Management of Take-All Patch of Creeping Bentgrass with Nitrogen, Sulfur, and Phenyl Mercury Acetate

PETER H. DERNOEDEN, Associate Professor, Department of Agronomy, University of Maryland, College Park 20742

ABSTRACT

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Take-all patch disease, incited by *Gaeumannomyces graminis* var. *avenae*, is a destructive disease of bentgrass (*Agrostis* spp.) turf. Ammonium chloride alone and phenyl mercury acetate plus ammonium sulfate effectively controlled the disease in both years of a field study. Ammonium sulfate and urea reduced disease severity to an acceptable level only in the second year. Granular sulfur was ineffective in controlling take-all patch. No correlation was found between disease injury and thatch or soil pH. Failure to find a correlation between disease and pH was possibly due to the highly buffered nature of thatch and to the use of basic (pH 8.2) irrigation water. Data indicate that treatment effects on thatch and soil pH (pH 6.1–6.8) had no important impact on the disease control observed. Treatments that effectively reduced disease increased thatch biomass, which was attributed to stimulation of plant growth accorded by nitrogen.

Additional key words: *Agrostis palustris*, Ophiobolus patch

Take-all patch disease, an extremely destructive disease of bentgrass (*Agrostis* spp.), is incited by *Gaeumannomyces graminis* (Sacc.) Arx & Olivier var. *avenae* (E. M. Turner) Dennis (*G. g.* var. *avenae*) (6). Lowering soil pH with ammonium forms of nitrogen fertilizer or sulfur is a cultural practice that minimizes the severity of take-all patch (8,14). Smith (14) and Davidson and Goss (5) reported that ammonium sulfate and other acidifying compounds such as sulfur and monoammonium phosphate stimulate turf growth and accelerate the recovery of take-all patch-diseased turf. Goss and Gould (8) observed that excessive rates of nitrogen from urea (980 kg/ha) initially enhanced take-all but in subsequent years reduced disease severity. These studies provided valuable insights into the management of take-all patch with nitrogen fertilizers. The effective rates and timing of nitrogen applications in the aforementioned study (8), however, are not consistent with proper use of fertilizer on bentgrass turf in most cool, humid regions of the United States today.

Much of the information on the effects of fertilizers is known from the study of wheat (*Triticum aestivum* L.) take-all, incited by *G. g.* var. *tritici* (E. M. Turner) Dennis. Smiley and Cook (13) evaluated several nitrogen sources on wheat take-all and reported that ammonium forms of nitrogen were more effective than nitrate forms in suppressing the disease. This effect was attributed to acidification of the root zone through active plant uptake of NH_4 rather than acidification of the soil. Although they were unable to demonstrate a consistent correlation between bulk soil pH and disease injury, they found a high correlation between injury and rhizosphere pH. These researchers (13) concluded that wheat take-all was reduced by direct inhibition of the pathogen at a rhizosphere pH less than 5.0 and that there was an indirect inhibition, possibly by microorganisms, above a rhizosphere pH of 5.0. Goss and Gould (8) found a small correlation ($R = 0.31$, P level not given) between take-all patch and bulk soil pH from the upper 15 cm of soil. Thatch, a layer of organic matter consisting of living, partially decomposed, and undecomposed stem tissues, lies primarily above the soil surface in turfs (11). Thatch is common in stoloniferous, bentgrass turfs. Thatch pH would likely be of importance because the roots of turfgrasses may be largely restricted to thatch layers, particularly in excessively fertilized turfs (1,9,11).

More recently, researchers in Oregon (15) reported that in take-all-affected fields, ammonium chloride enhanced wheat yields more than ammonium sulfate. Christensen et al (3) observed that Cl^- lowers the water potential of cell sap in wheat roots and hypothesized that this physiological response may have reduced the capacity of *G. g.* var. *tritici* to colonize roots. Further investigations by Christensen and Brett (2) revealed that take-all severity in wheat was negatively correlated with the length of time the NH_4^+-N:NO_3^--N ratio remained above an estimated critical ratio of 3:1. Because chloride can inhibit nitrification, they suggest that chloride may reduce take-all severity by reducing nitrification, thereby maintaining a more favorable NH_4^+-N:NO_3^--N ratio for disease suppression.

