TOLERANCE OF PERENNIAL RYEGRASS AND *POA ANNUA* CONTROL WITH HERBICIDES IN OVERSEEDED BERMUDAGRASS

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ABSTRACT

Annual bluegrass control and perennial ryegrass tolerance were evaluated in a series of experiments in overseeded bermudagrass. Herbicides applied prior to overseeding were oxadiazon at 1.1, 2.2, 3.3, or 4.4 kg ai ha^{-1}, prodiamine at 0.43, 0.56, 0.84, or 1.1 kg ai ha^{-1}, dithiopyr at 0.28 or 0.56 kg ai ha^{-1}, pendimethalin at 2.2 kg ai ha^{-1}, benefin at 3.1 kg ai ha^{-1}, or pronamide at 1.7 kg ai ha^{-1}. Ethofumesate was applied at 0.84 or 1.1 followed by 1.1 kg ai ha^{-1} after overseeding. Perennial ryegrass establishment was not affected by oxadiazon at 2.2 kg ai ha^{-1} applied 8 weeks before overseeding (WBO) but 4.4 kg ai ha^{-1} reduced establishment. Applications made closer than 8 WBO also reduced perennial ryegrass establishment. Prodiamine at 0.43 or 0.56 kg ai ha^{-1}, benefin at 3.1 kg ai ha^{-1}, pronamide at 1.7 kg ai ha^{-1}, or dithiopyr at 0.28 or 0.56 kg ai ha^{-1}, all applied 8 WBO, did not reduce perennial ryegrass establishment. Dithiopyr also did not reduce perennial ryegrass establishment when applied 4 WBO. Annual bluegrass control was good with oxadiazon at 2.2 kg ai ha^{-1}, prodiamine at rates at or above 0.56 kg ai ha^{-1}, pendimethalin at 2.2 kg ai ha^{-1}, and benefin at 3.1 kg ai ha^{-1}. Ethofumesate applied at 1.1 kg ai ha^{-1} 6 weeks after overseeding (WAO) followed by the same rate at 9 WAO provided excellent annual bluegrass control with no negative effects on perennial ryegrass establishment.

Keywords

Weed control; weed management; turfgrass tolerance

INTRODUCTION

Because bermudagrass (*Cynodon* sp.) foliage discolors when ambient air temperatures drop below 10° C for extended periods, this species is often overseeded with cool-season species such as perennial ryegrass (*Lolium perenne* L.) to provide fall and winter color [McCarty et al., 2000]. Other potential benefits of overseeding include a uniform playing surface, less thinning of dormant turf from equipment and foot traffic, and less weed invasion during winter dormancy [Mazur and Wagner, 1987]. Others suggest that overseeding may slowly increase weed pressure, especially annual bluegrass (*Poa annua* L.), when overseeding is conducted for several years continuously [McCarty et al., 2000]. This may be due to a decline in overall health of bermudagrass when continually overseeded. In addition, because annual bluegrass and perennial ryegrass are both cool-season species, management of this weed is more difficult in overseeded than in nonoverseeded warm-season turf [Yelverton, 1999].

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Many herbicide options exists for annual bluegrass control in nonoverseeded bermudagrass turf. Atrazine, simazine, metribuzin, and most of the preemergence turfgrass herbicides registered for control of crabgrass (*Digitaria* sp.) and goosegrass (*Eleusine indica* L.) will provide good annual bluegrass control if applied prior to, or shortly after germination [Yelverton, 2000]. Few herbicides are available for annual bluegrass control when perennial ryegrass is overseeded into bermudagrass [Yelverton, 2000]. Ethofumesate is registered for preemergence or early postemergence control of annual bluegrass in perennial ryegrass overseeded into bermudagrass [Anon., 2000c]. However, this product can only be used in areas where bermudagrass goes completely dormant. Ethofumesate use in semi-dormant bermudagrass can result in unacceptable bermudagrass injury [Anon., 2000c]. Benefin, a dinitroaniline herbicide, may be used for annual bluegrass control six weeks prior to overseeding perennial ryegrass into bermudagrass [Anon. 2000a]. However, because benefin has a short half-life compared to other dinitroanilines [Ahrens, 1994], a repeat application may be necessary after perennial ryegrass has emerged. Fenarimol is a turfgrass fungicide but is also registered as a preemergence herbicide for annual bluegrass control when perennial ryegrass, *Poa trivialis*, or creeping bentgrass (*Agrostis palustris* Huds) are overseeded into bermudagrass

[Anon., 2000d]. However, cost of this product (approximately $2,500 ha^{-1}) restricts its use for annual bluegrass control primarily to overseeded bermudagrass putting greens [McCarty et al., 2000].

