IV. BROWN PATCH SEVERITY IN PERENNIAL RYEGRASS AS INFLUENCED BY IRRIGATION, NITROGEN, PHOSPHORUS, AND POTASSIUM

SYNOPSIS

Brown patch (Rhizoctonia solani Kühn) is a common and destructive disease of turfgrasses. There is little information available regarding brown patch management by cultural practices. This two-year field study assessed the influence of irrigation, and nitrogen (N) source alone or in combination with phosphorus (P) and potassium (K) on brown patch severity. Perennial ryegrass (Lolium perenne L. cv. 'Caravelle') was subjected to either AM or PM irrigation. Sodium nitrate ($NaNO_3$), a quickly available non-soil reacting N-source was compared to sulfur-coated urea (SCU), a slowly available soil acidifying N-source. Fertilizer treatments were applied three (May-Sept-Oct) and six (Mar-May-June-Sept-Oct-Nov) times annually, representing lower and higher N application rates, respectively. Forty-nine kg N ha^{-1} were applied on each date. Plots were split with one-half treated with iprodione (3.1 kg ai ha^{-1}) on an extended 21-day interval. In non-fungicide-treated plots, brown patch severity was consistently reduced with AM-irrigation when compared to PM-irrigation. Glucose and fructose levels were lower in plants subjected to PM irrigation, reflecting the greater level of disease injury in PM-irrigated turf. Non-fungicide-treated plots fertilized with SCU generally had lower blight levels than $NaNO_3$-treated plots, regardless of N rate. Phosphorus (72 kg ha^{-1} yr^{-1}) and K (150 kg ha^{-1} yr^{-1}) reduced blight at the high N rate for both N-sources. Sulfur-coated urea applied at the high N rate plus P and K

resulted in blight levels equivalent to low N. Fungicide-treated plots receiving the high rate of N from SCU plus P and K had the highest summer quality in both years. While low soil pH was associated with less blight, the slow N release characteristics of SCU were probably a more important factor in disease reduction than soil acidification.

INTRODUCTION

Brown patch (Rhizoctonia solani Kühn) is an important and widespread fungal disease of cool- and warm-season turfgrasses worldwide (Smith et al., 1989). Bentgrasses (Agrostis sp.), perennial ryegrass (Lolium perenne L.), and tall fescue (Festuca arundinacea Schreb.) are among the most susceptible cool-season grasses to this disease (Smiley et al., 1992). Very little information exits regarding the influence of irrigation, nitrogen (N) source, phosphorus (P), and potassium (K) on brown patch.

Irrigation practices (i.e., timing, frequency, and duration) have been shown to influence the severity of some turfgrass diseases. For example, Madison et al. (1960) reported a reduction in pink snow mold (Fusarium nivale [Fr.] Ces.) in turf irrigated in the morning. Deep and infrequent irrigation was associated with reduced summer patch (Magnaporthe poae Landshoot and Jackson) severity (Davis and Dernoeden, 1991). Conversely, necrotic ring spot (Leptosphaeria korrae Walker and Smith) injury was reduced in turf by light, daily irrigation (Melvin and Vargas, 1994). While the impact of irrigation on brown patch has not been documented, Oakley (1924) suggested that early morning watering may reduce brown patch on putting green turf.

The amount and source of N can influence disease development in turf, and this has been documented for several turf diseases (Smiley et al., 1992; Dernoeden, 1993). For brown patch, Bloom and Couch (1960) and Watkins et al. (1990) reported greater disease incidence in turf treated with high levels of water soluble N. Oakley (1924, 1925) suggested a well-screened, loamy compost topdressing amended with an organic or an ammonium-based N-source would reduce brown patch severity on Agrostis spp. putting greens. Published data have been inconsistent regarding the influence of N-source on brown patch. In one-season field studies, Nelson and Craft (1990) and Soika and Sanders (1991), reported that brown patch was reduced by natural organic N-sources (i.e., organic fertilizers composed of plant and animal meals, animal manures, sewage sludge or leaves). Peacock and Daniel (1992), however, observed no effect from natural organic N (Ringer Turf Restore 10N-1P-5K with or without a biological inoculum amendment) in a greenhouse study. Green et al. (1994) reported that the severity of large patch (incitant R. solani) in zoysiagrass (Zoysia japonica Steud.) was not influenced by urea, ureaformalde-hyde, poultry litter, sewage sludge, or bovine waste in a two-year field study.

In addition to N fertility, P and K can influence disease levels in turfgrasses (Smiley et al., 1992; Watschke et al., 1994). The effect of P and K on turfgrass diseases was thoroughly reviewed by Turner (1986). He (1986) concluded that P and K applications either reduced or had a limited affect on disease severity. According to Turner (1986), the influence of P and K was dependent on the amount of N applied. A balanced N, P, and K fertility program was shown to influence the severity of several turfgrass diseases. For example, N, P, and K applications, when compared to N applied alone,

were reported to reduce the severity of dollar spot (Sclerotinia homoeocarpa Bennett) (Couch and Bloom, 1960), Fusarium blight (Fusarium spp.) (Cutright and Harrison, 1970), take-all patch (Gaeumannomyces graminis [Sacc.] Arx. & Oliver var avenae [Turner] Dennis) (Goss and Gould, 1967), and stripe smut (Ustilago striiformis [West.] Niessl.) (Hull et al., 1979). Dernoeden et al. (1991), reported that N + K reduced spring dead spot (Leptosphaeria korrae Walker and Smith) more effectively than N alone.

For brown patch, Shurtleff (1953) observed no differences in disease severity in turf subjected to 15 balanced and unbalanced nutrient solutions. In a greenhouse investigation involving turf grown in a continuous drip-culture system, Bloom and Couch (1960) reported no difference in brown patch incidence in turf receiving high or low levels of P and K alone. Brown patch, however, was affected by varying N levels in combination with P and K (Bloom and Couch, 1960). They (1960) concluded that turf subjected to low N and normal P and K levels had reduced plant vigor and less brown patch, however, disease proneness was accentuated by a decline in plant vigor. Bloom and Couch (1960) also observed that high N plus normal P and K was associated with greater disease development, when compared to turf treated with high N plus high P and K.

Field-based information that integrates irrigation, fertilization, and fungicide use on brown patch severity is not available. Integrated pest management (IPM) programs for turfgrass disease management involve a combination of cultural practices and chemical use to ensure quality turf with minimal fungicide inputs (Bruneau et al., 1992; Smiley et al., 1992). To develop a realistic IPM program for brown patch, it is necessary to investigate the influence of the aforementioned cultural practices with reduced fungicide

inputs. Brown patch control methods that emphasize reduced fungicide inputs, while maintaining acceptable turfgrass quality and function, are needed in golf course management and in commercial residential lawn care programs.

