ABSTRACT

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| Title of Thesis: | DOLLAR SPOT AND GRAY LEAF SPOT SEVERITY AS INFLUENCED BY IRRIGATION PRACTICE AND PLANT PROTECTION MATERIALS |
| | Steven James McDonald, Master of Science, 2005 |
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*Agrostis stolonifera* and *Lolium perenne* are widely used turfgrass species grown on golf fairways, however, they are susceptible to dollar spot (*Sclerotinia homoeocarpa*) and gray leaf spot (*Pyricularia grisea)* diseases, respectively. Two field studies were conducted to assess: 1) the influence of two irrigation regimes and seven chemical treatments on dollar spot and gray leaf spot severity; and 2) the effects of two spray volumes (468 and 1020 L water $ha^{-1}$), two fungicides (chlorothalonil and propiconazole) and three application timings (dew present or displaced and dry canopy) on dollar spot control. Dollar spot was more severe in *A. stolonifera* subjected to infrequent irrigation; whereas, gray leaf spot was more severe in frequently irrigated *L. perenne*. The plant growth regulator and wetting agent evaluated suppressed dollar spot, but they had no effect on gray leaf spot. Chlorothalonil was most effective when applied to a dry canopy in 468 L water $ha^{-1}$.

# DOLLAR SPOT AND GRAY LEAF SPOT SEVERITY
# AS INFLUENCED BY IRRIGATION PRACTICE AND DISEASE MANAGEMENT
# WITH PLANT PROTECTION MATERIALS

By

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## LIST OF ABBREVIATIONS†

| Full meaning | Abbreviation |
|---|---|
| 467.5 L water $ha^{-1}$ | Low-SV |
| 1019.5 L water $ha^{-1}$ | High-SV |
| Active ingredient | a.i. |
| Analyses of variance | ANOVA |
| Area under disease progress curve | AUDPC |
| Carbon dioxide | $CO_2$ |
| Centimeters | cm |
| Colony forming units | cfu's |
| Carbon to nitrogen ratio | C:N |
| Demethylation inhibitor | DMI |
| Effective concentration | EC |
| Gram | g |
| Hectare | ha |
| Isobutylidene urea | IBDU |
| Kilogram | kg |
| Least significant difference test | LSD test |
| Liter | L |
| Liter water $ha^{-1}$ | L $ha^{-1}$ |
| Meter | m |
| Millimeter | mm |
| Nitrogen | N |
| Paclobutrazol | PB |
| Parts $million^{-1}$ | ppm |
| Percent of plot area blighted | % PAB |
| Potato dextrose agar | PDA |
| Phenazine carboxylic acid | PCA |
| Plant growth regulator | PGR |
| Primer Select® (wetting agent) | WA |
| Quinol-oxiding inhibitor | $Q_oI$ |
| *Sclerotinia homoeocarpa* infection center | IC |
| Species | spp. |
| Spent mushroom substrate | SMS |
| Spray volumes | SV's |
| Sulfur coated urea | SCU |
| Superoxide dismutase | SOD |
| Time domain reflectometry | TDR |
| Ultra violet | UV |
| United States Golf Association | USGA |
| Vegetative compatibility group | VCG |

† This list is in alphabetical order and not in the order of use throughout the thesis text.

I. Literature Review

**Dollar spot** Dollar spot disease in creeping bentgrass (*Agrostis stolonifera* L.) was described by Monteith and Dahl in 1932. The casual agent initially was incorrectly identified as a *Rhizoctonia* spp. and the disease originally was referred to as small brown patch (Monteith, 1929). Monteith and Dahl (1932) noted that most turfgrass species were susceptible to dollar spot, especially *Agrostis* spp. In 1937, *Sclerotinia homoeocarpa* F. T. Bennett formally was described as the causal agent of dollar spot (Bennett, 1937). Although *S. homoeocarpa* commonly is noted as the casual agent of dollar spot, some believe that the true genus of the pathogen may be either *Lanzia*, *Moellerodiscus*, or *Rutstroemia* (Carbone and Kohn, 1993). The problem with properly naming the dollar spot pathogen is because American isolates of the fungus rarely produce apothecia and none have produced ascospores. The original British isolates of the fungus, which produced fertile apothecia, no longer exist (Smiley et al., 2005).

