Take-all Patch Suppression in Creeping Bentgrass with Manganese and Copper

W.J. Hill¹, J.R. Heckman², B.B. Clarke³, and J.A. Murphy⁴

Plant Science and Plant Pathology Departments, Rutgers, The State University of New Jersey, 59 Dudley Road, New Brunswick, NJ 08901-8520

Additional index words. manganese, copper, take-all patch, Mehlich-3, manganese availability index, *Agrostis stolonifera*, *Gaeumannomyces graminis*, disease, turfgrass

Abstract. Take-all patch, caused by *Gaeumannomyces graminis* (Sacc.) Arx. & D. Olivier var. *avenae* (E.M. Turner) Dennis (*Gga*), is a disease of creeping bentgrass (*Agrostis stolonifera* Huds.), which most often is associated with golf courses. Synthesis of ligneous and phenolic compounds by plants requires adequate Mn²⁺ and Cu²⁺ nutrition and may be a factor in disease resistance. An experiment was conducted on a creeping bentgrass fairway naturally infested with *Gga* to determine if foliar applications of Mn²⁺ (1.02 and 2.04 kg·ha⁻¹ per application) and Cu²⁺ (0.68 kg·ha⁻¹ per application) would reduce take-all severity. Prior to initiating treatments, soil pH was 6.4 and Mehlich-3 extractable Mn²⁺ and Cu²⁺ were 5 mg·kg⁻¹ and 1.7 mg·kg⁻¹, respectively. Manganese and copper sulfate treatments were initiated in July 1995 and foliarly applied every 4 weeks through 1997 with the exception of December, January, and February. Disease incidence was decreased from 20% on untreated turf to 5% with the high rate of MnSO₄. For both years, turf treated with the high rate of Mn²⁺ had less disease than turf receiving the low rate of Mn²⁺. The application of CuSO₄, however, did not influence disease development.

Take-all patch is caused by *Gaeumannomyces graminis* (Sacc.) Arx. & D. Olivier var. *avenae* (E.M. Turner) Dennis (*Gga*), and is primarily a disease of *Agrostis* spp. A related organism, *Gaeumannomyces graminis* (Sacc.) Arx. & D. Olivier var. *tritici* (*Ggt*), is a serious root disease of wheat (*Triticum aestivum* L. em. Thell). Garrett (1981) reported that the disease could be effectively suppressed by mineral nutrition and soil management practices that lower soil pH. The optimum pH for the growth of *Ggt* is 7.0 (Marschner, 1995). The severity of wheat take-all is influenced by Mn²⁺ availability in the rhizosphere and the Mn²⁺ concentration in roots (Huber and Wilhelm, 1988). Soil application of Mn²⁺ fertilizers helps to suppress wheat take-all on non-calcareous soils. In high

pH soils, Mn²⁺ is rapidly oxidized and made unavailable for plant uptake. Supplying N fertilizers in the ammonium form helps to lower soil pH and increase Mn²⁺ availability (Thompson et al., 1995). Soil application of Cu²⁺ also helps to reduce take-all of wheat grown on soil deficient in copper (Gardner and Flynn, 1988).

Applications of manganese and copper are thought to increase the plant's resistance to disease through utilization of these elements in the increased synthesis of phenolic and ligneous compounds. These compounds may serve as chemical barriers in plants to increase take-all resistance of wheat, even in soils adequately supplied with Mn²⁺ and Cu²⁺ (Graham and Rovira, 1984). The objective of this study was to determine the effect of Mn²⁺ and Cu²⁺ fertilization on the control of take-all patch of creeping bentgrass. More emphasis (two rates) was placed on manganese applications since there was more evidence in the literature to suggest that Mn²⁺ would have an effect on take-all.