Therefore, the primary objectives of this field investigation were to evaluate the effect of irrigation timings (AM versus PM) and N-sources (sulfur-coated urea versus sodium nitrate), P and K (applied in combination with low and high N), and a fungicide on brown patch severity in 'Caravelle' perennial ryegrass. The fungicide iprodione [3-(3,5-dichloro-phenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidine-carboxamide)] was applied at the recommended rate, but was delivered on an extended 21-day interval rather than the 10 to 14 day interval normally recommended for brown patch (Watschke et al., 1994). The goal was to identify irrigation and fertilization parameters, in combination with a reduced fungicide application frequency, which would provide an acceptable level of brown patch suppression compatible with an IPM program. Other objectives were to determine irrigation, fertilizer, and fungicide treatment effects on R. solani mycelium cover, overall turfgrass quality, turfgrass damage from other diseases, crown tissue carbohydrate content, and soil pH.

MATERIALS AND METHODS

This field study was initiated in September 1991 at the University of Maryland Cherry Hill Turfgrass Research and Education Facility in Silver Spring, MD. Soil was a Sassafras sandy loam (fine-loamy, siliceous, mesic Typic Hapludult) with an initial pH of 6.0 (measured in distilled water) and 14

mg organic matter g^{-1} soil. Initial P and K levels were 175 kg ha^{-1} (high) and 98 kg ha^{-1} (medium), respectively.

The study area consisted of eight, 36.6 m^2 blocks. In August 1991, an automated irrigation system was installed for each block prior to turf establishment. Along the perimeter of each block, eight Hunter S-Type Model 15-A (Hunter Industries, San Marcos, CA) irrigation sprinklers were installed and connected to a Weathermatic Mark 12A (Telsco Industries, Garland, Texas) irrigation controller. After the irrigation system was installed, the soil was tilled, cultipacked, raked and leveled. Prior to seeding, 24 kg N (urea 46N-0P-0K) ha^{-1} were applied to the seedbed. On 10 September 1991, 294 kg ha^{-1} 'Caravelle' perennial ryegrass were seeded in two directions with a drop spreader. The site was then lightly raked and rolled, and irrigated daily for two weeks. Seed germination was first observed on 16 September 1991.

To ensure uniform brown patch severity and distribution within the study area, 80 g (i.e., 172 kg ha^{-1}) of R. solani inoculum were applied uniformly to each plot with a shaker jar on 30 June 1992, and the site was irrigated immediately with 2 cm water. Inoculum was prepared by soaking perennial ryegrass seed in water overnight. The moist seed was autoclaved twice for 1 hr on two successive days. The R. solani isolate was identified as belonging to anastamosis group 1-IA, and was grown on potato dextrose agar. Sections of agar with R. solani were mixed into the cooled, autoclaved seed. The seed was placed in a plastic container, covered with aluminum foil, and allowed to incubate for 6 wk at room temperature. Periodically the seed was stirred to enhance fungal colonization.

The experiment was arranged as a split-split plot design with four replications. Whole plots measured 3.0 by 12.2 m and were subjected to the

two irrigation schedules. The sub-plots measured 1.5 by 3.0 m and consisted of eight fertilizer treatments. The fertilizer treatments were initiated in October 1991 (application dates listed in Appendix D, Table 41), and the irrigation treatments began in June 1992. The initial intent was not to use a fungicide, however, severe turf damage from brown patch became evident in July 1992. Plots were therefore split, and iprodione was applied curatively to one-half of each plot on 28 July and 17 August 1992. Fungicide-treated and untreated sub-sub-plots measured 1.5 by 1.5 m. In 1993, iprodione treatments were initiated on 7 June, before disease symptoms became evident. Iprodione was applied at 3.1 kg ai ha^{-1} with a CO_2 pressurized (262 kPa) sprayer equipped with an 8010 flan fan nozzle, and calibrated to deliver 1018 L ha^{-1} water. Dates of application are footnoted in Tables 1 and 3.

Plots were mowed with a rotary mower at 2.5 cm in the fall of 1991. Thereafter, plots were mowed three times weekly with a reel mower to a height of 1.7 cm, and twice weekly in the spring and fall of 1992 and 1993. Turfgrass clippings were removed.

Sprinkler-head valve pressure was set at 182 kPa for optimum performance as recommended by the manufacturer. For the two irrigation schedules, plots either were irrigated at 5 AM or at 10 PM. With both schedules, plots were irrigated for 30 min and approximately 3.0 cm water were applied. From June through August 1992 and 1993, plots were irrigated three times weekly. Since only one block could be irrigated at a time, the order of irrigating blocks was changed weekly.

Two N-sources, sodium nitrate ($NaNO_3$, 16N-0P-0K) and sulfur-coated urea (SCU, 37N-0P-0K), were applied at two rates (147 versus 294 kg N ha^{-1} yr^{-1}) alone or with P (treble superphosphate, 0N-19P-0K) and KCl (muriate of

potash, 0N-0P-51K) in a 3:1:2 ratio. Turf subjected to lower N received 49 kg N ha^{-1} in May, September, and October. At the higher N rate, plots received 49 kg N ha^{-1} in September, October, November, March, May and June. Where applicable, plots received 12 kg P ha^{-1} and 25 kg K ha^{-1} with each application. Fertilizer application dates are listed in Appendix D, Table 41.

Plots were assessed visually for disease severity using the Horsfall-Barratt scale (Horsfall and Cowling, 1978; Schumann and Wilkinson, 1992). Visual disease severity ratings in the Horsfall-Barratt scale are divided into 12 classes reflecting a range of percent plot area diseased as follows: 0 (0%), 1 (1-2%), 2 (3-5%), 3 (6-11%), 4 (12-24%), 5 (25-49%), 6 (50-74%), 7 (75-87%), 8 (88-93%), 9 (94-96%), 10 (97-99%), and 11 (100%). Percent area diseased was the desired variable, therefore each class value was converted to a percentage according to the midpoint rule prior to statistical analysis (Campbell and Madden, 1991). Subjectively, brown patch ratings of > 2% and > 5% plot area blighted would be unacceptable for high quality commercially managed turf or turf maintained in an IPM program, respectively. During periods conducive for disease development, plots were rated weekly for blight and active R. solani foliar mycelium, and for residual injury. The final assessment of damage after the disease subsided and turf had begun to recover was considered residual injury. Dollar spot and red thread (Laetisaria fuciformis [McAlpine] Burdsall) were assessed when present.