Fungicides registered for use on turfgrasses are considered ineffective in controlling take-all patch (12). Jackson (10) reported that organomercury fungicides were more effective than inorganic mercury or cadmium-based fungicides in controlling take-all patch. Dernoeden et al (7) observed that phenyl mercury acetate (PMA) was generally more effective than chlorothalonil, iprodione, propiconazole, and triadimefon in reducing take-all patch severity.

The objectives of this investigation were as follows: 1) to compare the take-all patch suppressive effects of ammonium sulfate, ammonium chloride, and urea at conventional use rates and times of application; 2) to determine if bulk thatch pH could be correlated with disease injury; and 3) to evaluate PMA alone or applied with either sulfur or ammonium sulfate for control of take-all patch. Secondary objectives were to compare methods for measuring bulk thatch and soil pH and to monitor thatch production in the creeping bentgrass turf.

MATERIALS AND METHODS

Application of treatments. This study was conducted in Easton, MD. The area was seeded to Penncross creeping bentgrass (*Agrostis palustris* Huds.) in the fall of 1975, and disease symptoms appeared the following spring. Previous observations (6) suggested that take-all decline was under way at this site in 1982 (Easton, MD); however, the disease continued to recur through 1985. Take-all, however, no longer recurs at the Upper Marlboro and Beltsville, MD, sites described previously (6). From 1976 to 1982, the test area was fertilized annually with 125 kg of nitrogen per hectare with isobutylidene diurea (31N-0-0). The area was topdressed (annually from 1976 to 1981) with a sterilized, sandy soil amended to pH 7.5 with limestone. The same unamended soil (pH 5.8) was used for topdressing in 1982 and

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1983. Soil underlying the turf was a man-mixed sandy loam with particle size analysis of 71% sand, 20% silt, and 9% clay. A pH of 6.2 was determined in 1983 from a composite sample taken 5 cm below the thatch layer.

Treatments consisted of applications of ammonium chloride (26N-0-0), ammonium sulfate (21N-0-0), urea (45N-0-0), sulfur (90G), and PMA (10L). Application rates were 36.6 kg/ha for sulfur and 0.3 kg Hg/ha for PMA. When sulfur and ammonium sulfate were applied to the same plots, the rates were 22.4 kg S/ha + 22.4 kg N/ha. The applications of all materials, except as noted, were made on 6 October, 3 November, and 1 December 1983; 26 April, 27 September, 1 November, and 7 December 1984; and 17 April 1985. PMA was not applied in December of 1983 or 1984, and ammonium chloride was not applied on 6 October 1983. Fertilizers and sulfur were applied with a shaker bottle, and PMA was applied with a CO_2-pressurized backpack sprayer in 1,018 L/ha at 262 kPa. The test area was irrigated 8–12 hr after application with about 2.5 cm of water. Plots were 1.5 × 3.0 m and arranged in a randomized complete block with four replicates per treatment. Percentage of plot area injured by take-all patch was visually determined on a scale of 0–100% in June of 1984 and 1985.

pH determination. In all pH determinations, the thatch was separated from soil, and only soil from a zone 0–2.5 cm below the thatch was sampled. Samples were taken randomly with a 2-cm-diameter soil probe from at least six areas within each plot and separated into thatch- and soil-sampling zones in July of each year. Each zone was ground separately within each repetition. In 1984 and 1985, a 10-g composite sample from each zone was allowed to equilibrate in 10 ml of distilled water for 1 hr before measuring pH. In 1985, pH was also measured using the procedure described by Smiley and Cook (13). Briefly, thatch and soil samples were separated, and a 5-g composite sample from each zone was placed in 10 ml of 0.01 M $CaCl_2$, stirred, and allowed to equilibrate 1 hr before pH measurement. Thatch samples were ground, but the soil cores (2.0 × 2.5 cm) were broken, and soil was scraped from root masses with a dissecting needle. All visible root fragments were removed from the soil samples. In this latter procedure, two subsamples from each replicate were obtained, and the pH mean was analyzed statistically.