Most research on annual bluegrass control in overseeded bermudagrass has focused on putting greens. Bunnell et al. [1999] reported good annual bluegrass control (>90%) and no perennial ryegrass injury with fenarimol, oxadiazon, or dithiopyr each applied prior to overseeding. Trenholm and McCarty [1996] reported >80% annual bluegrass control with fenarimol applied prior to overseeding either perennial ryegrass, *Poa trivialis* L., or creeping bentgrass; however, perennial ryegrass was the quickest to establish full cover.

Perennial ryegrass tolerance to herbicides applied prior to seeding has been investigated. Dernoeden et al. [1988] reported reduced perennial ryegrass growth when pendimethalin and prodiamine were applied 40 days prior to seeding; however, establishment was not reduced when pendimethalin or bensulide were applied 80 or 120 days prior to overseeding. In a similar study, Nash and Dernoeden [1982] reported acceptable perennial ryegrass tolerance to 2.2 kg ha^{-1} of oxadiazon applied 10 weeks prior to overseeding but 4.4 kg ha^{-1} of oxadiazon reduced turf establishment.

While acceptable perennial ryegrass tolerance to 2.2 kg ha^{-1} of oxadiazon or 3.1 kg ha^{-1} of benefin applied prior to overseeding has been reported at fairway heights of cut [Isgrigg et al., 1999], research is lacking on annual bluegrass management under these conditions. The objectives of this research were twofold: 1) to investigate perennial ryegrass tolerance to herbicides applied at various intervals prior to overseeding into bermudagrass and 2) to investigate the same treatments for annual bluegrass control.

MATERIALS AND METHODS

Three field experiments were conducted to evaluate perennial ryegrass tolerance to herbicides applied prior to overseeding into bermudagrass. Two of these trials were conducted on golf courses: Pinehurst Resort and Country Club in Pinehurst, NC in 1997-98 and Charwood Country Club near Clemson, SC in 1999-00. Both of these studies also evaluated annual bluegrass control. The third experiment, conducted at the Sandhills Research Station near Jackson Springs, NC in 1999-00, only evaluated perennial ryegrass tolerance to herbicides. Sand: silt: clay at each location were: 1) Sandhills Research Station; 94% sand, 4% silt, 2% clay, 2) Pinehurst Resort and Country Club; 94% sand, 3% silt, 3% clay, 3) Charwood Country Club; 98% sand, 1% silt, 1% clay.

Sandhills Research Station

Herbicide treatments included a 2% granular formulation of oxadiazon applied at 2.2 kg ha^{-1} 4, 6, or 8 weeks before overseeding (WBO), 4.4 kg ha^{-1} of oxadiazon applied 8 WBO, a 2% granular formulation of pendimethalin applied at 2.2 kg ha^{-1} 6 WBO, sprayable dithiopyr applied at 0.28 or 0.56 kg ha^{-1} 4 WBO or 8 WBO, and sprayable prodiamine applied at 0.43, 0.56, or 0.84 kg ha^{-1} at 6 or 8 WBO. Application dates were 8-18-99 for 8 WBO, 8-31-99 for 6 WBO, and 9-13-99 for 4 WBO. Plots were 1.5 m by 3.1 m and were arranged in a randomized complete block design. Granular products were weighed for each plot and applied with a shaker jar. All sprayable formulations were applied with a four-nozzle boom sprayer calibrated to deliver 304 L ha^{-1} with a spray pressure of 179 kPa. Herbicides were watered in with 6 mm of water within four hours of application.

