Response of Turfgrass Cultivars to Ozone and Sulfur Dioxide in the Atmosphere

Eileen Brennan and Philip M. Halisky

Associate Professors, Department of Plant Biology, Rutgers University, The State University of New Jersey, New Brunswick 08903.

Rutgers University Journal Series Paper No. 3953.

The authors express their appreciation to C. Reed Funk for supplying the turfgrasses.

Accepted for publication 18 May 1970.

ABSTRACT

Turfgrasses representing several genera and species were exposed for 6 hr to an atmosphere containing ozone (0.23-0.30 ppm) or sulfur dioxide (0.75-1.80 ppm). Response to either pollutant varied with the grass fumigated. Generally, bentgrass and annual bluegrass were most sensitive to O_3; Bermudagrass and zoysia were most resistant; and perennial ryegrass, Kentucky bluegrass, and red fescue were intermediate in their response. Symptoms of ozone toxicity were, typically, bleaching and necrosis of the leaf blade, except for pigmented stipples in red fescue. Red fescue and bentgrass were most sensitive to SO_2; bluegrass and ryegrass were intermediate; and Bermudagrass and zoysia were resistant. Sulfur dioxide toxicity consistently resulted in necrosis of the terminal portion of the leaf blade. Phytopathology 60:1544-1546.

The extreme sensitivity of annual bluegrass (*Poa annua*) to California smog was recognized 20 years ago (10). Because of the characteristic bleaching and necrosis produced on leaves of annual bluegrass, it was used as an indicator of air pollution level in the Los Angeles area (7); however, since both ozone and oxidized hydrocarbons produce similar symptoms on *Poa annua* (11), this species cannot be used to differentiate between the two toxicants. Canary grass (*Phalaris canariensis*) also is sensitive to California smog; crabgrass (*Digitaria sanguinalis*) and rabbitfoot grass (*Polypogon monspeliensis*) are intermediate; while Bermudagrass (*Cynodon dactylon*) and Johnson grass (*Sorghum halepense*) are resistant according to Thomas & Hendricks (12). Hill et al. (5) rated orchardgrass (*Dactylis glomerata*) as sensitive to ozone (since it was injured by a 2-hr exposure to 0.35 ppm O_3), and annual bluegrass as resistant, since it was not injured by 0.64 ppm O_3 in a similar time period. Benedict & Breen (1) found that 16-17% of the leaf area of Kentucky bluegrass (*Poa pratensis*) and annual bluegrass was destroyed after exposure to 2.0 ppm SO_2 for 4 hr. They rated the grasses as intermediate in sensitivity. O'Gara, cited by Thomas & Hendricks (12), found that cheatgrass (*Bromus techtorum*) was sensitive, orchardgrass was intermediate, and saltgrass (*Distichlis stricta*) was resistant to SO_2.

The studies reported here were conducted because of (i) the economic importance of turf; (ii) the increasing frequency of phytotoxic levels of air pollutants in our metropolitan areas; and (iii) the fact that no previous studies were focused on turfgrasses.

MATERIALS AND METHODS.—Seven species (11 cultivars) of common turfgrasses were selected: creeping bentgrass (*Agrostis palustris* Huds. 'Penncross,'); Bermudagrass (*Cynodon dactylon* [L.] Pers. 'Kansas P-16,'); red fescue (*Festuca rubra* L. 'Pennlawn' and 'Highlight'); perennial ryegrass (*Lolium perenne* L. 'Manhattan' and 'Lamora'); annual bluegrass (*Poa annua* L.); Kentucky bluegrass (*Poa pratensis* L. 'Merion' and 'Delta'); and Japanese lawngrass (*Zoysia japonica* Steud. 'Meyer' and 'Common'). The orthography of the turfgrass names is in accordance with Hanson (4) or Hitchcock & Chase (6).

Four-inch plugs of each grass were removed in May 1969 from mature turf plots and transplanted to greenhouse pots. The plants were watered daily and maintained at a cutting height of approximately 2 inches.