Thatch measurements. In July 1985, three samples 6 cm in diameter and deep enough to obtain 2.5–3.0 cm of soil were obtained from each replicate. Uncompressed thatch depths were measured immediately. The soil and thatch were then separated, and thatch was dried at 60 C for 10 days. The three thatch samples per replicate were weighed after drying, ashed at 850 C for 45 min, and reweighed to determine the organic matter content (i.e, biomass) on the basis of weight loss by ignition.

Data were analyzed by analysis of variance, and significant means were separated with the Bayes least significant difference multiple-comparison test (BLSD).

RESULTS AND DISCUSSION

As was noted by Taylor et al (15), working with take-all root rot of wheat, take-all patch symptoms develop in a variable pattern, often resulting in a large experimental error and either no or few statistical differences among treatments. Greenskeepers would consider disease injury exceeding 1% of turfgrass area damaged unacceptable. For this reason, any treatment providing less than 1% of plot area injured by take-all was subjectively judged effective in reducing disease severity in this study.

Percentage of plot area injured by take-all patch was assessed in June of each year (Table 1). In 1984, all treatments reduced the level of disease injury significantly, but only ammonium chloride alone and PMA + ammonium sulfate reduced injury to an acceptable level (i.e., < 1% of plot area injured). In 1985, all treatments except sulfur alone and PMA + sulfur reduced disease severity significantly. Furthermore, plots receiving sulfur tended to be injured more by take-all in 1985 than in 1984. Ammonium chloride and PMA + ammonium sulfate were the only treatments that provided acceptable control in both years. Although not previously evaluated for control of take-all patch, ammonium chloride has been reported to reduce the severity of wheat take-all (3,15). Both Smith (14) and Davidson and Goss (5) observed enhanced recovery of take-all patch-diseased turf with ammonium sulfate, which they attributed primarily to growth stimulation by nitrogen. Unlike the aforementioned studies, most nitrogen in this study was applied the fall before symptom expression in the spring. This would suggest that acidification, either directly or indirectly, provided the beneficial effect in suppressing the disease. This conclusion, however, could be challenged in view of the positive effects of urea (in 1985), which does not have as high an acidification potential as straight ammonium forms of nitrogen (16). Goss and Gould (8), however, observed a decrease in soil pH concomitant with a decrease in take-all patch over a 3-yr period where high rates (290, 590, and 980 kg/ha) of nitrogen from urea were applied. Therefore, there was a similarity between this and the aforementioned study in that the level of disease injury declined over time in plots treated with urea.

Although applications of limestone appear to enhance take-all patch (14), Davidson and Goss (5) demonstrated

Table 1. Influence of nitrogen fertilizers, sulfur, and phenyl mercury acetate (PMA) on take-all patch and thatch production in a Penncross creeping bentgrass turf[x]

Treatment	Application rate (kg/ha)	Percent plot area injured		Thatch in 1985[y]	
		1984	1985	Depth (cm)	Biomass (g)
Ammonium sulfate	36.6 N	1.2 b[z]	0.0 a	3.2 a	21.8 a
Ammonium chloride	36.6 N	0.2 b	0.0 a	3.0 abc	19.2 abc
Urea	36.6 N	3.7 b	0.3 a	2.9 abcd	19.9 ab
Sulfur 90G	36.6 S	4.7 b	6.0 bc	3.0 abc	17.4 bcd
Sulfur 90G + ammonium sulfate	24.4 S + 24.4 N	1.2 b	3.0 ab	3.1 ab	17.2 bcd
PMA 10L	0.3 Hg	4.7 b	1.3 ab	2.6 cd	17.7 bcd
PMA 10L + sulfur 90G	0.3 Hg + 36.6 S	2.0 b	8.7 c	2.7 bcd	15.7 cd
PMA 10L + ammonium sulfate	0.3 Hg + 36.6 N	0.3 b	1.0 ab	2.8 abcd	19.6 abc
Untreated control	···	10.7 a	9.0 c	2.5 d	15.2 d