Plots were overseeded on 10-12-99 with a mixture of 'Charger II', 'Citation II', and 'Brightstar II' perennial ryegrass. Seeding was conducted using a drop spreader that delivered a total of 487 kg ha^{-1}. Prior to overseeding, 'Tifway' bermudagrass was vertically mowed in two directions and cleared of resulting debris. Plots were maintained at a mowing height of 13 mm to simulate a golf course fairway. Percent perennial ryegrass cover was visually estimated on 12-17-99, 2-3-00, 3-23-00, and 4-27-00 on a 0 to 100 scale where 0 = no perennial ryegrass cover and 100 = complete perennial ryegrass cover.

Pinehurst Resort and Country Club

Herbicide treatments included a 2% granular formulation of oxadiazon applied at 1.1, 2.2, or 3.3 kg ha^{-1}, 0.67% oxadiazon formulated on a 5-10-15 fertilizer carrier and applied at 330 kg product ha^{-1} to deliver 2.2 kg ha^{-1} of oxadiazon, 2.5% granular benefin applied at 3.1 kg ha^{-1} and sprayable formulations of pendimethalin at 2.2 kg ha^{-1}, or pronamide at 1.7 kg ha^{-1}. Preemergence herbicide applications were applied 8 WBO. Sprayable ethofumesate was applied at 1.1 kg ha^{-1} six and nine weeks after overseeding (WAO). Application dates were 8-18-97 for 8 WBO and 11-26-97 and 12-18-97 for 6 and 9 WAO, respectively. Plot size was 3.1 m by 3.1 m. Statistical design and application parameters were identical to the trial at the Sandhills Research Station. Preemergence herbicides were watered in with approximately 6 mm of irrigation within one hour of application.

Plots were overseeded in two directions with a drop spreader on 10-13-97 with 'Palmer' perennial ryegrass totaling 448 kg ha^{-1}. 'Tifway' bermudagrass was vertically mowed in one direction two days prior to overseeding and cleared of resulting debris. Plots were maintained at a mowing height of 13 mm by the golf course staff. Perennial ryegrass cover was visually estimated on 11-26-97 and 3-27-98 using the same scale as at the Sandhills Research Station. Percent annual bluegrass control was also visually estimated on 3-27-98 and 5-5-98 on a 0 to 100% scale where 0 = no annual bluegrass control and 100 = total annual bluegrass control.

Charwood Country Club

Herbicide treatments included 2% granular of oxadiazon at 1.1 or 2.2 kg ha^{-1} applied 8 WBO or sprayable prodiamine applied at 0.56, 0.84, or 1.1 kg ha^{-1} 8 WBO or 6 WBO. Sprayable ethofumesate was applied at 0.84 kg ha^{-1} 4 WAO. Application dates were 8-12-99, 8-25-99 for 8 and 6 WBO, respectively, and 11-5-99 for 4 WAO. Plot size was 3.1 m by 6.2 m. Statistical design was a randomized complete block with three replications. Granular formulations were applied as per the previous trials. Sprayable formulations were applied with a six- nozzle boom calibrated to deliver 187 L ha^{-1} at 175 kPa. Preemergence herbicides were watered in with 6 mm of irrigation within two hours of application.

Plots were overseeded on 10-8-99 with 'Palmer' perennial ryegrass in two directions with a drop spreader to total 258 kg ha^{-1}. Prior to overseeding, 'Tifway' bermudagrass was vertically mowed in one direction and cleared of resulting debris. Perennial ryegrass cover was evaluated on 12-9-99 and 2-10-00 as previously described. Annual bluegrass control was evaluated on 2-10-00 and 4-14-00 as previously described.

Data from each trial were evaluated separately using analysis of variance for a randomized complete block design [SAS Institute, 1989]. When analysis of variance indicated a significant treatment effect ($p < 0.05$), treatment means were separated by the Least Significant Difference (LSD) procedure.