Visual quality ratings were taken twice-weekly during active brown patch periods and monthly thereafter. Overall turf quality was rated on a 0 to 10 scale, as described by Skogley and Sawyer (1992), where 0 = entire plot area brown or dead and 10 = optimum color and density. Subjective quality

ratings > 9.5, > 8.5, and > 7.5, and < 6.9 were considered excellent, good, fair, or unacceptable; respectively, for a perennial ryegrass fairway or lawn maintained in an IPM program. Quality data were combined for each season of the year and statistically analyzed. Turf quality ratings between 21 March and 20 June were combined for the spring; ratings between 21 June and 20 September were combined for summer; ratings between 21 September and 20 December were combined for fall; and ratings between 21 December and 20 March were combined for spring.

Carbohydrate content, specifically glucose, fructose, and sucrose, was determined by sampling ten plant crowns per plot (fertilizer treatment sub-plots without iprodione) on 10 September 1993. Plant crowns were removed, cleaned of soil and debris, and immediately stored in ice. Samples were freeze-dried prior to grinding. Samples were ground in a Wiley-Mill and tissues were passed through a 40-mesh (425-µm) screen. Carbohydrate extraction and analysis were performed according to the procedures described by Slaughter and Livingston (1994). Briefly, 20 mg freeze-dried, ground tissue were combined with 10 ml of boiling, deionized water in sterilized test tubes. Next, tissue were homogenized for 60 sec in a polytron blender. To halt enzyme activity, the tissue was immersed in a 95°C water bath for 30 min. Afterward, extracts were filtered through glass fiber filter discs (Nucleopore Filters, VWR Scientific, Bridgeport, NJ) and the volume adjusted to 10 ml with distilled water. Next, 2 ml aliquots of the extracts were filtered through Dowex-50W strongly acidic cation exchange resin (Sigma Chemical Co., St. Louis, MO), then 3 ml distilled water were filtered through the resin for a final volume of 5 ml. Carbohydrate analyses were perfomed on the final 5 ml solutions with high performance anion exchange chromatography with

pulsed amperometric detection. The final 5 ml solutions were analyzed for glucose, fructose, and sucrose concentration using a Dowex 4000 Series Bio LC Carbohydrate System (Dionex, Sunnyvale, CA).

Soil pH was determined by randomly removing ten, 2 cm diam by 6 cm deep soil plugs from each plot on 16 September 1993. Soil plugs were divided into 0 to 3 cm and 3 to 6 cm zones. Soil from each plot and sampling zone was mixed, air dried, and pulverized with a soil grinder. Soil pH was determined according to the procedures described by Smiley (1972). Briefly, a 5 g soil sample was combined with 10 ml of 0.01 M calcium chloride solution. The mixture was allowed to equilibrate for 1 hr before measuring pH with an electronic meter (Corning Model 7 pH Meter, Corning Science Products, Medfield, VA).

Soluble salt content in the turfgrass root zone was determined at the conclusion of the field study on 2 October 1993. Soil was sampled by randomly removing ten, 2 cm diam by 10 cm deep soil plugs, according to the field sampling procedures described by Harivandi et al. (1992). Soil plugs for each plot were mixed to ensure a uniform and representative sample. The composite soil samples from each plot were analyzed for soluble salt content with a Beckman Solu-bridge (Beckman Corp., Cedar Grove, NJ) at the Soils Testing Laboratory, University of Maryland, College Park, MD.

In April 1992 and 1993, 0.55 kg ai ha^{-1} dithiopyr [3,5-pyridine-dicarbothioic acid, 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-5,5-dimethyl ester] were applied for preemergence smooth crabgrass (Digitaria ischaemum [Schreb. ex Schweig] Schreb. ex Muhl.) control. Plots were spot-treated for broadleaf weeds on 11 June 1992 and for annual fleabane (Erigeron annuus [L.] Pers.) on 28 June 1993 with a pre-packaged mixture of

2,4-D [2,4-dichloro-phenoxy-acetic acid] + dicamba [3,6-dichloro-o-anisic acid] + MCPP [2-([4-chloro-o-toly]oxy) propionic acid]. To control dollar spot on 13 May 1993, 1.5 kg ai ha^{-1} chlorothalonil [2,4,5,6-tetrachloro-isophthalonitrile] were applied. On 17 May, 3 and 20 June, and 6 July 1993, 0.2 kg ai ha^{-1} fenarimol [2-(2-chloro-phenyl)-2-(4-chlorophenyl)-5-pyrimidine-methanol] were applied to control dollar spot or red thread. Fenarimol was used because it has little or no activity on brown patch at the low rate applied (P.H. Dernoeden, personal communication). Isosafos [O-(5-chloro-1-1-[methyl-ethyl]-1H-1,2,4-triazol-3-yl) O,O-diethyl- phosphorothioate] was applied at 1.2 kg ai ha^{-1} to control ant (Monomorium spp.) activity on 23 June and 9 July 1992, and 10 June 1993. On 2 and 26 August 1993, 2.0 kg ai ha^{-1} chlorpyrifos [O,O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate] were applied for ant control.

All data were subjected to analysis of variance performed on Statistical Analysis Software (SAS Institute, 1985). Separation of significantly different treatment means or treatment interactions were calculated with Fisher's protected least significant difference (LSD) test at $P \leq 0.05$ (Steel and Torrie, 1980; Madden et al., 1982). The appropriate LSD values for multiple treatment comparisons were determined from standard error calculations as described in Steel and Torrie (1980). Brown patch severity data were used to calculate the area under the disease progress curve (AUDPC) and area under the crop recovery curve (AUCRC), expressed as percent disease X day. Area under disease progress curve describes the course of the epidemic over time (Waggoner, 1981); whereas, Lawton and Burpee (1990) desribe AUCRC as an estimate of postepidemic regrowth of foliage or other vegetative plant parts. The AUDPC and AUCRC were calculated by the

following formula: $\sum[(y_i + y_{i+1})/2][t_{i+1} - t_i]$, where i = 1,2,3,...n-1, y_i is the amount of disease and t_i is the time of the *i*th rating (Shaner and Finney, 1977; Berger, 1988). Data collected between 7 July to 24 August 1992 and 9 July to 24 August 1993 were used to calculate AUDPC. Data collected between 25 August to 7 October 1992 and 25 August to 5 October 1993 were used to calculated AUCRC. Disease progress and crop recovery curve data were statistically analyzed as previously described. Disease progress and crop recovery curves also were analyzed as a split-split plot design combined over two years (McIntosh, 1983). Where appropriate, data were subjected to correlation and regression analysis according to procedures described in Draper and Smith (1981), and Freund and Littell (1991).

RESULTS AND DISCUSSION

Brown patch blight throughout the season is described by the AUDPC, whereas AUCRC values reflect turf recovery in late summer and early fall. Combined analyses of AUDPC and AUCRC data revealed significant treatment interactions (Appendix D, Table 42). Therefore, AUDPC and AUCRC data were analyzed separately by year. Foliar R. solani mycelium data are presented for days when there were significant or important treatment effects. Blight and turf recovery data from representative dates are provided to show the actual amount of disease damage.