RESULTS.—*Response of turfgrass cultivars to ozone fumigations.*—After the grasses attained uniform growth in the greenhouse, they were tested for their response to ozone. Four replicates of each cultivar were exposed to controlled fumigations at 0.30 ppm ozone for 6 hr. The temp during ozonation was 24-27 C, and the relative humidity was 30%. The chamber, monitoring equipment, and methods used have been described (9). Fumigations were conducted in June and repeated in August 1969. Following ozonation, the grasses were observed daily to determine the nature of their response and the degree of phytotoxicity. After 7 days, the comparative degree of leaf injury was scored on a numerical scale of 0 = no damage to 9 = severe damage (Table 1).

Considerable variation in response was observed among the 11 turfgrass cultivars evaluated. Bentgrass and annual bluegrass were most sensitive; Kentucky bluegrass, perennial ryegrass, and Pennlawn red fescue were intermediate; whereas Bermudagrass and Highlight red fescue were least sensitive to ozone. Neither cultivar of Japanese lawngrass was injured by O_3. In the most sensitive grasses, injury was indicated by water-soaking in the tips of leaf blades by the end of the fumigation period. After 1-2 days, depending on the amount of sunshine, the most commonly observed symptom of ozone toxicity was a bleaching and necrosis of the terminal portions of leaves in bentgrass, bluegrass, and Bermudagrass. Ryegrass foliage, on the other hand, became grossly discolored by a characteristic dark-brown necrosis. The surface of fumigated ryegrass leaves, however, remained glossy, albeit pigmented, in appearance. A third type of symptom was that observed in red fescue leaves consisting of minute, dark-brown

TABLE 1. Degree of injury and symptom expression in eleven turfgrass cultivars exposed to 0.30 ppm ozone for 6 hr

Turfgrass cv.	Injury rating[a]	Type of injury to foliage[b]
Penncross bentgrass	9	Tan necrosis, bleaching
Annual bluegrass	8	Tan to yellow necrosis, bleaching
Merion bluegrass	6	White necrosis, bleaching
Lamora ryegrass	6	Necrosis, dark-brown discoloration
Manhattan ryegrass	6	Necrosis, dark-brown discoloration
Pennlawn red fescue	6	Brown stippling, trace of bleaching
Delta bluegrass	4	White necrosis, bleaching
P-16 Bermudagrass	2	No necrosis, slight bleaching
Highlight red fescue	2	Some brown stippling
Common zoysia	0	None
Meyer zoysia	0	None

[a] Comparative degree of injury expressed numerically on a scale of 0 = no damage to 9 = severe damage.
[b] Type of symptoms developed in grass foliage 7 days after fumigation with ozone.

stipples. No visible symptom of injury was evident in zoysia cultivars.

Response of bentgrass cultivars to ozone fumigations.—To determine the amount of variability in the response of a given turfgrass "type" to ozone, seven cultivars representing three species of bentgrasses were selected for fumigation. The basis for selecting the bentgrasses was the highly susceptible response to ozone of 'Penncross' bentgrass (Table 1). Since bentgrasses are widely used on greens and fairways of golf courses in the USA, their susceptibility to ozone poses important economic implications. Four-inch plugs of each turfgrass were removed from 5-year-old turf plots and transplanted to the greenhouse in October, 1969. They were watered daily and maintained at a 2-inch cutting height. After 3 weeks, two replicates of each cultivar were fumigated for 6 hr at 0.23 or 0.30 ppm ozone. The temp during ozonation was 21-24 C, the relative humidity 25%. The grasses were observed daily for symptom development, and the comparative injury ratings (0 to 9) were scored 7 days following fumigation. The cultivars selected and the data obtained are recorded in Table 2.

When seven bentgrass cultivars were exposed to 0.30 ppm ozone for 6 hr, each one was severely injured. The degree of injury was high, ranging from 7 to 9, indicating that some of the cultivars of all three bentgrass species were sensitive to the ozone pollutant. The results confirm those of the previous test that showed Penncross bentgrass to be highly ozone-sensitive (Table 1). Only when the O_3 concn in the fumigation chamber was reduced from 0.30 to 0.23 ppm was a differential response noted among the cultivars. Thus, at the lower O_3 level both Kingstown velvet bentgrass and Highland colonial bentgrass showed significantly less injury than the remaining five cultivars which were moderately injured (Table 2).