RESULTS

Perennial Ryegrass Tolerance to Herbicides

Perennial ryegrass cover was reduced only on 27 April with 2.2 kg ai ha^{-1} of oxadiazon applied 4 or 6 WBO; cover was reduced at all four evaluation dates with 4.4 kg ai ha^{-1} of oxadiazon applied 8 WBO at the Sandhills Research Station (Table 1). Turf cover was not compromised with 2.2 kg ai ha^{-1} of oxadiazon applied 8 WBO. Similarly, 2.2 kg ai ha^{-1} of oxadiazon applied 8 WBO did not reduce perennial ryegrass cover at either of the other locations (Tables 2 & 3) while 3.3 kg ai ha^{-1} of oxadiazon did reduce turf cover at Pinehurst Resort and Country Club in 1997-98 (Table 2). Data suggest perennial ryegrass has acceptable tolerance to $\leq$2.2 kg ai ha^{-1} of oxadiazon applied 8 WBO but closer intervals from application to seeding may reduce perennial ryegrass cover. Reduced perennial ryegrass cover with 3.3 or 4.4 kg ai ha^{-1} of oxadiazon (Tables 1 & 2) also suggests there is little room for application error of 2.2 kg ai ha^{-1} rate, such as might occur with an overlap of a granular application.

Pendimethalin or dithiopyr did not reduce perennial ryegrass establishment, regardless of application timing (Tables 1 & 2). These data indicate perennial ryegrass has good tolerance to both pendimethalin and dithiopyr applied in advance of overseeding. In addition, perennial ryegrass was not reduced by either 3.1 kg ai ha^{-1} of benefin or 1.7 kg ai ha^{-1} of pronamide when applied 8 WBO (Table 2). Because this rate of benefin is

Table 1. Perennial ryegrass tolerance to various herbicides applied prior to overseeding into bermudagrass. Sandhills Research Station, Jackson Springs, NC, 1999-2000.

Herbicide ‡	Rate	Application Timing §	% Perennial Ryegrass Cover †			
	kg ai ha^{-1}		12-07	02-23	03-23	04-27
Oxadiazon 2G	2.2	4 WBO	31	51	61	69
Oxadiazon 2G	2.2	6 WBO	33	56	66	71
Oxadiazon 2G	2.2	8 WBO	34	60	63	76
Oxadiazon 2G	4.4	8 WBO	23	46	58	66
Pendimethalin 2G	2.2	6 WBO	38	64	68	78
Dithiopyr	0.28	4 WBO	38	63	68	76
Dithiopyr	0.28	8 WBO	43	71	70	80
Dithiopyr	0.56	4 WBO	39	65	69	79
Dithiopyr	0.56	8 WBO	35	66	65	79
Prodiamine	0.43	6 WBO	29	55	64	75
Prodiamine	0.56	6 WBO	26	58	65	71
Prodiamine	0.84	6 WBO	20	38	54	60
Prodiamine	0.43	8 WBO	34	63	68	76
Prodiamine	0.56	8 WBO	35	64	68	76
Prodiamine	0.84	8 WBO	24	48	59	68
Non treated	--		36	56	66	80
LSD 0.05 ¶			8	10	7	7

† % Perennial ryegrass cover was visually estimated on a 0 to 100 scale. 0 = no perennial ryegrass cover; 100 = complete perennial ryegrass cover.

‡ Oxadiazon and pendimethalin were applied as a 2% granular product. Dithiopyr and prodiamine were applied as sprayable formulations.

§ Abbreviations: WBO = weeks before overseeding.

¶ $LSD_{0.05}$ values indicate significant means separation at α=0.05

Table 2. Perennial ryegrass tolerance and annual bluegrass control with herbicides in overseeded 'Tifway' bermudagrass. Pinehurst, NC, 1997-98.

			% Perennial Ryegrass Cover §		% Annual Bluegrass Control ¶	
Herbicide †	Rate	Application Timing ‡	11-26	03-27	03-27	05-05
	(kg ai ha^{-1})					
Oxadiazon 2G	1.1	8 WBO	43	85	85	73
Oxadiazon 2G	2.2	8 WBO	35	79	94	84
Oxadiazon 2G	3.3	8 WBO	28	64	96	90
Oxadiazon 0.67G	2.2	8 WBO	41	90	78	59
Benefin 2.5G	3.1	8 WBO	45	89	89	84
Pendimethalin	2.2	8 WBO	48	88	94	78
Pronamide	1.7	8 WBO	45	86	55	48
Ethofumesate fb	1.1 fb	6 WAO	49	87	95	97
Ethofumesate	1.1	9 WAO				
Non treated	--	--	43	86	0	0
LSD $_{0.05}$ #			8	9	17	15