[x] Fertilizers and sulfur were applied three times on monthly intervals between October and December in 1983 and September and December 1984 and again in April 1983 and 1984. PMA alone or with either sulfur or ammonium sulfate was applied October and November 1983; April, September, and October 1984; and April 1985.

[y] Thatch samples were collected 26 July 1985.

[z] Means within a column followed by the same letter are not significantly different at $P = 0.05$ according to the Bayes LSD.

that sulfur (97.8 kg/ha/yr) enhanced recovery, but they did not test the effectiveness of sulfur in preventing or reducing disease development. In the Maryland study, sulfur (146 kg/ha/yr) did not reduce injury to acceptable levels. This may be attributed to the slower acidification rate by sulfur applied in granular rather than powder or flowable form. When sulfur and ammonium sulfate were combined but used at a reduced rate compared with individual applications, control was slightly improved over that with sulfur alone (Table 1).

Curative applications of PMA controlled take-all patch (7). In this study, preventative applications of PMA alone reduced disease severity, but the level of control was unacceptable. When PMA was combined with ammonium sulfate, acceptable control was achieved in both years, but the performance of PMA + sulfur was erratic.

Smiley and Cook (13) reported that acidification of the rhizosphere, and not bulk soil, was the critical factor in reducing wheat take-all. Goss and Gould (8) found a weak correlation with bulk soil pH and take-all patch. Unlike the aforementioned studies, thatch and soil pHs were measured independently in this study, because most of the roots would be expected to be restricted to thatch. Treatments applied in fall 1983 and spring 1984, however, failed to change bulk thatch and soil pHs by July 1984 (Table 2). Thatch pH tended to be higher than soil pH. As previously noted, the test area was topdressed annually from 1976 to 1981 with a sandy soil, which was amended with limestone to a pH of 7.5. The high organic matter content of thatch, and possibly the carbonates from limestone, would have greatly increased the buffering capacity of the thatch.

Because of the failure to obtain a significant difference in pH in 1984, both the routine method (distilled water suspension [DWS]) and the method used by Smiley and Cook (14) (0.01 M $CaCl_2$ suspension [CCS]) were evaluated. To test rhizosphere pH, Smiley and Cook (13) shook off soil that clung to roots, whereas in this study, soil was scraped from root masses and macroscopic root sections were removed from the sample. This procedure was time-consuming and was only employed to measure pH when $CaCl_2$ was used to suspend soil.

Data from 1985 showed that only ammonium chloride had significantly reduced thatch and soil pH when a DWS was used (Table 2). When a CCS was used, ammonium chloride, sulfur, and sulfur + ammonium sulfate had reduced thatch pH significantly, whereas none of the treatments had reduced soil pH. The anticipated lower thatch pH values were observed between CCS and DWS methods, but lower soil-minus-roots vs. soil pH values were not obtained. The high soil-minus-roots pH (CCS) values, compared with soil pH (DWS) in 1985 may be attributed to higher exchangeable hydrogen ion in soil samples containing roots. There was no correlation found between the level of take-all patch injury and soil pH or thatch pH using either the DWS or CCS method. These findings are somewhat inconsistent with those of Smiley and Cook (13). The confounding factor in this study is probably the high buffering capacity of the thatch and soil lying just below (2.5 cm) the organic matter layer. Furthermore, acidification of soil would have been slowed by carbonates in the irrigation water (pH 8.2) The data, however, do reveal a strong relationship between applications of ammonium chloride and control of take-all patch. Christensen and Brett (2) proposed that enhanced take-all suppression is related to the capacity of chloride to reduce nitrification and maintain a more favorable NH_4^+-N:NO_3^--N ratio for disease suppression. The ambiguities in the data (e.g., sulfur reduced thatch pH with the CCS method, but it did not control the disease in 1985) underscore Cook's (4) view that the relationship between take-all disease severity and soil acidification still remains imperfectly understood.