BROWN PATCH BLIGHT IN 1992

The site was inoculated with R. solani on 30 June 1992, and low disease levels (i.e., ≤ 4% plot area blighted) in all plots were first detected on 7 July. On 16 July, blighting increased slightly to ≤ 9% in all plots. A severe

brown patch infection event occurred on 24 July, which was followed by extensive blighting from late July through August. As noted previously, fungicide use was not originally planned, but iprodione treatments were initiated on 28 July due to extensive blighting.

Irrigation. Before iprodione was applied on 28 July, blight was significantly lower in AM versus PM-irrigated turf, averaging 21 and 73% plot area blighted, respectively (Table 11). Although blight levels increased dramatically in AM-irrigated turf, damage in PM-irrigated plots remained greater on 6 August. Persistent warm and humid weather conducive for brown patch development continued into early August. Therefore, iprodione applied on 28 July did not have a significant impact on brown patch on 6 August. By mid-to-late August, turf began to recover and blight levels remained lower in AM-irrigated turf, regardless of fungicide use. Despite severe blighting in July and August, particularly in PM-irrigated plots, all plots showed equivalent amounts of residual injury in September.

The AUDPC values confirm that greater disease severity had occurred in PM-irrigated turf. Because iprodione was not applied until late July when extensive injury was evident, it had no affect on disease severity as measured by the AUDPC. There were no AUCRC (i.e., residual blight) differences among irrigation and fungicide treatments.

Fertilizer. Foliar R. solani mycelium and blight data from selected dates are presented in Table 11. Blight levels among plots were similar and ranged from 2 to 9% of plot area blighted on 7 and 16 July. On 24 July, foliar mycelium levels were greatest in turf treated with high N plus P and K. Extensive damage (i.e., ≥ 37% plot area blighted) among all treatments was noted on 28 July. Despite high levels of foliar mycelium in high N plus P and

K-treated plots on 24 July, turf treated with SCU plus P and K were among the least injured on 28 July. Turf fertilized with $NaNO_3$ was most severely blighted on 28 July, but blight data did not differ from plots fertilized with the high rate of SCU alone.

By 6 August, disease levels among all fertilizer and fungicide treatments ranged from 70 to 87% plot area blighted with few significant differences among non-fungicide-treated plots (Table 11). On 6 August, blight was generally higher in turf treated with $NaNO_3$, regardless of P and K or fungicide application. Iprodione applied on 28 July did not have a significant impact on brown patch by 6 August, however, a beneficial effect was most notably observed in SCU-treated plots by 17 August.

On 17 August, brown patch was generally more severe in all $NaNO_3$-treated plots (range of 22 to 50% plot area blighted) versus turf treated with SCU (range of 7 to 23%) (Table 11). Blight levels, however, decreased in iprodione-treated turf, especially in all SCU-treated plots ($\leq$ 10% blight), when compared to $NaNO_3$-treated plots ($\geq$ 22%). Interestingly, the low rate of SCU plus P and K and SCU alone in non-fungicide-treated plots had blight levels equivalent to counterpart fungicide-treated plots. This also was observed on 24 August. While turf continued to show signs of recovery, blight levels remained highest in plots receiving $NaNO_3$ without P and K in non-fungicide-treated plots on 24 August. Where iprodione was applied, plots treated with $NaNO_3$ at the high N rate had higher blight levels than counterpart SCU-treated plots.

Turf treated with the high rate of $NaNO_3$ showed highest residual blight injury on 7 September (Table 11). By 28 September, residual blight was

similar among all treatments, with greater injury still evident in plots treated with the high rate of $NaNO_3$ without P and K.

Except for low N treatments plus iprodione, AUDPC values were greater for $NaNO_3$ versus counterpart SCU-treated plots (Table 11). Fungicide-treated SCU plus P and K plots had lowest AUDPC values, which did not significantly differ from all other SCU-treated plots with or without iprodione. Turf treated with 294 kg N ha^{-1} yr^{-1} from $NaNO_3$ were slowest to recover (i.e., highest AUCRC values). In general, $NaNO_3$-treated plots were slower to recover when compared to SCU-treated turf. Except for the low rate of N plus P and K, SCU-fertilized plots had lower AUCRC values versus counterpart $NaNO_3$-treated plots.

TURFGRASS QUALITY IN 1992

Irrigation. Turf quality was poor (i.e., $\leq$ 6.4 quality rating) in spring (Table 12). Since iprodione was not applied until 28 July, extensive blight was observed in both non-fungicide and fungicide-treated turf during the summer. Unacceptable summer quality (i.e., average = 5.8) therefore was recorded in AM and PM-irrigated plots, regardless of fungicide treatment. Fertilizer applied in September assisted in turf recovery during the fall. Average fall quality was fair (i.e., $\geq$ 7.3) in all irrigation by fungicide treatments, however, winter quality decreased equally among all treatments (i.e., $\leq$ 6.6).

Fertilizer. In spring, turf treated with SCU at 294 kg N ha^{-1} yr^{-1} had the highest quality (average = 6.9) (Table 12). Quality for all other treatments ranged from 5.5. to 6.3 in the spring. As noted previously, iprodione was applied after extensive blighting occurred, therefore summer quality ratings were similar among most treatments. Fair quality (rating = 7.1), however, was observed in turf treated with the high rate of SCU plus P and K, regardless of

fungicide treatment. Very poor quality (i.e., ≤ 6.0) was associated with all remaining treatments. The addition of P and K to the high N rate was associated with increased quality when compared to high N alone.

In the fall and winter, similar quality ratings were noted among fungicide and non-fungicide-treated plots (Table 12). In the fall, all fertilizer treatments were associated with improved quality (i.e., ≥ 7.2), except turf treated with $NaNO_3$ at 294 kg N ha^{-1} yr^{-1} without P and K (average = 6.7). Best winter quality (i.e., ≥ 6.6) was noted in turf treated with high N, regardless of N-source. Turf treated with the high rate of SCU plus P and K had higher (not significant) quality (average = 7.1) than turf fertilized with the high rate of SCU without P and K (average = 6.7). Winter quality was poorest (i.e., ≤ 6.2) in plots treated with the low rate of $NaNO_3$.

BROWN PATCH BLIGHT IN 1993

Irrigation. Foliar R. solani mycelium was first observed on 4 July and noticeable blight was first recorded on 9 July. Iprodione suppressed the appearance of foliar mycelium on 4 July, whereas non-fungicide-treated turf had foliar mycelium cover ranging from 18 to 25% (Table 13).