† Oxadiazon and benefin were applied as granular formulations, pendimethalin, pronamide, and ethofumesate were applied as sprayable formulations. Oxadiazon 0.67G was applied on a 5-10-15 fertilizer carrier.
‡ Abbreviations; WBO = weeks before overseeding; WAO = weeks after overseeding; fb = followed by.
§ Perennial ryegrass cover was visually estimated on a 0 to 100 scale. 0 = no perennial ryegrass cover; 100 = complete perennial ryegrass cover.
¶ % annual bluegrass control was visually estimated on a 0-100 scale. 0 = no control; 100 = complete control.
 # LSD$_{0.05}$ values indicate significant means separation at α=0.05

registered for use 6 WBO [Anon., 2000a], results were not surprising. However, the pronamide label suggests overseeding should not occur within 90 days of application [Anon., 2000b]. These data indicate the pronamide precaution may be too conservative. Only 0.84 kg ai ha^{-1} of ethofumesate at 4 WAO resulted in stand reduction at Charwood Country Club, and only at the early evaluation date (Table 3). Injury was not observed at other rates and evaluation dates or at other locations.

Six WBO, only the lowest rate (0.43 kg ai ha^{-1}) of prodiamine was not injurious to perennial ryegrass (Table 1). Prodiamine at 0.56 (two of four evaluation dates) or 0.84 kg ai ha^{-1} (all evaluation dates) at the Sandhills Research Station (Table 1) or at 0.56 (last evaluation date), 0.84 (both evaluation dates), or 1.1 kg ai ha^{-1} (both evaluation dates) at Charwood Country Club reduced perennial ryegrass cover when applied 6 WBO (Table 3). However, perennial ryegrass establishment increased in plots where prodiamine was applied 8 WBO. At the Sandhills Research Station, perennial ryegrass cover was not reduced with either 0.43 or 0.56 kg ai ha^{-1} of prodiamine but was reduced with 0.84 kg ai ha^{-1} of prodiamine (Table 1). However, at Charwood Country Club, both 0.56 or 0.84 kg ai ha^{-1} of prodiamine did not reduce perennial ryegrass cover while 1.1 kg ai ha^{-1} did reduce establishment (Table 3). These data indicate perennial ryegrass is tolerant to prodiamine applied at 0.43 kg ai ha^{-1} 6 WBO or 0.56 kg ai ha^{-1} 8 WBO. As with oxadiazon, there appears to be little room for application error with prodiamine. However, because prodiamine can be applied as a spray, preventing application overlaps may be easier than with oxadiazon which must be applied to actively growing bermudagrass as a granular formulation.

Annual Bluegrass Control

Annual bluegrass control decreased from the early rating date to the late rating date at both locations where annual bluegrass control was evaluated (Tables 2 & 3). This was expected because herbicidal effects tend to dissipate over time and annual bluegrass vigor increases through the spring. Annual bluegrass control tended to be better at the Pinehurst location (Table 2) than at the Charwood location (Table 3). This is most likely due to random variation between locations, because annual bluegrass populations were dense at both locations (> 95 annual bluegrass plants m^{-2}).

At the Pinehurst location, 2.2 or 3.3 kg ai ha^{-1} of oxadiazon applied as a 2% granular provided > 80% control of annual bluegrass. Oxadiazon at 1.1 kg ai ha^{-1} provided 85% and 73% control at the early and late rating dates, respectively. Interestingly, 2.2 kg ai ha^{-1} of oxadiazon applied as a 0.67% granular on a 5-10-15 fertilizer carrier provided less control than the same rate applied as a 2% granular. This was most likely due to the 2G having a smaller particle size than the 0.67G, resulting in a higher granule density for the 2G. The better particle distribution provided by the 2G most likely was the reason for enhanced control. At Charwood Country Club, oxadiazon at 1.1 and 2.2 kg ai ha^{-1} provided 35% and 62% annual bluegrass control, respectively, at the last rating date (Table 3). Although control was lower compared to the Pinehurst site, 2.2 kg ai ha^{-1} of oxadiazon was as good as any other treatment at the Charwood location.