Dollar spot continues to be a difficult disease to manage in creeping bentgrass grown on golf course fairways. In a typical season in the mid-Atlantic region, dollar spot is most active in late-spring and early autumn. Some cultivars of creeping bentgrass, such as ‘Crenshaw’ and ‘SR1020,’ are chronically attacked by *S. homoeocarpa* in the summer. Disease symptoms first appear as small, white or tan lesions on individual leaves. On bentgrass leaves, lesions appear oval or irregular-shaped and white with brownish borders or as a tip dieback. The hourglass lesion, which is commonly found on course textured species, is not common on close cut bentgrass. Under ideal environmental conditions, the small circular flecks (about 1-3 cm) develop into sunken patches (3-6 cm) of off-white colored turf within a few days. These sunken areas often remain visible for long periods, particularly if fertilizers and/or fungicides are not applied. The fungus can produce an abundance of foliar mycelium, which disperses the pathogen to other turfgrass plants quickly. No conidia or other types of spores are produced by *S. homoeocarpa.*

**Dollar Spot Management As Influenced By Cultural Practices, Composts, Fertilizers and Soil pH**

A greenhouse study demonstrated that low soil moisture levels enhance dollar spot (Couch and Bloom, 1960). Couch and Bloom (1960) evaluated the impact of five different soil moisture levels ranging from field capacity to permanent wilting point on dollar spot severity in Kentucky bluegrass (*Poa pratensis* L.). Mature Kentucky bluegrass plants were subjected to two weeks of a pre-determined soil moisture stress level and then watered to field capacity. Plants were inoculated once soil moisture was at the predetermined stress point. From that point, plants were incubated at 21ºC under high relative humidity (i.e.>90%) in plastic bags. Dollar spot developed five days after plants were inoculated. Soil moisture levels equal to or less than 75% of field capacity resulted in an increase in dollar spot severity, when compared to plants maintained at field capacity. Dollar spot severity generally was found to be greater when irrigation practices favored low soil moisture (i.e., drought stress). The impact of leaf wetness duration or the timing of irrigation in the greenhouse study, however, were not recorded. It is likely that free water was present in the canopy during most of the study because of the high relative humidity created by bagging the plants.

Jiang et al. (1998) found that dollar spot in perennial ryegrass (*Lolium perenne* L.) maintained at fairway height was enhanced 50% when it received daily irrigation in one year of a two year field study in Kansas. Jiang et al. (1998) observed that there was an increase in clipping weights in the frequently irrigated plots. They suggested that as clippings were removed from the study site, nitrogen (N) was depleted, which promoted the increased blighting.

Watkins et al. (2001) studied the influence of two irrigation regimes on dollar spot in field trials on creeping bentgrass in Nebraska. In that study, turf was irrigated daily at 100% or 60% (between April to mid-June) to 80% (between mid-June and 9 September) of potential evapotranspiration. Neither turf quality or dollar spot severity was affected by either irrigation regime. The total rainfall, however, was above the 14-year average during both study years. These results and those of Jiang et al. (1998) do not support the earlier findings of Couch and Bloom (1960).

In bahiagrass (*Paspalum notatum* Flueggé), it was observed that dollar spot was more severe in many of the commonly grown cultivars following several periods of spring drought in Florida (Blount et al. 2002). It was reported that the major factors contributing to dollar spot development in bahiagrass were periods of drought followed by humid conditions and rainfall.

Deep and infrequent irrigation is recommended as a disease management tool as one would predict that drying conditions become less conducive for plant infection by foliar pathogens (Beard, 1973; Couch, 1995; Vargas, 2004; Watschke et al., 1995). Free water must be present on the foliage, however, for dollar spot to develop (Hall, 1984). According to Couch (1995), irrigation practices that maintain soil moisture levels near field capacity in combination with high nitrogen fertility can reduce dollar spot severity.

On golf courses, mowing typically occurs during the early morning hours. Mowing during this time will displace dew and guttation fluid(s) from the canopy and can lessen dollar spot severity. In Kentucky, Williams et al. (1996) investigated six different mowing treatments for their effects on dollar spot incidence and severity in creeping bentgrass maintained to a height of either 6 or 11 mm. It was determined that the removal or replacement of turfgrass clippings had no impact on dollar spot incidence or severity. Dew displacement by early morning mowing, however, reduced dollar spot severity as much as 82% on fairway (11 mm) and 53% on putting green (6 mm) height turf. It is likely that the displacement of the dew by mowing reduces the duration of leaf wetness and speeds drying, which ultimately reduces conditions conducive for infection in this microenvironment. The aforementioned reduction in dollar spot resulting from the displacement of dew by mowing was as great as 82%, yet provided a level of disease suppression that may not be acceptable for golf course turf.