Non-Fungicide-Treated Irrigation Plots. Brown patch again was severe in 1993. In non-fungicide-treated turf, unacceptable blighting was first observed on 9 July (Table 13). Between 9 and 15 July, blight was greater in PM-irrigated turf. From 28 July to 24 August, brown patch severity levels for both AM and PM-irrigated turf ranged from 20 to 44% plot area blighted. Because brown patch pressure persisted throughout August, turf was slower to recover in September 1993 compared to September 1992. Between 15 September and 5 October 1993, fall fertilization contributed to increased turf recovery, but residual injury was greatest in non-fungicide-treated plots. The

seasonal AUDPC values show that PM-irrigation encouraged brown patch in non-fungicide-treated plots. Values for the AUCRC were similar for AM and PM-irrigated turf, but non-fungicide-treated turf was slower to recover.

Fungicide-Treated Irrigation Plots. In 1993, iprodione was applied preventively starting on 7 June. Brown patch was reduced in both AM and PM-irrigated turf treated with iprodione (Table 13). Blight levels in PM-irrigated turf, however, were generally unacceptable (i.e., > 5%) in August. The AUDPC and AUCRC values for fungicide-treated turf were lower than non-fungicide-treated turf. No differences in AUDPC or AUCRC values were observed between AM and PM-irrigated plots treated with iprodione.

Fertilizer. On 4 July, R. solani foliar mycelium was observed only in non-fungicide-treated plots (Table 13). There was generally more mycelium in turf receiving high N, when compared to low N. Greater amounts of foliar mycelium were observed in plots treated with 294 kg N ha^{-1} yr^{-1} from $NaNO_3$ (with or without P and K) and SCU at 294 kg N ha^{-1} yr^{-1} (without P and K). A lower mycelium level was associated with 294 kg N ha^{-1} yr^{-1} from SCU plus P and K versus the same amount of SCU without P and K. Foliar mycelium levels in turf treated with the high rate of $NaNO_3$, but not the high rate of SCU, corresponded to higher blight levels in those plots throughout July and August.

Non-Fungicide-Treated Fertilizer Plots. Unacceptable blight levels were first recorded on 9 July (Table 13). Greater blight levels were associated with 294 kg N ha^{-1} yr^{-1} from $NaNO_3$, and lower levels with SCU-treated turf at this time. From 9 July through 24 August, turf treated with the high rate of $NaNO_3$ had consistently higher blight levels (ranging from 39 to

77% plot area blighted). On 15 and 28 July, plots treated with SCU at 294 kg N ha^{-1} yr^{-1} (without P and K) had lower blight levels versus turf that received the high rate of $NaNO_3$ (with or without P and K). On 28 July and 18 August, plots that received SCU without P and K had more blight than plots treated with SCU plus P and K. This beneficial effect (i.e., reduced blighting) from P and K only occurred at the high N rate in non-fungicide-treated turf.

During July and August in non-fungicide-treated turf, SCU-treated plots and plots receiving 147 kg N ha^{-1} yr^{-1} from $NaNO_3$ had blight levels lower than turf treated with $NaNO_3$ at 294 kg N ha^{-1} yr^{-1}. When compared to counterpart $NaNO_3$-treated rates, consistently lower blight ratings were observed in SCU-treated plots in August. Throughout most of the season, blight levels in non-fungicide-treated plots receiving the low rate of N from SCU and the high rate of SCU with P and K had blight levels equivalent to fungicide-treated plots.

Except for non-fungicide-treated plots receiving high N from $NaNO_3$ (with or without P and K) turf began to recover by 15 September. As late as 5 October, turf that received high N from $NaNO_3$ continued to exhibit greater residual injury (≥ 8% plot area damaged), when compared to all other fertilizer treatments (≤ 3%) in non-fungicide-treated plots.

The AUDPC data show that greater disease severity was associated with 294 kg N ha^{-1} yr^{-1} from $NaNO_3$ (without P and K), followed by plots receiving 294 kg N ha^{-1} yr^{-1} from $NaNO_3$ plus P and K (Table 13). Data collected in 1993, but not 1992, also showed that there was more injury with high N versus low N alone for both fertilizers in non-fungicide-treated plots. AUDPC values confirmed that P and K helped to reduce brown patch with

both N-sources, but only at the high N rate in non-fungicide-treated plots. Phosphorous and potassium, however, had no effect on brown patch severity with both N-sources at the low N rate.

Fungicide-Treated Fertilizer Plots. Iprodione effectively prevented the appearance of foliar R. solani mycelium on 4 July, and there was no severe blighting on 9 and 15 July (Table 13). Severe blight in fungicide-treated plots was first observed on 28 July in $NaNO_3$-treated turf (high N without P and K). From 28 July through 24 August, iprodione effectively reduced blight to acceptable levels (≤ 5%) or marginally acceptable levels (≤ 9%) in all plots except turf treated with 294 kg N ha^{-1} yr^{-1} from $NaNO_3$ (with or without P and K) or 294 kg N ha^{-1} yr^{-1} from SCU (without P and K). Fungicide-treated SCU plots (both N rates) plus P and K had blight levels ≤ 5% on all rating dates in 1993.

In fungicide-treated turf, plots that received the high rate of $NaNO_3$ (without P and K) had the highest AUDPC and AUCRC values, which also were equivalent to non-fungicide-treated turf (Table 13). Even in fungicide-treated plots, there was more injury at the high rate versus the low rate of N from $NaNO_3$ where P and K were not applied. Hence, high N from the water soluble $NaNO_3$ greatly enhanced disease susceptibility, which resulted in more severe blighting. Turf treated with SCU (both N rates plus P and K) had similar AUDPC and AUCRC values in both fungicide and non-fungicide-treated plots. No other differences in AUDPC or AUCRC values were observed among the remaining fertilizer treatments in iprodione-treated turf.

TURFGRASS QUALITY IN 1993

Irrigation. Overall turf quality in spring 1993 was fair (i.e., ≥ 7.1) among treatments (Table 12). In the summer, severe brown patch pressure

contributed to poor turf quality (i.e., ≤ 6.0) in non-fungicide-treated turf. Fungicide-treated turf exhibited higher quality (average = 6.9) in the summer. All treatments were associated with fair quality (i.e., ≥ 7.0) in the fall, however, iprodione-treated plots had improved quality (average = 7.7) when compared to non-fungicide-treated turf (average = 7.0).

Fertilizer. Fair spring quality (i.e., ≥ 7.5) was observed in plots that received the high rate of $NaNO_3$ or SCU (Table 12). All plots fertilized with low N had poor spring quality (i.e., ≤ 6.8).