Benefin and pendimethalin provided 84% and 78% control, respectively, at the Pinehurst site (Table 2).

Table 3. Perennial ryegrass tolerance and annual bluegrass control with herbicide in overseeded 'Tifway' bermudagrass. Charwood Country Club, Clemson, SC. 1999-2000.

			% Perennial Ryegrass Cover §		% Annual Bluegrass Control¶	
Herbicide †	Rate	Application Timing ‡	12-09	02-10	02-10	04-14
	kg ai ha^{-1}					
Oxadiazon 2G	1.1	8 WBO	80	73	62	35
Oxadiazon 2G	2.2	8 WBO	75	62	87	62
Prodiamine	0.56	8 WBO	70	68	78	53
Prodiamine	0.84	8 WBO	70	62	90	62
Prodiamine	1.1	8 WBO	63	52	83	72
Prodiamine	0.56	6 WBO	67	45	82	70
Prodiamine	0.84	6 WBO	60	53	90	70
Prodiamine	1.1	6 WBO	47	35	87	63
Ethofumesate	0.84	4 WAO	58	75	77	35
Non treated	---	---	80	75	0	0
LSD 0.05 #			14	14	21	27

† Oxadiazon was applied as a granular formulation. Prodiamine and ethofumesate were applied as sprayable formulations.
‡ Abbreviations: WBO = weeks before overseeding; WAO = weeks after overseeding.
§ % Perennial ryegrass cover was visually estimated on a 0-100 cover scale. 0 = no perennial ryegrass cover; 100 = complete control.
¶ Annual bluegrass control was visually estimated on a 0-100 scale. 0 = no control; 100=complete control.
 # LSD 0.05 values indicate significant means separation at α =0.05

While pronamide was significantly less effective at either rating date, two applications of ethofumesate at 1.1 kg ai ha^{-1} applied 6 and 9 WAO provided excellent annual bluegrass control (Table 2). Some turfgrass managers have reported problems with bermudagrass spring transition with ethofumesate. In this trial, bermudagrass spring transition was not affected by ethofumesate (data not shown).

Prodiamine at all rates provided annual bluegrass control comparable to 2.2 kg ai ha^{-1} of oxadiazon at the Charwood Country Club site (Table 3). As with all other treatments, control with prodiamine decreased from the February to April evaluation dates. Annual bluegrass control was not different when prodiamine was applied 8 WBO vs 6 WBO. In addition, rate of prodiamine did not have an effect on annual bluegrass control (Table 3). If these data are repeatable, it would suggest the application rate and timing for prodiamine would be approximately 0.56 kg ai ha^{-1} applied 8 WBO.

DISCUSSION

Viable herbicide options for management of annual bluegrass in perennial ryegrass overseeded into bermudagrass have been identified. Oxadiazon applied at 2.2 kg ai ha^{-1} 8 WBO resulted in both acceptable perennial ryegrass establishment and good annual bluegrass control. However, oxadiazon formulation appears to be an important criteria for good annual bluegrass control. In most areas in the United States, perennial ryegrass is overseeded into bermudagrass from early to mid-October. An oxadiazon application 8 WBO would therefore take place in early to mid-August. At this time of year, bermudagrass is actively growing thereby justifying application of oxadiazon on a fertilizer carrier. However, this could lead to two problems: 1) overlaps in application of the granular product that would likely cause problems with perennial ryegrass establishment and, 2) impregnation of oxadiazon on a poor quality fertilizer carrier (irregular particle size, inadequate loading of herbicide on fertilizer, etc). The latter could cause poor distribution of oxadiazon that could lead to poor control. Results from this research supported both of these concerns.