Materials and Methods

An experiment was conducted on the third fairway of the Metedeconk National Golf Course in Jackson, N.J., where the creeping bentgrass turf ('Pennncross' and 'Penneagle') was known to be infested with *Gga*. The fairway was established on a modified Lakehurst sand (mesic-coated Haplaquodic quartzipsamment) soil 10 years prior to the initiation of the experiment. The experimental area was maintained under normal fairway management throughout the duration of the study. The golf course crew used an 11-mm

mowing height and clippings were removed. Applications of a 16N–2P–7K fertilizer, which contained ammonium phosphate, ammonium sulfate, potassium chloride, iron sulfate, and iron oxide as nutrient sources, were made monthly for a yearly total of 146 kg·ha⁻¹ N.

The Mn²⁺ and Cu²⁺ fertilizer treatments listed in Table 1 were initially applied on 27 July 1995, and with the exception of December, January, and February were applied every 4 weeks throughout 1996 and 1997. Commercial sources of manganese and copper, dissolved in 1 L of water and sprayed over 4.3-m × 6.1-m plots with a backpack sprayer calibrated to deliver 374 L·ha⁻¹. The turf was irrigated with ≈1/3 cm of water after treatments were applied on hot sunny days to reduce the potential for foliar injury. Initial treatment rates (1.53 and 3.05 kg·ha⁻¹ Mn per application; 1.02 kg·ha⁻¹ Cu per application) were reduced by one-third as shown in Table 1 after the first application on 27 July 1995. This was due to concern by the golf course superintendent about the potential for foliar injury. The experimental design was a randomized complete block with six replications.

Composite soil samples of five cores (0 to 5 cm) and the thatch were collected from each plot just prior to the application of treatments on 27 Mar. 1996 and 11 June 1997. Soil samples were analyzed for Mehlich-3 (Mehlich, 1984) extractable Mn²⁺ and Cu²⁺. Soil pH was determined using a 1 soil : 1 water (by volume) ratio. The Mn²⁺ availability index (MnAI) was used to determine the soil Mn²⁺ status (Mascagni and Cox, 1985). The MnAI is a function of both soil pH and Mn²⁺ extracted by the Mehlich-3 extractant: M3MnAI = 101.7 – 15.2 (pH) + M3Mn (no units).

The incidence of take-all patch was recorded on 30 May 1996 and 20 June 1997 to determine the effects of the treatments on symptom expression. Disease incidence was calculated from a grid that was placed over each plot. Cross marks falling on necrotic tissue were counted as disease. Incidence is reported as the percentage of the plot area that was affected by the take-all fungus. Statistical analyses of the disease data were performed using the GLM procedure of SAS.

Single degree of freedom contrasts also were evaluated to test treatment effects.

Results and Discussion

Take-all patch was observed each spring and disease ratings were taken on 30 May 1996 and 20 June 1997. There was no phytotoxicity observed for any of the treatments. The application of Mn²⁺ reduced disease severity in both years (Table 2). Plots treated with the high rate of Mn²⁺ exhibited less disease than turf receiving the low rate of Mn²⁺. In both years, disease incidence was decreased from 20% on untreated turf to 5% with the high rate of Mn²⁺. Treatment effects were apparent for the period of time that disease symptoms were expressed (late spring to mid summer). These findings suggest that Mn²⁺ may play a role in improving the resistance of creeping bentgrass against take-all.

Received for publication 6 Nov. 1998. Accepted for publication 18 Feb. 1999. The research reported in this publication was supported by the New Jersey Agricultural Experiment Station Project No. D12177-9-98, and the Center for Turfgrass Science. Use of trade names does not imply endorsement of the products named nor criticism of similar ones not named. We appreciate the technical assistance of Dennis Haines and Wayne Anastasia. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Graduate Student in Plant Science and Technology Program. Present address: Lidochem, Inc. 20 Village Court, Hazlet, NJ 07730. E-mail: whlidochem@monmouth.com

²Specialist in Soil Fertility.

³Specialist in Plant Pathology.

⁴Specialist in Turf Management.

Table 1. Soil pH, Mehlich-3 extractable manganese and copper, and Mehlich-3 manganese availability index (M3MnAI) as affected by application of MnSO₄ and CuSO₄.