All non-fungicide-treated plots had unacceptable summer quality (Table 12). Among non-fungicide-treated plots, those that received the high rate of SCU plus P and K had the highest summer quality rating (6.7), when compared to the remaining fertilizer treatments (rating ≤ 6.3). Lowest quality was observed in non-fungicide-treated turf fertilized with $NaNO_3$, especially at the high N rate. Iprodione-treated, $NaNO_3$ plots had summer quality ratings equivalent to non-fungicide-treated plots. In fungicide-treated turf, the high rate of SCU with P and K produced the best summer quality (rating = 7.9). Fair quality (ratings = 7.0 to 7.3), however, also was observed in fungicide-treated SCU plots receiving high N alone or low N plus P and K.

Improved fall quality was associated with all treatments, regardless of fungicide use. Highest quality (rating = 8.1) was noted in fungicide-treated SCU (high N plus P and K), but this rating did not vary significantly from many other treatments (Table 12). Unacceptable quality was observed in non-fungicide-treated plots fertilized with the low rate of N from SCU (without P and K) and high N from $NaNO_3$ (with P and K). The aforementioned treatments, however, did not vary significantly in quality from most other non-fungicide-treated plots.

CARBOHYDRATE ANALYSES IN 1993

Carbohydrate levels from only non-fungicide-treated plants were quantified, and glucose, fructose, and sucrose data are presented in Appendix D, Table 43. Only glucose and fructose concentrations were affected by irrigation. Crown tissue glucose and fructose levels were greater in AM-irrigated plots (averaging 38 and 78 mg g^{-1}, respectively) when compared to turf irrigated at night (averaging 26 and 45 mg g^{-1}, respectively). Low levels of carbohydrate reserves are generally an indication of plant stress and injury (Zanoni et al., 1969). Therefore, the lower carbohydrate levels in PM-irrigated plots probably reflect greater level of turf injury in those plots. Glucose, fructose, and sucrose concentrations were not influenced significantly by the fertilizer treatments. No significant correlation was observed between carbohydrate concentration and brown patch severity (Appendix D, Table 44).

SOIL pH IN 1993

There was a soil pH depth by fertilizer interaction (Appendix D, Table 45). At the 0 to 3 cm soil depth, soil pH was lowest in SCU-treated plots ($pH \leq 5.6$) versus $NaNO_3$-treated turf ($pH \geq 5.8$). At both soil sampling depths, acidification was greatest (average pH = 5.3) in plots receiving the higher amount of SCU. There was a significant, but weak correlation (average $r = 0.352$) between soil pH and brown patch severity in 1993 (Appendix D, Table 46). This correlation represents data averaged over both soil sampling depths and both N-sources and N application rates.

SOLUBLE SALTS IN 1993

Since high application rates of soluble fertilizers can contribute to an increase in soil salinity (Beard, 1973), soil was assayed for soluble salt

content at the conclusion of the study in fall 1993. Soil was sampled from the upper 10 cm. Irrigation and fertilizer treatments had no affect on soluble salt concentration (data not shown). Average soluble salt concentration for all treatments was 72 mg kg^{-1} soil. Good soil drainage is considered beneficial for soluble salt control (Harivandi et al., 1992). Therefore, the sandy-loam soil with good internal drainage at this field site assisted in maintaining a low concentration of soluble salts.

WEED COVER IN 1993

Annual fleabane (Erigeron annuss [L.] Pers.) cover in the study area was assessed on 28 July 1993 and their population was influenced by N-level, but not N-source or irrigation (Appendix D, Table 47). Weed cover generally was reduced in plots receiving high N (average = 3% plot area covered) versus low N (average = 8%). Highest weed cover (i.e., 12% plot area covered) was observed in plots treated with 147 kg N ha^{-1} yr^{-1} from $NaNO_3$ plus P and K versus all other treatments (≤ 8% cover).

DOLLAR SPOT SEVERITY IN 1992 AND 1993

Dollar spot was assessed on 19 August and 3 September 1992 and 3 June, 6 July, and 26 August 1993 (data not shown). On both rating dates in 1992, no dollar spot was observed in plots treated with iprodione, but trace amounts (i.e., ≤ 1% plot area blighted) were recorded in non-fungicide-treated plots. In 1993, trace amounts of dollar spot were observed on all dates except on 26 August, when 1% plot area blighted was observed in iprodione-treated plots versus 11% in non-fungicide-treated plots. On 26 August, dollar spot was more severe in non-fungicide-treated turf that received SCU at 147 kg N ha^{-1} yr^{-1} (average = 12% plot area blighted) versus all other fertilizer treatments (average = 5%).

SUMMARY AND CONCLUSIONS

In 1992, iprodione was applied after severe blighting occurred. Blighting was greater in PM-irrigated plots, regardless of the applications of iprodione. On some dates blighting was more severe in PM versus AM-irrigated plots that were treated with iprodione. Summer quality in 1992, however, was unacceptable between irrigation treatments regardless of fungicide inputs. There were no AUCRC differences among irrigation treatments in 1992.

In 1993, less brown patch was again observed in AM-irrigated plots, but only in non-fungicide-treated turf. The preventive iprodione applications effectively suppressed brown patch equally in both AM and PM-irrigated plots, and fungicide-treated plots exhibited improved summer quality. The AUDPC and AUCRC values were lowest for fungicide-treated plots, regardless of irrigation treatment in 1993. Residual blight was lower and turf recovery was improved in AM-irrigated plots treated with iprodione.

Hence, during both years, PM irrigation increased disease severity when compared to AM irrigation in non-fungicide-treated plots. Glucose and fructose concentrations were lower in PM-irrigated versus AM-irrigated turf, which corresponded to higher blight levels in plots irrigated at night. Blight levels in non-fungicide-treated plots, however, where generally very high regardless of when the plots were irrigated.

In 1992, blight was consistently greater in turf fertilized with $NaNO_3$ versus SCU regardless of N rate, the addition of P and K, or curative fungicide applications. Blight, however, was generally lower in all SCU-treated plots

fertilized with P and K. Lower residual blight and better turf recovery also was observed in turf fertilized with SCU plus P and K.

The 1993 AUDPC data showed that blight in non-fungicide-treated turf was greater in plots fertilized with high N versus low N, regardless of N-source. These data support the findings of Bloom and Couch (1960) and Watkins et al. (1990), who reported that brown patch was less severe under low versus high N. The high N rate of $NaNO_3$, however, was associated with the greatest blighting. Turf fertilized with the high N rate plus P and K exhibited a reduction in disease severity, when compared to plots receiving the high N rate alone. Non-fungicide-treated plots fertilized with SCU plus P and K (both N rates) had blight levels equivalent to most fungicide-treated plots. In fungicide-treated turf, plots fertilized with $NaNO_3$ (regardless of N rate or P and K) had AUDPC values similar to non-fungicide-treated turf. Hence, turf was rendered far more susceptible to brown patch by $NaNO_3$; whereas, SCU with P and K reduced disease severity. Crown carbohydrate levels were not influenced by any fertilizer treatment.

