment; fb, followed by; NS, nonsignificant.

[b] All treatments were applied twice, 3 wk apart; imazamox and imazapic treatments contained a methylated seed oil surfactant at 1% v/v.

[c] Zoysiagrass color was evaluated on a 1 (brown) to 9 (dark green) scale with a score ≥6 considered acceptable.

In Tennessee, imazamox effectively reduced 'Meyer' zoysiagrass seedhead production (Table 4). Sequential applications of imazamox at ≥ 52 g ha^{-1} reduced seedhead counts > 90%. Zoysiagrass responses to imazapic (52 g ha^{-1}) were similar to imazamox. Seedhead count reductions for imazamox at ≥ 52 g ha^{-1} and imazapic at 52 g ha^{-1} were not different than with ethephon (89% reduction) in Tennessee. Although a direct statistical comparison could not be made, seedhead counts were reduced by a similar percentage on Meyer and Zenith zoysiagrass following imazamox and imazapic treatment in Tennessee (Tables 1 and 4). In Indiana, imazamox at ≥ 52 g ha^{-1} and imazapic at 52 g ha^{-1} reduced seedhead counts greater than 90%; however, no statistically significant differences were detected between the three rates of imazamox evaluated. Reductions in seedhead counts with rates of imazamox at ≥ 52 g ha^{-1} and imazapic at 52 g ha^{-1} were significantly greater than with ethephon (60% reduction) in Indiana.

Imazamox at ≥ 52 g ha^{-1} and imazapic injured Meyer zoysiagrass 4 and 5 WAIT in Tennessee. Injury ranged from 5 to 18% (Table 5). No injury was observed with imazapic 6 WAIT, but imazamox treatments at ≥ 52 g ha^{-1} injured zoysiagrass 8 to 13% on the same date. Although a statistical comparison was not made, injury to Meyer zoysiagrass with imazamox at ≥ 52 g ha^{-1} and imazapic was greater than that observed on Zenith zoysiagrass (Table 5). High levels (25 to 50%) of injury to Meyer zoysiagrass were observed with all rates of imazamox and imazapic in 4 to 6 WAIT in Indiana. The reason for the injury observed in Indiana is not clear. Imazapic is known to cause more injury to bermudagrass when applied in spring compared with other application timings (Montgomery et al. 1999). It may be that the cooler temperatures in Indiana in spring led to slower zoysiagrass green-up and made Meyer zoysiagrass more susceptible to imazamox and imazapic injury than was seen in Tennessee. The average daily high air temperature during the 3 WAIT measured 22 C in Tennessee compared with 18 C in Indiana.

Neither imazamox nor imazapic increased Meyer zoysiagrass color compared with the nontreated control in Tennessee (Table 6). In Indiana, Meyer zoysiagrass color was improved 8 and 9 WAIT with imazamox and imazapic. However, improved turf color was short lived and followed a period of injury (Tables 5 and 6). A similar response was observed with imazamox and imazapic applications to Zenith zoysiagrass in Tennessee. Despite short-term visual improvements in Meyer zoysiagrass color in Indiana, no significant differences in zoysiagrass RCI were detected in Tennessee or Indiana (data not presented). Lack of significant differences in RCI on Meyer zoysiagrass could be that both the Tennessee and Indiana sites were mowed regularly during this experiment. Plant growth regulators have been shown to reduce mowing frequency leading to increased chlorophyll accumulation compared with nontreated plants (Heckman et al. 2001). Regular mowing in Tennessee and Indiana may have prevented this accumulation resulting in no differences between treated and nontreated zoysiagrass in RCI.

Results illustrate that imazamox and imazapic can be used to effectively suppress zoysiagrass seedheads. Effective seedhead suppression resulted in increased green color (i.e., darker) on Zenith zoysiagrass for several weeks after treatment; however, this response was less pronounced in the second year of these studies. Inconsistent effects on green color were observed with Meyer zoysiagrass in Tennessee and Indiana. Further research is needed to evaluate effects of turfgrass cultural practices, such as fertilization and mowing frequency on green color after imazamox and imazapic treatment. Injury to Meyer zoysiagrass with imazamox and imazapic was greater than that observed on Zenith zoysiagrass. Reasons for this difference are not clear. Genetic differences between these cultivars may explain the differences in injury observed because variable tolerance to herbicide applications has been reported among zoysiagrass cultivars (Flessner et al. 2011; Johnson and Carrow 1999). Environmental conditions at application or plant physiological status (e.g., transitioning out of dormancy in spring) may also affect injury potential. Additional studies are needed to determine factors affecting zoysiagrass injury potential with imazamox and imazapic.

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