TABLE 2. Comparative injury sustained by seven cultivars of bentgrass (*Agrostis* spp.) exposed for 6 hr to controlled ozone fumigations

Bentgrass cv.	Species of *Agrostis*	Ozone concn and injury ratings[a]	
		0.30 ppm	0.23 ppm
Cohansey	*A. palustris* Huds.	9	7
Seaside	*A. palustris* Huds.	9	7
Astoria	*A. tenuis* Sibth.	7	7
Penncross	*A. palustris* Huds.	9	5
Holfior	*A. tenuis* Sibth.	7	5
Kingstown	*A. canina* L.	7	1
Highland	*A. tenuis* Sibth.	7	1

[a] Comparative injury ratings are based on a numerical scale of 0 = no damage to 9 = severe damage. These were scored 7 days after ozonation.

Response of turfgrass cultivars to sulfur dioxide fumigations.—Fumigations to determine the comparative response of turfgrass cultivars to sulfur dioxide were conducted in July 1969. Four replicates of each of eleven cultivars were exposed in a greenhouse chamber to sulfur dioxide for 6 hr. The concn of SO_2 used were 0.75, 0.85, and 1.80 ppm, respectively. The temp during these trials was 27-30 C, and the relative humidity was 50%. Again, the grasses were observed daily for symptom expression and the degree of phytotoxicity (0-9) scored 7 days following fumigation.

Considerable variability in response to SO_2 was revealed (Table 3). Red fescue and bentgrass were most sensitive, whereas bluegrass and ryegrass were intermediate. Bermudagrass and Japanese lawngrass were not injured. The characteristic symptom of SO_2 toxicity was a bleaching of the terminal parts of the leaf blade. Other symptoms, such as chlorosis or mottling, were not associated with SO_2 injury.

DISCUSSION.—Turfgrasses, like other forms of vegetation, vary in their response to ozone and sulfur dioxide. Such variation was evident among the genera of grasses and occasionally among the cultivars within a species. Penncross bentgrass was highly sensitive, whereas zoysia was apparently immune to both O_3 and

TABLE 3. Comparative injury sustained by eleven turfgrass cultivars exposed to controlled 6-hr fumigations of sulfur dioxide

Turfgrass cultivar	SO_2 concn (ppm) and injury rating[a]		
	0.75	0.85	1.80
Highlight red fescue	4	7	9
Pennlawn red fescue	2.5	7	9
Penncross bentgrass	1	7	9
Annual bluegrass	1	3	4
Delta bluegrass	0	3	4
Merion bluegrass	0	4	4
Lamora ryegrass	1	2	3
Manhattan ryegrass	0.5	0	2
P-16 Bermudagrass	0	0	0
Common zoysia	0	0	0
Meyer zoysia	0	0	0

[a] Comparative injury ratings are expressed numerically on a scale of 0 = no damage to 9 = severe damage. These were scored 7 days after fumigation.

SO_2 in our trials. Bermudagrass also was resistant to O_3 and SO_2. Since all three grasses are stoloniferous, growth habit apparently is not related to the response of turfgrasses to air pollutants.

Within the bluegrasses, annual bluegrass appears to be especially sensitive to ozone, a pollutant commonly associated with eastern metropolitan areas in the USA. Since loss of well-cared-for stands of *Poa annua* is commonplace during the summer months and constitutes a recurring problem on many golf courses, ozone may well be a contributing factor to summer dieback. The extreme sensitivity of annual bluegrass to "smog" is well established (3, 7); however, the toxicant responsible for that damage is peroxyacetylnitrate (PAN) or its analogues. In California, plant damage generally is of the PAN type, while in the Northeast, ozone injury is of major importance.

Among the perennial bluegrasses, some difference in response to ozone was observed between the cultivars Merion and Delta (Table 1). These differences suggest that screening of large populations of bluegrasses would yield wide variations in their response to ozone. Such evaluations could conceivably lead to the eventual selection and breeding of resistant cultivars (2).