Bloom and Couch (1960) noted that low N with normal P and K or high N plus high P and K resulted in less brown patch, when compared to plants fertilized with high N plus normal P and K. In this study, the reduction of brown patch with P and K was noted only under high N. There was, however, a further reduction in brown patch using SCU rather than $NaNO_3$. Regrowth and recovery in non-fungicide-treated turf was slowest in plots subjected to the high rate of N from $NaNO_3$, but turf recovery was not adversely affected by high N from SCU. The moderation in brown patch severity provided by SCU can likely be attributed to its slow N-release characteristics, rather than a biologicial influence on the pathogen.

Summer turf quality was not greatly influenced by any fertilizer in 1992 because iprodione was first applied after severe turf injury occurred. Highest summer quality in 1992 (rating = 7.1) was observed in plots receiving SCU plus P and K, regardless of fungicide use. In 1993, best summer quality (rating = 7.9) was recorded for fungicide-treated SCU plots at high N plus P and K. Other treatments with summer quality ratings between 7.0 and 7.3 also received iprodione and SCU (low N plus P and K and high N without P and K). All other treatments provided unacceptable summer quality in both years.

Soil pH was lower in plots fertilized with SCU. Lower blight levels were weakly correlated with low soil pH. This association was strongest (r = 0.529) for SCU-treated turf receiving the low N rate, regardless of P and K (data not shown). Bloom and Couch (1960), however, reported that pH did not influence brown patch under low N. Disease severity, however, was greater with high N at pH levels of 5.6 and 9.0 versus a pH of 4.0 (Bloom and Couch, 1960). In a greenhouse study, Haygood et al. (1989) reported no significant effect from soil pH ranging from 4.0 to 8.0 on brown patch in centipedegrass (Eremochloa ophiuroides Munro). It is therefore likely that the slow N-release characteristics of SCU, and the beneficial effects from P and K, had a greater influence on reducing disease severity than soil pH.

Table 11. Influence of irrigation, fertilizer treatment, and iprodione on R. solani foliar mycelium, blight, and injury in perennial ryegrass, 1992.

Irrigation			Fungicide[†]	Plot area: Covered with mycelium 24July	Blighted 7July	16July	28July	6Aug	17Aug	24Aug	Residual injury 7Sept	28Sept	AUDPC[‡]	AUCRC
				(%)										
AM			-	19 a[§]	2 a	4 a	22 b	73 b	19 bc	15 b	5 a	1 a	1054 b	249 a
PM			-	27 a	3 a	7 a	72 a	85 a	37 a	21 a	5 a	2 a	1679 a	289 a
AM			+	—	—	—	21 b	71 b	14 c	13 b	3 a	1 a	997 b	224 a
PM			+	—	—	—	74 a	84 a	22 b	17 ab	4 a	1 a	1444 a	259 a
N-Source and Rate[¶]		P & K	Fungicide[†]											
$NaNO_3$	147	-	-	12 b[§]	4 a	8 a	46 abc	81 ab	40 b	23 ab	6 abcd	1 b	1453 a	329 bc
SCU	147	-	-	21 b	2 a	3 a	39 c	78 ab	16 ef	12 c	2 d	1 b	1112 bc	141 de
$NaNO_3$	294	-	-	22 b	3 a	9 a	58 a	74 ab	43 ab	30 a	10 a	3 a	1595 a	501 a
SCU	294	-	-	17 b	2 a	8 a	47 abc	71 b	23 de	16 bc	5 bcd	1 b	1184 bc	238 cde
$NaNO_3$	147	+	-	18 b	3 a	7 a	49 abc	87 a	50 a	21 ab	7 abc	1 b	1617 a	290 bcd
SCU	147	+	-	19 b	2 a	4 a	40 bc	71 b	17 ef	13 bc	3 cd	1 b	1082 bc	164 de
$NaNO_3$	294	+	-	39 a	2 a	3 a	59 a	86 a	30 cd	17 bc	7 abc	1 b	1456 a	378 abc
SCU	294	+	-	42 a	2 a	2 a	37 c	74 ab	10 f	10 c	2 d	<1 b	1032 bc	115 e
$NaNO_3$	147	-	+	—	—	—	50 abc	83 ab	28 cd	14 bc	6 abcd	1 b	1351 ab	338 abc
SCU	147	-	+	—	—	—	35 c	80 ab	10 f	13 bc	2 d	1 b	1093 bc	144 de
$NaNO_3$	294	-	+	—	—	—	55 ab	86 a	32 bc	28 a	8 ab	4 a	1491 a	438 ab
SCU	294	-	+	—	—	—	54 ab	73 b	9 f	8 c	3 cd	1 b	1078 bc	167 de
$NaNO_3$	147	+	+	—	—	—	51 abc	82 ab	35 bc	17 bc	4 bcd	1 b	1432 a	249 cde
SCU	147	+	+	—	—	—	34 c	72 b	8 f	12 c	2 d	<1 b	978 c	132 de
$NaNO_3$	294	+	+	—	—	—	60 a	85 a	22 de	23 ab	6 abcd	1 b	1389 a	388 abc
SCU	294	+	+	—	—	—	38 c	70 b	7 f	7 c	2 d	<1 b	953 c	81 e

[†]Iprodione was applied at 3.1 kg ai ha^{-1} on the following dates: 28 July and 17 Aug, 1992.

[‡]Area under disease progress curve (AUDPC) data were collected between 7 July and 24 Aug; and area under crop recovery curve (AUCRC) data were collected between 25 Aug and 7 Oct, 1992.

[§]Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference test.

[¶]Fertilizer treatment: 49 kg N ha^{-1} or 49 kg N +12 Kg P + 25 kg K ha^{-1} were applied in May, Sept, and Oct (total = 147 kg N ha^{-1} yr^{-1}) or Mar, May, June, Sept, Oct, and Nov (total = 294 kg N ha^{-1} yr^{-1}).

Table 12. Influence of irrigation, fertilizer treatment, and iprodione on perennial ryegrass quality, 1992 and 1993.

