Interrelationships Between Fertility and Red Thread Fungal Disease of Turfgrass

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ABSTRACT

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In field plots treated with nitrogen (N), potash (K), and phosphorus (P), only 291 kg N/ha (highest rate of ammonium nitrate) in both 1980 and 1981 showed a significant ($P = 0.05$) reduction in severity of red thread foliar disease of perennial ryegrass (*Lolium perenne*) caused by *Laetisaria fuciformis*. Data in 1981 showed a significant ($P = 0.05$) N × K interaction whereby disease severity was reduced using intermediate levels of nitrogen (194 kg N/ha) and potassium (135 kg K/ha). Significantly ($P = 0.05$) lower disease severity ratings were observed in plots fertilized with 291 kg N/ha. Red thread disease severity was highest in plots treated with 98 kg N/ha (lowest rate used), regardless of the potassium level. Applications of phosphorus did not appear to affect disease severity. Tissue analysis showed a decrease in disease severity as potassium and nitrogen content increased in leaf tissue. Disease incidence and severity was higher in plots fertilized with the lowest level of nitrogen (98 kg N/ha) when foliar calcium content was low. At higher nitrogen levels (291 kg N/ha), disease severity increased with foliar calcium content. There was no apparent effect of phosphorus or potassium nutrition on turf quality. Best turf quality was achieved in plots receiving 291 kg N/ha; however, 194 kg N/ha produced acceptable turf quality for home lawns. Small amounts of nitrogen (24 and 49 kg N/ha) as single applications effectively reduced the severity of naturally occurring red thread disease within 1 mo of application, but turf treated with only hydrated lime and potassium showed no significant reduction in red thread disease.

Red thread disease incited by *Laetisaria fuciformis* (McAlp.) Burdsall (formerly attributed to *Corticium fuciforme* (McAlp.) Wakef.) (5), is a common problem on red fescue, *Festuca rubra* L., and perennial ryegrass, *Lolium perenne* L., in Maryland. When optimum conditions are present, a pink gelatinous mycelial growth completely covers the leaves of affected plants. Diagnosis of this disease is easiest in later stages of development when red thread-like structures (ie, mycelium) can be seen at the tips of grass blades. Although *L. fuciformis* does not attack the root system, it can severely damage the foliar portions of the turfgrass plant.

The severity of plant injury caused by red thread depends primarily on environmental conditions and vigor of susceptible plants. Fertilization practices are known to interact with environmental conditions affecting the red thread pathogen and the turfgrass host. Influence of host nutrition on turfgrass disease development has been investigated extensively (3,4,7,9,11,13–16). Such elements as nitrogen and calcium appear to influence turfgrass susceptibility by changing the physiological condition of the host. In general, high nitrogen fertility favors lush, succulent growth of turfgrasses, Rhizoctonia brown patch (4), Fusarium patch (11), and Drechslera leaf spot (14), whereas inadequate levels of nitrogen fertilizer retard growth of turfgrasses and favor Sclerotinia dollar spot (7) and Laetisaria red thread (16).

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This study was initiated to corroborate similar fertility studies conducted in geographical areas outside of the transition zone (a zone where neither cool-season nor warm-season turfgrasses are well adapted) and to further elucidate the relationship between red thread and fertilizer levels of nitrogen, potassium, and calcium in leaf tissues.

MATERIALS AND METHODS

Relationship between red thread and fertilizer levels of nitrogen, potassium, and calcium in leaf tissues (experiment 1). One-tenth hectare of perennial ryegrass, *L. perenne*, consisting of a blend of three cultivars, Pennfine, Citation, and Yorktown, was seeded on Chewacla-silt loam (fine loamy mixed thermic Fluvaquentic Dystrochepts) soil in April 1979. The field was divided into plots 3.08 m square and treatments began in the fall of 1979. Treatments were arranged in a split-split-plot design with three replicates. Main plots received 98, 194, or 291 kg/ha of nitrogen per year for 2 yr from ammonium nitrate. Nitrogen treatments (yearly rate) were divided equally into two fall applications applied on 15 October and 15 November in 1979 and into four equal applications applied on 15 April, 15 June, 15 October, and 15 November in 1980, and in the spring (April) of 1981, 25% of the yearly rate was applied. Each subplot received 0, 67, or 135 kg/ha of phosphate (P) from superphosphate in a single application during the fall of each year. Each sub-subplot received 0, 135, or 270 kg/ha of potassium (K) from potassium sulfate in a single application during the fall (October 15) of each year.