As Ledbetter et al. (8) observed, ozone damage in foliage may appear as light flecks, dark stipples, necrotic patches, or general chlorosis. In the case of turfgrasses, necrosis combined with bleaching was the predominant symptom. Only in red fescue did pigmented stipples appear such as those commonly seen in ozonated leaves of bean, grape, or white potato. Ozone-injured foliage of perennial ryegrass, in contrast, showed as a glossy, dark-brown discoloration over the entire leaf blade. Thus, in turfgrasses, the type of symptom that developed appeared to be related, in part, to the genus, species, or cultivar of the grass in question.

On a comparative basis, the turfgrasses are not as sensitive to short exposures of low ozone concn as are several commonly used indicator plants. Plants such as Pinto bean (*Phaseolus vulgaris*) and Bel W-3 tobacco (*Nicotiana tabacum*) are readily injured by 0.15-0.25 ppm ozone in 3 hr, whereas the turfgrasses generally required both higher concn (0.30 ppm) and longer exposures (6 hr) to attain comparable injury.

SO_2 injury in grasses was typical of the acute type of injury produced in most types of vegetation as described by Thomas & Hendricks (12). Immediately following exposure, the interveinal areas assume a dull, water-soaked appearance. Subsequently, this tissue dries up and usually bleaches to an ivory color.

The refractory response of Bermudagrass and zoysia was generally similar with both pollutants (Tables 1, 3). With the remaining grasses, however, a differential response was observed among certain of the cultivars. Red fescue, though generally resistant to O_3 injury, was the most susceptible grass to SO_2 injury. Conversely, perennial ryegrass which was generally resistant to SO_2 injury was moderately susceptible to O_3 injury. It appears, therefore, that a differential response among turfgrass cultivars is probably related to the specific effect of each pollutant rather than to the anatomical structure of the cultivar.

LITERATURE CITED

1. Benedict, H. M., & W. H. Breen. 1955. The use of weeds as a means of evaluating vegetation damage caused by air pollution. 3rd Nat. Air Pollution Symp., Proc. 177-190.
2. Brennan, Eileen, Ida A. Leone, & R. H. Daines. 1964. The importance of variety in ozone plant damage. Plant Dis. Reptr. 48:923-924.
3. Bobrov, Ruth Ann. 1955. The leaf structure of *Poa annua* with observations on its smog sensitivity in Los Angeles County. Amer. J. Bot. 42:467-473.
4. Hanson, A. A. 1965. Grass varieties in the United States. USDA Agr. Handbook No. 170. 102 pages.
5. Hill, A. C., M. R. Pack, M. Treshow, R. J. Downs, & L. G. Transtrum. 1961. Plant injury induced by ozone. Phytopathology 51:356-363.
6. Hitchcock, A. S., & Agnes Chase. 1951. Manual of the grasses of the United States. USDA Misc. Pub. No. 200. 1051 p.
7. Juhren, Marcella, W. Noble, & F. W. Went. 1957. The standardization of *Poa annua* as an indicator of smog concentrations. Plant Physiol. 32:576-586.
8. Ledbetter, M. C., P. W. Zimmerman, & A. E. Hitchcock. 1959. The histopathological effects of ozone on plant foliage. Contrib. Boyce Thompson Inst. 20:275-282.
9. Leone, Ida A., Eileen Brennan, & R. H. Daines. 1966. Effect of nitrogen nutrition on the response of tobacco to ozone in the atmosphere. J. Air Pollution Control Assoc. 16:191-196.
10. Middleton, J. T., J. B. Kendrick, Jr., & H. W. Schwalm. 1950. Injury to herbaceous plants by smog or air pollution. Plant Dis. Reptr. 34:245-252.
11. Middleton, J. T., & A. O. Paulus. 1956. The identification and distribution of air pollutants through plant response. Amer. Med. Ass. Archives of Ind. Health 14:526-532.
12. Thomas, M. D., & R. H. Hendricks. 1956. Effect of air pollution on plants. Air Pollution Handbook, Sect. 9:1-44. McGraw Hill Book Co., N.Y.