Creeping Bentgrass Damaged by Low Levels of Atrazine in Irrigation Water

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Abstract. Throughout the north-south climatic transition zone of the eastern United States, cool- and warm-season turfgrasses are used adjacently. A greenhouse study with creeping bentgrass (*Agrostis palustris* Huds.) was initiated to determine threshold concentrations of atrazine, an effective pre- and postemergence herbicide for warm-season turfgrasses, that would result in unacceptable levels of phytotoxicity to seedling and mature creeping bentgrass. Mature and 8-week-old seedling 'Pennncross' creeping bentgrass were given 6.5 mm of daily irrigation of untreated water or water containing atrazine at 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28, or 2.56 mg·liter⁻¹. A model of quality ratings taken 20 days after the initiation of treatments indicated threshold concentrations resulting in unacceptable turf quality to be approximately 0.05 and 0.08 mg·liter⁻¹ for seedling and mature bentgrass, respectively. Chemical name used: 2-chloro-4-ethylamino-5-isopropylamino-s-triazine (atrazine).

Throughout the transition zone, a 300-km-wide belt in the eastern United States centered around 37° north latitude, both cool- and warm-season turfgrasses are used. The use of atrazine provides effective pre- and postemergence weed control on warm-season turfgrass species (Humburg, 1989). Unlike warm-season turfgrasses, however, cool-season turfgrasses cannot detoxify atrazine to nontoxic metabolites (Jensen et al., 1977), and root and foliar absorption of this photosynthetic inhibitor results in severe phytotoxicity and death of sensitive species (Esser et al., 1975).

Public concern has recently increased over possible groundwater contamination by agricultural pesticides, including atrazine. Although the concentrations observed are considered below hazardous levels for human consumption (Wehtje et al., 1983), wide seasonal fluctuations in pesticide concentrations have been detected in streams (Erickson and Kuhlman, 1987), especially when heavy rainfall occurs soon after pesticide application (Wu et al., 1983). This may have

serious implications for transition zone and southern turfgrass managers where both warm- and cool-season turfgrass species may be grown in the same watershed.

Small surface reservoirs ($<9.6 \times 10^3 \text{ m}^3$) provide only 2% of the U.S. total water storage capacity, yet they comprise a common source of water for golf courses and park areas (Watson, 1985). Transition zone golf courses with fairways of zoysiagrass (*Zoysia japonica* Steud.) or bermudagrass [*Cynodon dactylon* (L.) Pers.], or southern golf courses with roughs of centipedegrass [*Eremochloa ophiuroides* (Munro.) Hack.] or St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] may use triazine herbicides, including atrazine, for weed control. If a golf course has surface reservoirs that are fed from triazine-treated fairways, heavy rainfall or excess irrigation following application may result in surface water contamination. Irrigation of creeping bentgrass putting greens with triazine-contaminated water may lead to severe phytotoxicity and death of the grass. We therefore determined the threshold atrazine concentrations in daily irrigation that would result in an unacceptable level of phytotoxicity of seedling and mature 'Pennncross' creeping bentgrass from such exposure.

'Pennncross' creeping bentgrass was seeded at 9.76 g seed/m² into 102 × 102 × 75 mm (deep) plastic pots containing 80 mason sand : 20 sphagnum peat (v/v). Plugs of mature 'Pennncross' bentgrass were taken from the Rocky Ford Turfgrass Research Plots,

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Table 1. Concentrations (mg·liter⁻¹) of atrazine used in daily irrigation water and their cumulative application rates (g·m⁻²) for 10, 15, and 20 days of treatment at 6.5 mm irrigation per day.