Quantity applied ²		pH	Extractable		M3MnAI
Mn	Cu		Mn	Cu	
-----kg·ha ⁻¹ -----			-----mg·kg ⁻¹ -----		
0	0	6.5	6.0	2.0	8.9
	0.68	6.6	6.2	2.9	8.1
1.02	0	6.6	7.6	1.4	8.4
1.02	0.68	6.6	6.4	2.6	7.3
2.04	0	6.5	7.0	1.5	9.7
2.04	0.68	6.5	8.0	2.8	10.3
<i>P</i> > F					
Treatment		0.94	0.60	0.0001	0.81
No Cu vs. Cu		0.78	0.99	0.0001	0.75
No Mn vs. Mn		0.66	0.17	0.03	0.77
Low Mn vs. high Mn		0.37	0.57	0.79	0.20
cv%		4.5	32.7	16.4	46.2
-----kg·ha ⁻¹ -----			-----mg·kg ⁻¹ -----		
0	0	5.8	4.6	2.6	17.9
1.02	0	6.1	6.6	2.4	15.3
2.04	0	6.0	8.7	2.3	19.5
0	0.68	6.3	5.5	4.1	12.2
1.02	0.68	6.1	6.4	4.5	16.1
2.04	0.68	6.1	8.0	5.6	16.7
<i>P</i> > F					
Treatment		0.47	0.10	0.0001	0.03
No Cu vs. Cu		0.78	0.98	0.0001	0.75
No Mn vs. Mn		0.66	0.17	0.03	0.76
Low Mn vs. high Mn		0.37	0.57	0.79	0.20
cv%		5.4	39.1	31.7	21.8

²Treatments applied every 4 weeks. The treatments listed are the reduced rates; original rates, were Mn: 1.53 and 3.05 kg·ha⁻¹, Cu: 1.02 kg·ha⁻¹

The application of Cu²⁺ alone or in conjunction with manganese did not affect disease development. The ineffectiveness of Cu²⁺ in reducing disease severity suggests that either Cu²⁺ was not limiting in this soil or that Cu²⁺ may be less involved in disease suppression than Mn²⁺. Initial soil testing in the experimental site found an extractable Cu²⁺ level of 1.7 mg·kg⁻¹ averaged across the plots. A soil test level of 0.4 mg·kg⁻¹ of Cu²⁺ is generally considered to be adequate for plant growth (Sims and Johnson, 1991). Thus, based upon the soil test data, Cu²⁺ was probably not a limiting plant nutrient at this site.

Soil tests performed on samples taken each spring during the time of disease appearance found no differences among treatments in soil pH, extractable Mn²⁺, or the calculated Mehlich-3 Mn²⁺ availability index (M3MnAI) (Table 1). Applications of Cu²⁺, however, significantly increased extractable Cu²⁺ from soil in both years. The increase in soil test Cu²⁺ but not Mn²⁺ may be related to the chemistry of Cu²⁺ and Mn²⁺ reaction in soil. Alkaline soil reactions and soil pH levels near neutral favor the oxidation of soil Mn²⁺ in or applied to the soil. *Gaeumannomyces graminis* var. *avenae* is presumed to have the capacity to oxidize Mn²⁺ into plant-unavailable Mn³⁺ and/or Mn⁴⁺ in the rhizosphere (Huber and McCay-Buis, 1993). These processes may account for the inability to demonstrate buildup of Mn²⁺ in treated plots.

The M3MnAI has been used to predict manganese deficiencies in other crops. For

soybean, [*Glycine max* (L.) Merrill], M3MnAI values of <25 predict that soybean will likely be deficient in Mn²⁺ (Mascagni and Cox, 1985) and values as low as 12 have been associated with Mn²⁺ deficiency in alfalfa (Heckman et al., 1993). Since take-all disease severity is thought to be related to manganese availability, the M3MnAI was used in an attempt to measure not only whether manganese was deficient, but also whether disease severity could be predicted in creeping bentgrass. In this study, the highest M3MnAI in 1996 was 10.3 and in 1997 was 19.5. Since some symptoms of take-all were still evident even with the high Mn²⁺ rate, a critical level for M3MnAI could not be defined for creeping bentgrass. The soil test data from 1997 (Table 1) suggest, however, that for take-all suppression in creeping bentgrass the M3MnAI critical level may be >19.5.