Perennial ryegrass appears to be tolerant to dithiopyr applied as close to seeding as 4 WBO (Table 1). This can be partially explained by differences in soil half-lives among the products tested. The soil half-life of dithiopyr is significantly shorter than oxadiazon, pendimethalin, and prodiamine [Ahrens, 1994]. Annual bluegrass control was not evaluated with dithiopyr in these experiments and should be the focus of future research. Prodiamine applied at 0.56 kg ai ha^{-1} 8 WBO did not adversely affect perennial ryegrass establishment at both sites in this research (Tables 1 & 3). Along with dithiopyr, prodiamine should be further investigated as a tool for annual bluegrass control in perennial ryegrass overseeded into bermudagrass.

Because of the long half-lives of prodiamine, oxadiazon, and pendimethalin, and because of their herbicidal activity on many grass species, it is relevant to ask the question about how perennial ryegrass can grow through these herbicides with the short intervals from herbicide application to seeding utilized in this research. One possible explanation could be the position of the ryegrass seed or seedling relative to the position of the herbicide in the thatch/soil. Perennial ryegrass often germinates in the upper part of the thatch or mat layer in

bermudagrass. Because these herbicides are tightly bound to organic matter and other proteinaceous substances in soil, they may pass through the thatch layer such that perennial ryegrass germinates on top of the herbicide. Because annual bluegrass has a smaller seed and because the seed would have dropped into the bermudagrass canopy the previous spring, it is possible this species is positioned below the herbicide barrier. Therefore, when annual bluegrass germinates, it has to grow through the barrier where it absorbs the herbicide and dies. This should also be a focus of future research.

REFERENCES

Ahrens, W. H., ed. 1994. Herbicide handbook, 7th ed. Weed Sci. Soc. Amer., Champaign, IL.

Anonymous. 2000a. Balan herbicide label. p. 697-699 *in* Turf and Ornamental Reference. C&P Press, New York.

Anonymous. 2000b. Kerb herbicide label. p. 579-582 *in* Turf and Ornamental Reference. C&P Press, New York.

Anonymous. 2000c. Prograss herbicide label. p. 38-41 *in* Turf and Ornamental Reference. C&P Press, New York.

Anonymous. 2000d. Rubigan herbicide label. p. 142-145 *in* Turf and Ornamental Reference. C&P Press, New York.

Bunnell, B. T., F. C. Waltz, J. K. Higingbottom, and L. B. McCarty. 1999. Annual bluegrass (*Poa annua*) control and overseeded grass establishment following pesticide use. Proc. South. Weed Sci. Soc. 52:70.

Dernoeden, P. H., D. B. Davis, and J. D. Fry. 1988. Rooting and cover of three turf species as influenced by preemergence herbicides. Proc. Northeastern Weed Sci. Soc. 42:169.

Isgrigg III, J., F. H. Yelverton, and H. D. Coble. 1997. The effects of preemergence herbicides on the establishment of perennial ryegrass in overseeded bermudagrass. Proc. South. Weed Sci. Soc. 50:72-73.

Mazur, A. R. and D. F. Wagner. 1987. Influence of aeration, topdressing, and vertical mowing on overseeded bermudagrass putting green turf. Hort-Science 22:1276-1278.

McCarty, B., A. R. Mazur, and L. C. Miller. 2000. Overseeding. p. 356-373 *in* D. Yarnell (ed.) Best Golf Course Management Practices. Prentice-Hall, Inc., Upper Saddle River, New Jersey.

Nash, A. S. and P. H. Dernoeden. 1982. Effectiveness and persistence of oxadiazon as a preemergence crabgrass herbicide and subsequent effects on overseeded perennial ryegrass. Proc. Northeastern Weed Sci. Soc. 36:301-306.

SAS Institute, Inc. 1989. SAS users guide: Statistics. 6th ed. SAS Inst., Cary, N.C.

Trenholm, L. E. and L. B. McCarty. 1996. Cool-season turfgrass performance and *Poa annua* control following fenarimol application timing. Proc. South. Weed Sci. Soc. 49:62–63.

Yelverton, F. 1999. *Poa annua* sneaks into winter bermudagrass. Golf Course Management. December p. 62-67.

Yelverton, F. H. 2000. Weed Control. p. 8-17 *in* F. H. Yelverton (ed.) Pest control for professional turfgrass managers 2000. North Carolina Coop. Ext. Serv., Publication AG-408.