Clippings generally are removed from golf course turf for playability reasons. In higher cut turf, such as lawns and athletic fields, clippings are allowed to remain after mowing. These clippings provide a source of N and other nutrients for plants (Vargas, 2004). Dunn et al. (1996) evaluated the influence of clippings on dollar spot in perennial ryegrass maintained to a height of 16 mm. In July of the year following establishment, clippings were collected from half of the plots by placing baskets on the mowers. By August of the same year, and during the following two summers, clippings allowed to remain on the perennial ryegrass resulted in a reduction of dollar spot between 10 to 40%. The authors suggested that the N recycled to turf by clippings may have stimulated more rapid growth and therefore recovery from blighting. These findings do not support those of Williams et al. (1996), however, the two studies were conducted on different species of grass.

Putting greens frequently are rolled by lightweight machines to increase ball roll (i.e. green speed). Nikolai et al. (2001) evaluated the effect of lightweight rolling on greens constructed with three different root zone mixes and seeded to ‘Penncross’ creeping bentgrass. The three root zones were: 85% sand and15% peat (v/v) =USGA specified; 80% sand, 10% peat, and 10% soil built with a bottom gravel layer; and a non-disturbed, native soil (sandy clay loam). The two rolling treatments were rolling three times per week following early morning mowing, and not rolling after early morning mowing. They found that rolling three times per week in combination with early morning mowing reduced dollar spot severity by 50 to 200% on selected dates, when compared to mowing alone. It should be noted, however, that the amount of dollar spot in those plots ranged from 2.4 infection centers in rolled plots to 8.4 in non-rolled plots. Hence, the magnitude of the difference was not great. The mechanism by which dollar spot is suppressed by rolling is unknown. Researchers hypothesized that rolling after early morning mowing may disperse concentrated guttation fluids that are released from wounds created by mowing, thus lessening the nutrient substrate needed for infection.

National Turfgrass Evaluation Program (NTEP) data have shown that the susceptibility of creeping bentgrass to dollar spot varies among cultivars. Abernathy et al. (2001) evaluated ‘Penn A-4’, ‘Crenshaw’, ‘L-93’, ‘Mariner’ and ‘Penncross’ as either monostands or as two or three-way blends for differences among their susceptibility to dollar spot. They reported that blending a moderately resistant cultivar (‘L-93’) with a susceptible cultivar (‘Crenshaw’) substantially reduced dollar spot, when compared to

‘Crenshaw’ alone. The blended stand, however, had between 71 and 114 infection centers 3.3 $m^{-2}$. Therefore, it is unlikely that an acceptable level of dollar spot reduction can be achieved by blending creeping bentgrass cultivars. Regardless, proper blending likely will help reduce the frequency and amounts of fungicides needed to manage dollar spot.

Vincelli et al. (1997) evaluated twenty cultivars of four *Agrostis* species including: *A. palustris Huds* (*A. stolonifera* L.), *A..capillaris* L. (browntop bentgrass), *A. castellana* Boiss. & Reuter. (dryland bentgrass) and *A. tenuis* Sibth (colonial bentgrass) for their susceptibility to *S. homoeocarpa* and their ability to recover from dollar spot epidemics in the field. The authors observed few consistent patterns in the level of resistance to *S. homoeocarpa* and recuperative ability among the cultivars. For example, in the first study year both ‘Providence’ and ‘SR1020’ had an equal number of infection centers, however, in the second and third study years ‘Providence’ had significantly fewer infection centers than ‘SR1020’. The same two cultivars did not recover at the same rate because the number of infection centers increased in one cultivar, while it decreased in the other. For example, ‘Providence’ went from 86 infection centers on 30 June 1993 to 109 on 7 July 1993, whereas, ‘SR1020’ went from 164 to 104 during the same period. It was concluded that turf recovery from dollar spot likely was due to the plants’ ability to become tolerant, rather than resistant to infection by *S. homoeocarpa* (Vincelli et al., 1997)

In 1929, Monteith summarized observations from the Arlington Turf Garden in which different types of fertilizers provided for different levels of dollar spot suppression in ‘Metropolitan’ creeping bentgrass. In that study, equivalent amounts of N were applied over the course of a year from either cotton seed meal (an organic slow-release N-source) or sulphate of ammonia. Plots treated with cotton seed meal remained disease-free, while the sulphate of ammonia-treated plots became severely blighted by *S. homoeocarpa*. Monteith (1929) offered no explanation for these findings.