Each plot was rated separately each month during the growing season for turfgrass quality (linear scale integrating all factors of turfgrass quality) and for disease severity, using a visual scale of 1–9, where 1 = poor turf quality (low shoot density, poor uniformity, and poor surface smoothness) or 0–1% nondiseased; 3 = low density, moderate uniformity, and poor surface smoothness or 15.1–28% nondiseased; 5 = medium density, good uniformity, and moderate smoothness or 42.1–56% nondiseased; 7 = high density, moderate uniformity and surface smoothness; and 9 = best turf quality (ie, turf with high density and uniformity and good surface smoothness) or 99–100% nondiseased. Turf quality scores of 5 and 7 were considered acceptable for home lawn and golf course turfs, respectively. The test area was mowed at a height of 3.75 cm and irrigated and treated with herbicides as needed. No fungicides were used during the test period.

Leaf clippings were collected from each individual treatment when red thread disease was prevalent during the spring of the second year (1981) of the study. The tissues were dried for 48 hr at 46 C, ground to a powder, and sent to Pennsylvania State University, University Park, for elemental analysis. Each element in the analyses was quantified as a percent based on a 3-g sample of dry matter for each replicate within each treatment. This procedure was done to determine if there was an association between disease severity ratings and nitrogen, potassium, and calcium content in leaf tissue collected from plants in each of the fertility treatments. Regression analysis was used to determine if a relationship existed between the mean red thread disease ratings (obtained on four occasions in 1981) and fertility treatments.

The soil pH of each treatment in all four replicates was also determined by randomly sampling six areas of each 3.08-m section in the fall of 1980. The mean range of pH in the test plot area was 6.3–6.9.

Effect of a single fertilizer application on disease severity (experiment 2). The effect of a single application of nitrogen, potassium, and calcium on control of a naturally occurring red thread infestation was determined in June 1980. An experiment was conducted adjacent to experiment 1 in the field, and the turfgrass mixture, plot size, and management regime were the same as described for experiment 1. The plot area had not been fertilized since 15 November 1979. The experimental design was a randomized complete block with four replicates. The test area received the following nine separate fertility treatments: 12, 24, or 49 kg/ha of nitrogen from ammonium nitrate, 12, 24, or 49 kg/ha of potassium from potassium sulfate, and 21 or 42 kg/ha of calcium applied as a liquid suspension of hydrated lime. Control plots received no fertilizer or lime. Plots were rated for red thread disease before fertilizer treatments were applied, using a visual scale of 1–9 as described for experiment 1.

RESULTS

Significant differences ($P = 0.05$) in disease and quality ratings were observed among nitrogen treatments during both 1980 and 1981 (Table 1). Severity of the red thread disease significantly decreased and turf quality significantly increased with each increment of nitrogen applied.

In 1980, no significant differences in disease ratings or quality caused by potassium fertilization were observed (Table 2). In 1981, however, when the occurrence of the red thread disease was greater, significant differences ($P = 0.05$) in turf disease severity were evident in plots receiving 135 kg/ha of potassium compared with plots fertilized with 0 and 270 kg/ha of potassium. Although significant differences were achieved, the range of disease severity ratings among potassium level treatments was small (ie, 5.8 vs. 6.2).

The nitrogen and potassium interaction was significant in 1981 for red thread disease severity ratings (Fig. 1). Disease severity ratings were significantly lower ($P = 0.05$) among all plots receiving 291 kg/ha of nitrogen, regardless of the potassium level, compared with all other nitrogen-potassium treatments. Disease severity ratings were generally lower in plots receiving 194 kg/ha of nitrogen compared with plots receiving 98 kg/ha of nitrogen, regardless of the potassium level; however, few significant differences occurred among the potassium treatments. Minimal differences were obtained in disease severity in the 98- or 291-kg/ha nitrogen treatments, regardless of the potassium level. A significant interaction, however, occurred whereby disease severity was reduced where intermediate levels of nitrogen (194 kg/ha) and potassium (135 kg/ha) were applied.

Phosphorus treatments had no apparent effect on red thread disease severity or turfgrass quality in 1980 or 1981. No interaction among nitrogen, phosphorus, and potassium treatments in any combination was observed during either year.

The association between red thread disease severity in 1981 and nutrient element composition of leaves from treated plots was determined by linear regression. Because phosphorus had no apparent effect on red thread disease, this treatment was excluded from the regression analysis. Significant correlation coefficients were found between disease severity and nitrogen, potassium, and calcium content in leaves (Figs. 2–4). Percent potassium, nitrogen, and calcium in leaves represents a percentage range of the appropriate elemental content within tissues collected from treatments (n = 4 treatments × 3 replicates = 12).