Irrigation			Fungicide	Quality 1992 Spring	1992 Summer	1992 Fall	1992 Winter	1993 Spring	1993 Summer	1993 Fall
				(0-10 scale)[†]						
AM			-	6.4 a[‡]	5.9 a	7.4 a	6.6 a	7.1 a	6.0 b	7.0 b
PM			-	6.3 a	5.7 a	7.3 a	6.5 a	7.1 a	5.9 b	7.0 b
AM			+	—[§]	5.9 a	7.4 a	6.6 a	7.2 a	7.0 a	7.8 a
PM			+	—	5.7 a	7.3 a	6.6 a	7.1 a	6.8 a	7.6 a
N-Source and Rate		P & K	Fungicide							
$NaNO_3$	147	-	-	5.7 cd[‡]	5.0 e	7.4 a	5.6 e	6.4 b	5.7 fg	7.1 cd
SCU	147	-	-	5.8 cd	5.8 c	7.2 ab	6.0 d	6.8 b	6.0 ef	6.8 d
$NaNO_3$	294	-	-	6.1 bcd	5.0 e	6.7 b	7.5 a	7.6 a	5.3 g	7.5 abc
SCU	294	-	-	6.7 ab	6.5 b	7.7 a	6.7 bc	7.8 a	6.3 de	7.5 abc
$NaNO_3$	147	+	-	5.5 d	5.2 de	7.4 a	5.6 e	6.4 b	5.7 fg	7.1 cd
SCU	147	+	-	6.1 bcd	6.0 bc	7.2 ab	6.2 cd	6.6 b	6.1 ef	7.3 bcd
$NaNO_3$	294	+	-	6.3 b	5.6 cd	7.2 ab	7.5 a	7.5 a	5.5 fg	6.7 d
SCU	294	+	-	7.0 a	7.1 a	7.6 a	7.1 ab	7.8 a	6.7 cd	7.5 abc
$NaNO_3$	147	-	+	—[§]	4.9 e	7.4 a	5.7 e	6.5 b	6.4 cde	7.8 ab
SCU	147	-	+	—	5.8 c	7.3 ab	6.0 d	6.8 b	6.8 bcd	7.7 ab
$NaNO_3$	294	-	+	—	5.0 e	6.7 b	7.5 a	7.6 a	6.4 cde	7.5 abc
SCU	294	-	+	—	6.5 b	7.7 a	6.6 bc	7.8 a	7.3 b	7.5 abc
$NaNO_3$	147	+	+	—	5.2 de	7.5 a	5.8 de	6.4 b	6.6 cde	7.7 ab
SCU	147	+	+	—	6.1 bc	7.2 ab	6.2 cd	6.6 b	7.0 b	7.8 ab
$NaNO_3$	294	+	+	—	5.6 cd	7.2 ab	7.5 a	7.5 a	6.6 cde	7.1 cd
SCU	294	+	+	—	7.1 a	7.5 a	7.1 ab	7.8 a	7.9 a	8.1 a

[†]Turf quality assessed on a visual scale where 0 = brown or dead turf and 10 = optimum quality.

[‡]Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference test.

[§]Iprodione was not applied until 28 July in 1992.

Table 13. Influence of irrigation, fertilizer treatment, and iprodione on R. solani foliar mycelium, blight, and injury in perennial ryegrass, 1993.

Irrigation			Fungicide[†]	Plot area: Covered with mycelium 4July	Blighted 9July	15July	28July	11Aug	18Aug	24Aug	Residual injury 15Sept	5Oct	AUDPC[‡]	AUCRC
				(%)										
AM			-	18 a[§]	12 b	25 b	20 a	35 a	28 a	23 a	18 a	4 a	925 b	678 a
PM			-	25 a	26 a	45 a	27 a	44 a	32 a	27 a	22 a	6 a	1289 a	824 a
AM			+	0 b	0 c	<1 c	3 b	5 b	5 b	9 b	6 b	<1 b	113 c	240 b
PM			+	0 b	0 c	<1 c	6 b	13 b	10 b	13 b	11 b	<1 b	254 c	379 b
N-Source and Rate[¶]		**P & K**	**Fungicide[†]**											
$NaNO_3$	147	-	-	12 b[¶]	10 cd	22 cd	9 d	40 b	25 b	21 bc	15 b	3 b	754 d	600 bc
SCU	147	-	-	14 b	7 cd	28 c	6 d	24 c	9 cd	11 de	12 b	3 b	571 de	393 cde
$NaNO_3$	294	-	-	39 a	41 a	64 a	74 a	77a	70 a	65 a	36 a	10 a	2569 a	1642 a
SCU	294	-	-	31 a	21 b	45 b	23 c	26 c	21 bc	13 de	13 b	2 b	1119 c	460 cd
$NaNO_3$	147	+	-	11 b	15 bc	23 c	9 d	43 b	28 b	19 cd	18 b	3 b	795 cd	660 bc
SCU	147	+	-	15 b	7 cd	12 de	3 d	20 c	8 cd	7 e	14 b	3 b	384 ef	386 cde
$NaNO_3$	294	+	-	30 a	39 a	47 b	49 b	66 a	69 a	56 a	35 a	8 a	2094 b	1495 a
SCU	294	+	-	21 b	9 cd	33 bc	11 d	16 c	8 d	7 e	14 b	2 b	572 de	373 cdef
$NaNO_3$	147	-	+	0 c	0 d	0 e	1 d	5 d	5 d	6 e	4 c	1 b	88 fg	179 ef
SCU	147	-	+	0 c	0 d	0 e	1 d	1 d	1 d	8 e	5 c	1 b	32 g	196 ef
$NaNO_3$	294	-	+	0 c	0 d	2 e	24 c	26 c	23 b	30 b	17 b	2 b	688 de	713 b
SCU	294	-	+	0 c	0 d	0 e	1 d	14 c	6 d	9 e	13 b	1 b	208 fg	359 def
$NaNO_3$	147	+	+	0 c	0 d	0 e	1 d	3 d	2 d	6 e	5 c	1 b	52 fg	173 ef
SCU	147	+	+	0 c	0 d	0 e	0 d	1 d	3 d	4 e	5 c	<1 b	41 fg	149 f
$NaNO_3$	294	+	+	0 c	0 d	1 e	6 d	21 c	17 b	25 bc	12 b	1 b	354 efg	555 bcd
SCU	294	+	+	0 c	0 d	0 e	0 d	1 d	2 d	5 e	5 c	<1 b	17 g	152 ef

[†]Iprodione was applied at 3.1 kg ai ha^{-1} on the following dates: 7 and 28 June, 19 July, and 9 and 28 Aug, 1993.

[‡]Area under disease progress curve (AUDPC) data were collected between 9 July and 24 Aug; and area under crop recovery curve (AUCRC) data were collected between 25 Aug and 5 Oct, 1993.

[§]Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's protected least significant difference test.

[¶]Fertilizer treatment: 49 kg N ha^{-1} or 49 kg N +12 Kg P + 25 kg K ha^{-1} were applied in May, Sept, and Oct (total = 147 kg N ha^{-1} yr^{-1}) or Mar, May, June, Sept, Oct, and Nov (total = 294 kg N ha^{-1} yr^{-1}).