Liu et al. (1995a.) evaluated several natural organic and inorganic N-sources for their effect on dollar spot suppression and measured bacterial and fungal population densities in turfgrass leaves, thatch and soil. The N-sources were applied over a three year period to creeping bentgrass maintained at 5 mm and Kentucky bluegrass turf maintained at 5 cm. The N-sources evaluated included: Alignate (1-0-2; from Norwegian kelp meal); ammonium nitrate (34-0-0); Bovamura (dairy manure; no analysis given, however applied at 150 kg N $ha^{-1}$ ); Milorganite (6-2-0); Ringer Greens Super (10-2-6); Ringer Lawn Restore (9-4-4); Sandaid (1-0-2; from granular sea plant meal); sewage sludge (no analysis) and sulfur-coated urea (SCU) (35-0-0). The N-sources were applied at the same time, but at different rates of N varying from 50-250 kg N $ha^{-1}$. High microbial populations were found on the leaves and in the thatch of plots treated with Ringer Greens Super, Ringer Lawn Restore, ammonium nitrate and SCU, when compared to all other N-sources. No differences, however, were observed in the microbial populations found in the soils underlying each turfgrass species. Ammonium nitrate and Ringer products provided for better dollar spot suppression, when compared to all other treatments. The authors concluded that N from the fertilizers encouraged microbial populations, which in turn suppressed disease. They proposed no other mechanism by which dollar spot was suppressed. Because the rates of N differed, the level of dollar spot control could not be correlated to the amount of N applied among the different fertilizers.

Landschoot and McNitt (1997) evaluated seven fertilizers for their effect on dollar spot development in 'Penncross' creeping bentgrass over a three year period in Pennsylvania. Five of the fertilizers [Ringer Greens Super (10-2-6), Ringer Compost (7-4-0), Sustane (5-2-4), Milorganite (6-2-0) and Harmony (14-3-6)] were natural organics and the remaining two were synthetic organic N- sources (urea formaldehyde; 38-0-0, and urea; 41-0-0). All treatments, except urea formaldehyde, were applied four times per year at two rates (24 or 48 kg N $ha^{-1}$), while urea formaldehyde was applied twice per year at 96 kg N $ha^{-1}$. Landschoot and McNitt (1997) found that urea, which is a water soluble synthetic organic fertilizer, gave equal if not better dollar spot suppression than products containing natural organic N. Landschoot and McNitt (1997) also noted that turf that had been stimulated to a dark green color typically was damaged less by dollar spot. They suggested that N availability and the resulting vigorous growth were reasons for better dollar spot suppression.

Davis and Dernoeden (2002) evaluated nine N-sources applied at 200 kg N $ha^{-1}$ $year^{-1}$ for their effect on dollar spot in 'Southshore' creeping bentgrass maintained at fairway height in Maryland. Urea, SCU, Milorganite (6-2-0), Sustane Medium (5-2-4), Earthgro 1881 select (8-2-4), Earthgro Dehydrated Manure (2-2-2), Ringer Lawn Restore (10-2-6), Com-Pro (1-2-0) and Scotts All Natural Turf Builder (11-2-4) had been applied for seven continuous years and dollar spot levels were assessed during the last three years. In this field study, dollar spot incidence and severity, tissue N and soil microbial activity were measured. They reported that only Ringer Lawn Restore (10-2-

6) and urea (46-0-0) delayed the initial spring onset of dollar spot, while other bio-organics enhanced or had less of an effect on dollar spot. None of the nine N-sources evaluated, however, consistently reduced total seasonal disease levels (AUDPC), when compared to the untreated control. A strong negative correlation (higher tissue N with less dollar spot) between the amounts of tissue N and dollar spot severity was observed in one of two years of data collection. In one of two years of soil microbial activity measurements, Milorganite, Earthgro-S, and urea were weakly and negatively correlated with higher microbial activity and decreased dollar spot, when compared to other treatments. Davis and Dernoeden (2002) concluded that the mechanism of dollar spot suppression appeared to be more attributable to N availability rather than soil microbial activity. Since N encourages rapid leaf growth, it is widely believed that the plants are able to re-grow tissue and recover faster than the pathogen can blight and thereby sustain less damage from *S. homoeocarpa* (Couch, 1995).