Atrazine in daily irrigation (mg·liter ⁻¹)	Cumulative application rate (g·m ⁻²)		
	Days of treatment		
	10	15	20
0.0	0.0	0.0	0.0
0.01	0.0007	0.0010	0.0013
0.02	0.0013	0.0020	0.0026
0.04	0.0026	0.0039	0.0053
0.08	0.0052	0.0079	0.0105
0.16	0.0104	0.0158	0.0209
0.32	0.0208	0.0315	0.0417
0.64	0.0416	0.0631	0.0833
1.28	0.0832	0.1262	0.1664
2.56	0.1664	0.2523	0.3329

Manhattan, Kan., using a standard cup cutter and also established on 80 mason sand : 20 sphagnum peat (v/v) mix in 160 × 170 mm (diam/depth) round pots. Seedling and mature bentgrass were grown in a greenhouse for 8 weeks before atrazine treatments were initiated. Greenhouse conditions included a 24/18 ± 3C day/night cycle, natural day-length (Nov. 1987-Mar. 1988), and total irradiance (no supplemental lighting), averaging 2940 W·m⁻²·day⁻¹, but ranged from a low

of 240 to a high of 6760 W·m⁻²·day⁻¹ during the experimental period. Plants were treated with 4.9 g N/m², 1.1 g P₂O₅/m², and 2.7 g K₂O/m² at 4-week intervals and were clipped daily at 5 mm mowing height; clippings were removed.

Atrazine (Aatrex 4L, Ciba-Geigy, Greensboro, N.C.) at 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28, or 2.56 mg·liter⁻¹ was applied daily in 6.5 mm of irrigation water; unamended water served as the control. Pots were placed in small catch basins on a bench, and all leachate was retained in the catch basins during the experiment. Treatments were replicated three times in a completely randomized design, and the experiment was performed three times. Cumulative application rates for 10, 15, and 20 days are shown in Table 1.

Data were pooled for regression analyses, and each treatment mean included nine observations. A mathematical model was chosen from Landsberg (1977) to establish atrazine response curves for both seedling and mature creeping bentgrass vs. the logarithm (base 10) of increasing concentrations of atrazine for 10, 15, and 20 days after the initiation of daily treatments Eq. [1].

$$y = a / \left[1 + \left(\frac{\log_{10} x + 2}{c} \right)^b \right] \quad [1]$$

y = quality rating (1 = completely dead

and 9 = excellent quality, no visible phytotoxicity); x = atrazine concentration (mg·liter⁻¹); a, b, and c are model estimates derived by iteration. Critical threshold concentrations were defined as those resulting in mean quality ratings of 6.

After 20 days of treatment, rooting mix was collected from three replications of seedling bentgrass that had received atrazine at 0.01, 0.02, 0.04, or 0.08 mg·liter⁻¹ to test for atrazine accumulation. Samples were refrigerated at 4C in sealable plastic bags until shipment to Harris Laboratories (Lincoln, Neb.) for analysis as described by Schwab (1988).

Critical threshold atrazine concentrations resulting in unacceptable turf quality were time-dependent. As the number of days of exposure increased, the critical atrazine concentration in daily irrigation water necessary to result in unacceptable quality decreased for mature and seedling bentgrass (Figs. 1 and 2). Predicted threshold concentrations were calculated by giving y a value of 6 (unacceptable turf quality) in Eq. [2], which was derived by solving for x in Eq. [1].

$$x = 10^z \quad [2]$$

$$\text{where } z = \left[\left(\frac{a - y}{y} \right)^{1/b} c \right] - 2$$

x = atrazine concentration (mg·liter⁻¹); y = quality rating (1 = completely dead and 9 = excellent quality, no visible phytotoxicity); a, b, and c are model estimates derived by iteration.

Table 2 lists the model estimates and predicted critical threshold concentrations of atrazine in daily irrigation water that resulted in unacceptable turf quality (y = 6) of seedling and mature 'Pennncross' creeping bentgrass after 10, 15, and 20 days of exposure. Seedling bentgrass exhibited unacceptable quality after 20 days of atrazine concentrations of 0.05 mg·liter⁻¹ whereas mature bentgrass was less sensitive, exhibiting unacceptable quality at 0.08 mg·liter⁻¹. Because the response curves were time-dependent, the threshold concentrations might have been even lower if treatments had been extended beyond 20 days.