Ammonium sulfate and ammonium chloride use had increased both thatch depth and biomass, whereas treatments involving PMA had little or no effect on thatch accumulation (Table 1). There were significant ($P = 0.02$) negative correlations between disease injury and thatch depth ($R = -0.46$) as well as biomass ($R = -0.57$). An increase in thatch, however, was expected with nitrogen applications compared with unfertilized turf over the 2-yr test period. An interesting agronomic aspect of these data is that deeper thatch does not necessarily mean significantly more organic matter per unit area. For example, thatch depth, but not biomass, was increased by sulfur alone. It is also important to note that all treatments providing acceptable levels of disease control were characterized as having produced a greater amount of biomass. These data, therefore, could be misinterpreted as showing that by increasing thatch, disease severity is reduced. It is more likely that by virtue of there being more roots in thatch (and therefore more *G. g.* var. *avenae* inocula), the beneficial treatments had a more pronounced effect on the pathogen in thatch than in the underlying soil.

Data indicate that treatment effects on thatch and soil pH in this investigation (pH 6.1–6.8) had no important impact on the disease control observed. To better understand the relationship between rhizosphere pH in thatch and soil and disease severity, a rapid and accurate technique to measure soil water and rhizosphere pH is needed.

Table 2. Influence of nitrogen fertilizers, sulfur, and phenyl mercury acetate (PMA) applications to Penncross creeping bentgrass on thatch and soil pH

		pH					
		1984, Water[x]		1985, Water[x]		1985, CaCl[y]	
Treatment	**Application rate (kg/ha)**	**Thatch**	**Soil**	**Thatch**	**Soil**	**Thatch**	**Soil minus roots**
Ammonium sulfate	36.6 N	6.5 a[z]	6.1 a	6.6 ab	6.3 b	6.5 abc	6.8 a
Ammonium chloride	36.6 N	6.4 a	6.2 a	6.5 b	6.3 b	6.2 c	6.7 a
Urea	36.6 N	6.5 a	6.2 a	6.9 a	6.5 ab	6.6 ab	6.8 a
Sulfur 90G	36.6 S	6.4 a	6.2 a	6.7 ab	6.4 ab	6.3 bc	6.7 a
Sulfur 90G + ammonium sulfate	22.4 S + 22.4 N	6.5 a	6.3 a	6.7 ab	6.5 ab	6.4 bc	6.7 a
PMA 10L	0.3 Hg	6.6 a	6.2 a	6.9 a	6.5 ab	6.7 a	6.6 a
PMA 10L + sulfur 90G	0.3 Hg + 36.6 S	6.4 a	6.3 a	6.7 ab	6.4 ab	6.6 ab	6.8 a
PMA 10L + ammonium sulfate	0.3 Hg + 36.6 N	6.6 a	6.3 a	6.9 a	6.4 ab	6.6 ab	6.8 a
Untreated control	···	6.7 a	6.3 a	6.9 a	6.6 a	6.7 a	6.7 a

[x] Ten grams of each sample from each zone (i.e., thatch or soil) were allowed to equilibrate 1 hr in 10 ml of distilled water before measuring pH.

[y] Five grams of each sample from each zone (i.e., thatch or soil minus roots) were allowed to equilibrate 1 hr in 10 ml of 0.01 M CaCl solution before measuring pH.

[z] Means within a column followed by the same letter are not significantly different at $P = 0.05$ according to the Bayes LSD.

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