Boulter et al. (2002) evaluated five composts of varying ages applied at different timings on dollar spot in Ontario, Canada and compared them to preventive applications of chlorothalonil (tetrachloroisophthalontitrile) over a two year period. Chlorothalonil was applied at the lowest labeled rate of (38.4 ml a.i. 100 $m^{-2}$) on 14 day intervals. The composts used were a blend of feedstocks and manures (horse manure, chicken manure, paunch manure, bone meal ash, bark mix, soybean meal and Milorganite), which had C: N ratio’s between 24-32 C:N. Regardless of whether the composts were applied in a single or multiple applications or at varying ages, there generally were no differences in the level of dollar spot suppression achieved, when compared to the untreated control. In the first year of the study, disease pressure was high (from 9.3-23.0 % of plot area blighted 28 days into study), and no differences in dollar spot levels among treatments control were observed until 63 days after the study began. From that point on, the fungicide provided better dollar spot control than all compost treatments. During the second year, plots treated with all five composts developed less dollar spot compared to untreated plots for most of the season, and provided a level of control nearly equivalent to that of chlorothalonil. Chlorothalonil probably did not provide better control in both study years because a low rate was applied on a 14 day interval, which may have been too long.

There has been limited study of the influence of soil pH on dollar spot. Couch and Bloom (1960), found that soil pH had little effect on dollar spot development, when it was assessed at pH's of 4.0, 5.6, 7.0 and 9.0 in a greenhouse study. These findings were similar to field observations made earlier by Monteith (1929).

## Chemical and Biological Control Of Dollar Spot

There have been many attempts to use biological agents to control dollar spot, however, few of these products and methods have provided acceptable levels of control, especially during periods of high disease pressure. Nelson and Craft (1991), conducted a three-year field study on a mixed stand of bentgrass (cultivar not named) and annual bluegrass (*Poa annua* L.). Turf was maintained at a putting green height (5 mm) in New York. They evaluated the effectiveness of 8 strains of *Enterobacter cloacae* and compared the bacteria to two commonly used fungicides. Treatments in this field study included eight strains of the bacterium *E. cloacae* individually applied preventively as a topdressing (465 $cm^3$ $m^{-2}$ cornmeal/sand mixture consisting of 70% fine sand and 30% cornmeal v/v) versus curative applications of propiconazole (1-[[2-(2, 4-dichlorophenyl)-

4-propyl-1, 3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole). Propiconazole was applied twice at 174 mg a.i. $m^{-2}$ and all treatments were rated on monthly intervals. In a second study, iprodione ((3, 5-dichlorophenyl)-N-(1-methylethyl)-2, 4,-dioxo-1-imidazolidinecarboxamide) was applied at 0.6 g a.i. $m^{-2}$ once curatively and treated plots were evaluated twelve days after application. The putting green used for the study had been naturally infested with *S. homoeocarpa*. The levels of disease reduction were assessed and colony forming units (cfu's) of *E. cloacae* from the soil were enumerated. The eight topdressings infested with a strain of *E. cloacae* provided between 5 and 63% dollar spot suppression over the course of the study. Strain EcCT-501 was especially effective in reducing dollar spot levels (63%). Curative applications of propiconazole provided 97% dollar spot control two months after applications ceased, while EcCT-501 provided 56% control. Strain EcCT-501 provided a level of dollar spot control equal to iprodione 12 days after application. Although cfu's of the bacteria declined over time, bacteria were detected in thatch the spring after summer applications. Nelson and Craft (1991) concluded that certain strains of *E. cloacae* provided near equivalent dollar spot suppression, when compared to the two aforementioned fungicides applied curatively. It should be noted that they compared curative fungicide treatments to preventive applications of the bacteria. They also did not state if the level of control provided by any of the strains would be considered acceptable for golf course turf.

Hodges et al. (1994) evaluated four *Pseudomonas* strains for their ability to suppress *S. homoeocarpa* in a greenhouse study. Three isolates of *Pseudomonas fluorescens* and one of *Pseudomonas lindbergii* were applied to young Kentucky bluegrass plants and maintained in the dark and under high levels of relative humidity.

Plants then were inoculated with an isolate of *S. homoeocarpa*. Because *S. homoeocarpa* causes rapid chlorosis of leaf tissue during the infection process, disease severity in this study was assessed by the loss of chlorophyll at the end of three days. The *S. homoeocarpa*-inoculated control plants had a 26% reduction in chlorophyll content within 12 hours. Plants treated with all *Pseudomonas* strains had chlorophyll levels equal to the uninoculated control. This study was conducted on the phylloplane of turfgrass plants in controlled environments and there was no attempt to evaluate these bacteria in the field.