Correlation coefficients were significant ($P = 0.05$) between percent foliar

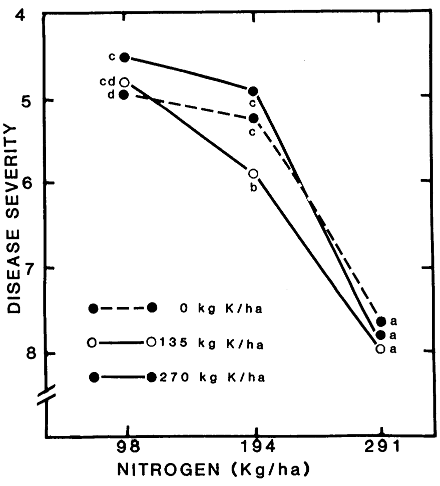

Fig. 1. Mean values of red thread disease scores in perennial ryegrass at three levels of nitrogen and potassium. Mean disease scores were based on visual estimates where 1 = high disease severity, all tillers blighted, and 9 = low disease severity, few or no tillers blighted. Points marked by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1. Severity of red thread disease and turfgrass quality ratings of perennial ryegrass as affected by nitrogen fertilization from ammonium nitrate

Nitrogen[w] (kg/ha)	Red thread disease ratings[x]		Turfgrass quality ratings[y]	
	1980	1981	1980	1981
98	6.4 c[z]	4.8 c	5.2 c	4.7 c
194	7.5 b	5.4 b	6.0 b	5.9 b
291	8.5 a	7.9 a	7.0 a	7.4 a

[w] Zero level not included because without some nitrogen added, ryegrass does not persist for more than one season.
[x] Values are means of visual estimates based on a 1–9 scale, where 1 = 0–1% of the leaves nondiseased, 3 = 15.1–28% nondiseased, 5 = 42.1–56% nondiseased, 7 = 70.1–84% nondiseased, and 9 = 99–100% nondiseased.
[y] Values are means of visual estimates based on a 1–9 scale, where 1 = poor turf quality (low shoot density, poor uniformity, and poor surface smoothness); 3 = low density, moderate uniformity, and poor surface smoothness; 5 = medium density, good uniformity, and moderate smoothness; 7 = high density, moderate uniformity and surface smoothness; and 9 = best turf quality, high density and uniformity and good surface smoothness.
[z] Means in columns with no letters in common differ at the 5% significance level according to Duncan's new multiple range test.

Table 2. Severity of red thread disease and turfgrass quality ratings of perennial ryegrass as affected by potassium fertilization from potassium sulfate

Potassium (kg/ha)	Red thread disease ratings[x]		Turfgrass quality ratings[y]	
	1980	1981	1980	1981
0	7.4 a[z]	5.8 b	6.0 a	5.9 a
135	7.5 a	6.2 a	6.0 a	6.0 a
270	7.5 a	6.0 b	6.1 a	6.0 a

[x] Values are means of visual estimates based on a 1–9 scale, where 1 = 0–1% of the leaves nondiseased, 3 = 15.1–28% nondiseased, 5 = 42.1–56% nondiseased, 7 = 70.1–84% nondiseased, and 9 = 99–100% nondiseased.
[y] Values are means of visual estimates based on a 1–9 scale, where 1 = poor turf quality (low shoot density, poor uniformity, and poor surface smoothness); 3 = low density, moderate uniformity, and poor surface smoothness; 5 = medium density, good uniformity, and moderate smoothness; 7 = high density, moderate uniformity, and surface smoothness; and 9 = best turf quality, high density and uniformity, and good surface smoothness.
[z] Means followed by the same letter in columns are not significantly different at the 5% level according to Duncan's new multiple range test.

potassium content and red thread disease severity in plots treated with 291 kg N and 135 kg K/ha, 194 kg N and 135 kg K/ha, and 194 kg N and 270 kg K/ha (Fig. 2). These data show that disease severity decreased with increasing levels of potassium within leaf tissues. No relationship between the other nitrogen-potassium treatments and foliar potassium content was observed.

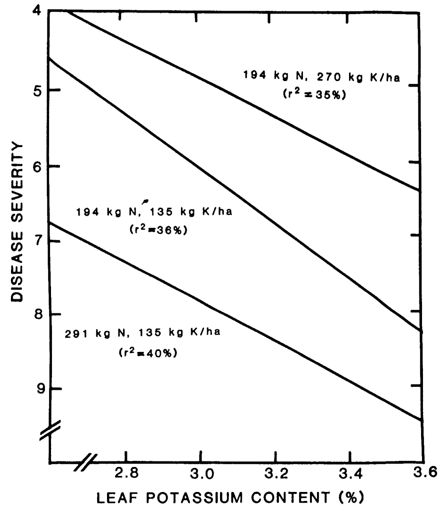

Fig. 2. Association between foliar potassium content in perennial ryegrass and red thread disease severity in plots treated with different levels of nitrogen and potassium fertilizer. Mean disease scores were based on visual estimates where 1 = high disease severity, all tillers blighted, and 9 = low disease severity, few or no tillers blighted.