Plant nutrition is an important consideration in the management of soilborne diseases. This study demonstrated a decrease in take-all patch severity in creeping bentgrass by using multiple applications of Mn²⁺ over a 2-year period. Because *Gga* probably has the capacity to oxidize applied Mn²⁺, the frequency of Mn²⁺ application may be an important factor in the use of Mn²⁺ for take-all management. Further research is needed to determine an optimum application frequency and rate of Mn²⁺ for the most effective suppression of take-all. Soil testing and pH management also should be a part of a take-all patch control program.

Table 2. Influence of manganese and copper fertilizer application on the incidence of take-all patch in a bentgrass fairway.

Quantity applied ²		Disease incidence ³	
Mn ^y	Cu ^y	30 May 1996	20 Jun 1997
-----kg·ha ⁻¹ -----		-----%-----	
0	0	21	19
1.02	0	15	10
2.04	0	4	6
0	0.68	18	21
1.02	0.68	11	12
2.04	0.68	7	8
<i>P > F</i>			
Treatment		0.02	0.0001
No Cu vs. Cu		0.52	0.07
No Mn vs. Mn		0.004	0.0001
Low Mn vs. high Mn rate		0.05	0.005
Cu × Mn		0.77	0.81
Cu × Mn rate		0.34	0.76
cv%		70	28

²Amount applied every 4 weeks. The treatments listed are the reduced rates; original rates were Mn: 1.53 and 3.05 kg·ha⁻¹, Cu: 1.02 kg·ha⁻¹.

³Percentage of the plot area affected.

Literature Cited

- Gardner, W.K. and A. Flynn. 1988. The effect of gypsum on copper nutrition of wheat grown in marginally deficient soil. *J. Plant Nutr.* 11:475-493.
- Garrett, S.D. 1981. Introduction, p. 1-14. In: M.J.C. Asher and P.J. Shipton (eds.). *Biology and control of take-all*. Academic, New York.
- Graham, R.D. and A.D. Rovira. 1984. A role for Mn in the resistance of wheat plants to take-all. *Plant Soil* 78:441-444.
- Heckman, J.R., J.M. Ingerson-Mahar, D.L. Lee, and E.P. Prostko. 1993. Alfalfa responses to foliar and soil applications of manganese. *Commun. Soil Sci. Plant Anal.* 24:559-572.
- Huber, D.M. and T.S. McCay-Buis. 1993. A multiple component analysis of the take-all disease of cereals. *Plant Dis.* 77:437-447.
- Huber, D.M. and N.S. Wilhelm. 1988. The role of manganese in resistance to plant diseases, p. 155-173. In: R.D. Graham, R.J. Hannan, and N.C. Uren (eds.). *Manganese in soils and plants*. Kluwer Academic, Dordrecht, The Netherlands.
- Marschner, H. 1995. *Mineral nutrition of higher plants*. 2nd ed. Academic, San Diego.
- Mascagni, H.J., Jr. and F.R. Cox. 1985. Calibration of a manganese availability index for soybean soil test data. *Soil Sci. Soc. Amer. J.* 49:382-386.
- Mehlich, A. 1984. Mehlich 3 soil extractant: A modification of the Mehlich 2 extractant. *Commun. Soil Sci. and Plant Anal.* 15:1409-1416.
- Sims, J.T. and G.V. Johnson. 1991. Micronutrient soil tests, p. 427-472. In: R.J. Luxmoore (ed.). *Micronutrients in agriculture*. Soil Sci. Soc. Amer., Madison, Wis.
- Thompson, D.C., B.B. Clarke, and J.R. Heckman. 1995. Nitrogen form and rate of nitrogen and chloride application for the control of summer patch disease in Kentucky bluegrass. *Plant Dis.* 79:51-56.
- Wilhelm, N.S., R.D. Graham, and A.D. Rovira. 1990. Control of Mn status and infection rate by genotype of both host and pathogen in the wheat take-all interaction. *Plant Soil* 123:267-275.