The time-dependency of the critical threshold concentration of atrazine necessary to result in unacceptable bentgrass quality suggests that atrazine may have accumulated in the rooting mix. Analyses of the rooting mix of seedling bentgrass after 20 days of treatment with atrazine at 0.01, 0.02, 0.04, or 0.08 mg·liter⁻¹ revealed atrazine concentrations at or below detectable levels (0.01 mg·kg⁻¹) at the three lower concentrations. However, with the 0.08 mg·liter⁻¹ treatment, the mean atrazine concentration in the rooting mix was 0.15 mg·kg⁻¹. Atrazine accumulation may be due to adsorption to organic matter (20% sphagnum peat) within the mix (Hitbold and Buchanan, 1977).

When creeping bentgrass putting greens undergo a sudden loss of quality, disease is often suspected, but phytotoxicity from triazine herbicides in irrigation water may be causing the problem. This may be especially

Table 2. Model estimates and predicted threshold atrazine concentrations resulting in unacceptable quality of 8-week-old seedling and mature 'Pennncross' creeping bentgrass after 10, 15, and 20 days of atrazine exposure.

Maturity ^z	Days of atrazine exposure	Model estimates ^y			Predicted threshold concn (mg·liter ⁻¹) ^x
		a	b	c	
Seedling	10	8.86	2.73	1.41	0.119
	15	9.05	2.61	1.02	0.061
	20	8.86	2.91	0.89	0.049
Mature	10	8.83	3.59	2.02	0.435
	15	9.07	3.25	1.34	0.123
	20	8.93	3.59	1.12	0.083

^zSeedling bentgrass was 8 weeks old. Mature bentgrass was taken from 6-year-old field planting.

^ya, b, c model estimates were derived iteratively (see Eqs. [1] and [2] in text).

^xThreshold concentrations used a y value of 6 for acceptable quality.

Fig. 1. Mean quality ratings and regression curves for mature 'Pennncross' creeping bentgrass after 10, 15, and 20 days of exposure to low levels of atrazine in irrigation water. Means of nine observations.

Fig. 2. Mean quality ratings and regression curves of 8-week-old 'Penncross' creeping bentgrass after 10, 15, and 20 days of exposure to low levels of atrazine in irrigation water. Means of nine observations.

true if triazine-treated warm-season turfgrasses share the same watershed and resultant surface reservoir with cool-season turfgrass species.

Atrazine ranked third in a group of seven s-triazines for leachability on a fine sandy soil and is considered to be leachable (Rodgers, 1968). Investigations into the groundwater quality in Iowa and Minnesota (Hallberg, 1987), as well as Ohio (Baker, 1985), have reported atrazine concentration up to 21.1, 42.4, and 30.0 mg·liter⁻¹, respectively. Results of the present study suggest that daily use of atrazine-contaminated groundwater sources at lower concentration warrants concerns for managers of creeping bentgrass putting greens.

Although oats (*Avena sativa* L.) and cucumbers (*Cucumis sativus* L.) have been used

as indicator species for the presence of s-triazines (Rodgers, 1968), this study has demonstrated the extreme sensitivity of creeping bentgrass to low levels of atrazine in irrigation water. Golf course superintendents in the transition zone and south need to be keenly aware of this, especially if a significant portion of the irrigation source is drawn from surface reservoirs whose watersheds support warm-season turfgrass species. Treating zoysiagrass or bermudagrass fairways or centipedegrass or St. Augustinegrass roughs with s-triazines may ultimately lead to severe damage to creeping bentgrass. In addition, this research has shown that such damage to creeping bentgrass from daily exposure to atrazine is time-dependent (threshold concentrations decrease with a longer period of exposure); phytotoxicity oc-

curs at concentrations much below those associated with herbicide efficacy; and newly seeded bentgrass is more sensitive to injury than mature stands.

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