Table 3. Effect of nitrogen, potassium, and lime on a natural infestation of red thread (*Laetisaria fuciformis*) disease on perennial ryegrass turf

	Disease ratings	
Treatment[w]	**1 Day before treatment**[x]	**30 Days after treatment**[y]
49 kg N/ha	4.0 a[z]	6.3 a
24 kg N/ha	4.0 a	5.9 a
12 kg N/ha	3.8 a	5.1 b
49 kg K/ha	4.3 a	5.0 b
24 kg K/ha	4.5 a	4.5 b
12 kg K/ha	3.5 a	4.7 b
42 kg Ca/ha	3.7 a	4.9 b
21 kg Ca/ha	4.5 a	4.7 b
Unfertilized	4.0 a	4.3 b

[w] N from ammonium nitrate, K from potassium sulfate, and Ca from hydrated lime.

[x] Red thread disease ratings were recorded before application of fertilizer and lime on 6 June 1980.

[y] Red thread disease ratings obtained 31 days after fertilizer and lime treatments were applied on 7 July 1980. Data are visual estimates based on a 1–9 scale, where 1 = 0–1% of the leaves nondiseased, 3 = 15.1–28% nondiseased, 5 = 42.1–56% nondiseased, 7 = 70.1–84% nondiseased, and 9 = 99–100% nondiseased.

[z] Means having the same letter in a column are not significantly different at the 5% level according to Duncan's new multiple range test. Each value is a mean of four replicates per treatment.

A linear relationship ($P = 0.05$) existed between foliar nitrogen content and disease severity in plots treated with 291 kg N and 135 kg K/ha, 291 kg N and 0 kg K/ha, and 194 kg N and 270 kg K/ha (Fig. 3). These data show that disease severity decreased with increasing levels of nitrogen in leaf tissues. No relationship between the other nitrogen-potassium treatments and foliar nitrogen content was observed.

The association between percent foliar calcium content and red thread disease severity depended on nitrogen treatments in plots treated with 291 kg N and 0 kg K/ha, 291 kg N and 135 kg K/ha, and 98 kg N and 0 kg K/ha (Fig. 4). In plots

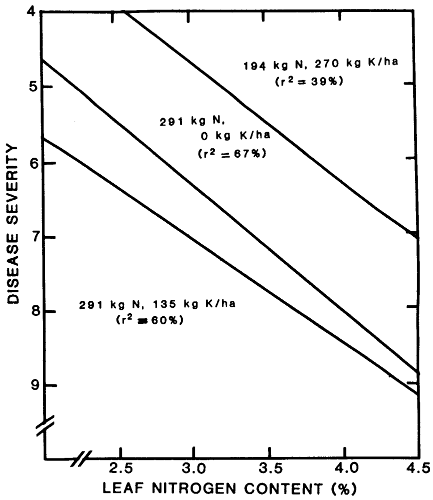

Fig. 3. Association between foliar nitrogen content in perennial ryegrass and red thread disease severity in plots treated with different levels of nitrogen and potassium fertilizer. Mean disease scores were based on visual estimates where 1 = high disease severity, all tillers blighted, and 9 = low disease severity, few or no tillers blighted.

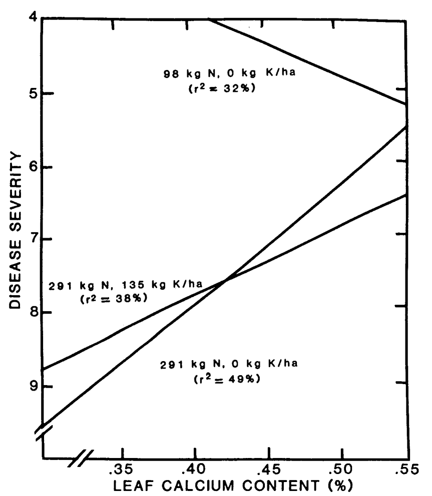

Fig. 4. Association between foliar calcium content in perennial ryegrass and red thread disease severity in plots treated with different levels of nitrogen and potassium fertilizer. Mean disease scores were based on visual estimates where 1 = high disease severity, all tillers blighted, and 9 = low disease severity, few or no tillers blighted.

treated with high nitrogen levels, disease severity increased as levels of calcium increased in leaf tissues, whereas in plots treated with low nitrogen levels, disease severity increased as foliar calcium content decreased. Data from leaf analysis of tissues collected from the other combination treatments did not reveal any significant association between calcium, nitrogen, or potassium nutrient tissue levels and disease severity.

In the second experiment, where a single fertilizer application was applied to plots with naturally occurring red thread disease, no significant differences in disease ratings were observed throughout the test area before these treatments were applied (Table 3). One month after fertilizers and lime were applied, perennial ryegrass turf in the 24 and 49 kg of nitrogen fertilizer per hectare treatments had significantly ($P = 0.05$) less red thread disease when compared with all other treatments including the unfertilized control (Table 3).

DISCUSSION

Our results support the theory that adequate nitrogen levels reduce severity of red thread disease by enhancing plant vigor. These findings agree with those of Muse and Couch (13) and Goss and Gould (9), who also showed that high nitrogen levels lowered the incidence and severity of the red thread disease. Our data showed that 49 and 24 kg/ha of nitrogen reduced red thread disease significantly ($P = 0.05$), whereas 12 kg/ha had no significant effect on disease severity (Table 3). Turf fertilized with the higher rates of nitrogen appeared greener and healthier. Because nitrogen stimulates vegetative growth, the turfgrass plant is able to replace injured tissues (recover) more rapidly than plants fertilized with lower rates of nitrogen; however, the lower incidence and severity of the red thread disease at higher nitrogen rates cannot be attributed entirely to enhanced plant vigor. Red thread disease development generally starts in the thatch or plant crown area and progresses upward on the foliage. Weekly mowing would not remove diseased foliage or reduce the number of diseased plot areas sufficiently to account for differences observed in the plots. The influence of nitrogen on growth of *L. fuciformis* on host leaves is, however, unknown.

Potassium has been shown to reduce the incidence and severity of the red thread disease on several grass species (8–10). No significant reduction in disease resulted from the use of potassium alone in this study (Table 3). Our data, however, support studies reported by Goss (8–10), which have shown that nitrogen interacts with potassium to reduce the severity of red thread disease. Our data showed a correlation between increasing levels of potassium in tissues and a decrease in severity of disease. Goss (8) also observed lower potassium levels in the tissue of plants severely infected by *L. fuciformis*. Furthermore, Goss and Gould (8) found a decrease in *L. fuciformis* infection after potassium was applied to red fescue and bentgrasses (*Agrostis* spp.).

The role of potassium in reducing the incidence and severity of diseases is not clearly understood. It has been hypothesized but not shown that reduced severity may be related to the ability of potassium to promote development of thicker outer walls in epidermal cells, thus inhibiting ingress of the pathogen (12). Also, because plant metabolism is greatly influenced by potassium, it has been suggested that a deficiency may alter the capacity of plants to actively resist infection (2).

Goss and Gould (9) also demonstrated that phosphorus applied with low levels of nitrogen reduced red thread disease. Additionally, there was an increase in injury by red thread disease when high rates of nitrogen were used in combination with phosphorus. Results from our tests do not substantiate these findings because our phosphorus-nitrogen treatments had no effect on disease severity.

Turf given a single application of hydrated lime showed no significant change in either the incidence or severity of the red thread disease (Table 3). These results agree with Bennett (3), who also found no reduction in red thread disease incidence in turf treated with 66 kg of limestone per hectare.

Application of liming materials supplies Ca^{++} to plant tissues. According to Couch (6), calcium as a nutrient element appears to exert a "profound" influence on disease susceptibility of turfgrasses. Muse and Couch (13) reported that calcium-deficient plants grown in silica sand in the greenhouse were more susceptible to infection by *L. fuciformis*. No field studies have been reported to substantiate these findings, however. Our results showed that calcium from hydrated lime was ineffective in reducing the incidence of this disease under field conditions within 1 mo of application to perennial ryegrass. Plants in the untreated control plots, however, were not deficient in calcium.

The role of calcium in red thread disease resistance may be related to its integral role as a constituent of plant cell walls. Disturbed membrane permeability or cell wall formation could affect growth and development of the fungal pathogen. Formation of calcium pectate in the middle lamella of cell walls is believed to aid in rendering plants resistant to fungal invasion (1). Calcium deficiency in plants may occur without being obvious but does result in disturbed membrane permeability (12). Bateman and Millar (1) have suggested that calcium increases host resistance to pathogens that produce pectin enzymes.

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