In 1997, Rodriguez and Pfender evaluated *Pseudomonas fluorescens* (Pf-5) on four-month old field grown Kentucky bluegrass and 'Penncross' creeping bentgrass, *in vitro*, and in infested grass clippings for its effect on *S. homoeocarpa*. Strain Pf-5 produces metabolites (antibiotics, pyoverdine, siderophores and cyanide) antagonistic to *S. homoeocarpa*. Grass clippings were taken from the greenhouse study, autoclaved and infested with *S. homoeocarpa* by placing them in contact with colonized agar in a moist, warm chamber for 10 to 15 days. The Pf-5 inoculum was sprayed ($10^8$ cfu's $ml^{-1}$ water) over live plants and infested clippings one or two times. The ability of Pf-5 to reduce *S. homoeocarpa* also was assessed on various antibiotic –amended media. Four nutrient medias (King's medium B agar, dilute cornmeal agar, 523 agar and nutrient agar amended with 2% glucose or 1% glycerol) were amended with either ampicillin, streptomycin, kanamycin or cycloheximide. Bacteria were applied to the plates in a suspension and mycelial plugs of *S. homoeocarpa* were transferred to the media. The radial distance between the edge of the bacterial colony and the edge of fungal growth was measured after 2, 3 and 4 days of incubation. Strain Pf-5 reduced *S. homoeocarpa* aerial mycelia levels in infested grass clippings, when applied once or twice. Strain Pf-5 also reduced dollar spot incidence and severity in both creeping bentgrass and Kentucky bluegrass plants, when the bacterium was sprayed either once or twice over the inoculated turf. In *vitro* studies, Pf-5 was inhibitory to *S. homoeocarpa* growth on all media's evaluated.

Strains of *Pseudomonas aureofaciens* (TX-1 and TX-2) were investigated by Powell et al. (2000) in a greenhouse and field study for their ability to suppress *S. homoeocarpa*. A single metabolite of the bacterium (phenazine-1 carboxylic acid; PCA) was identified as the antagonistic ingredient against *S. homoeocarpa*. Phenazine-1 carboxylic acid was tested in a greenhouse study on 'Penncross' creeping bentgrass and compared to two commonly used fungicides (chlorothalonil and triadimefon [1 (4-hlorophenoxy)-3, 3-dimethyl-1-(1H-1, 2, 4- triazol-1-yl)-2-butanone]) in the Michigan field study. The PCA provided a level of control equal to the fungicides in the greenhouse study. Similar results were observed in the field; however, triadimefon provided better control than either chlorothalonil or PCA.

Greenhouse and growth chamber studies have revealed that biological control of *S. homoeocarpa* may be effective in controlled experiments (i.e. darkness, high relative humidity, and controlled temperature). The uses of biological control measures on a large scale in the field, however, have resulted in erratic levels of dollar spot control. The increased survival of TX-1 and other bacteria following exposure to UV light and improved delivery methods were investigated in field studies in Maryland and Indiana (Davis and Dernoeden, 2001; Hardebeck et al., 2004). To overcome difficulties with applying bacteria to golf courses and other turfgrass sites, a unit known as the BioJect

Biological Management System ™ (Bioject) was developed. The BioJect allows for the fermentation, injection and delivery of desirable bacteria (e.g., *Pseudomonas* spp.) via the golf course irrigation system. This automated delivery system made the handling, mixing and application of large amounts of bacteria easy for golf course managers. Additionally, bacteria could be applied at night to prevent UV light degradation. Davis and Dernoeden (2001) performed a field study to assess the number of cfu's of *Pseudomonas aureofaciens* strain TX-1 that were fermented and delivered to the turf by the BioJect. They also assessed the level of dollar spot suppression provided by this bacterium applied alone or with fungicides to 'Crenshaw' creeping bentgrass. Between $2.9 \times 10^7$ and $2.0 \times 10^{10}$ cfu's were fermented in the tank during a 12 hour fermentation cycle. When the irrigation water was analyzed for cfu's, an average of $7.8 \times 10^5$ of Tx-1 $cm^{-2}$ were delivered to the turf daily. When averaged over both years of the study, $4.0 \times 10^7$ and $3.4 \times 10^4$ cfu's of TX-1 were recovered from the foliage plus thatch and soil, respectively. It was reported that TX-1 reduced dollar spot by 33% in the first year of the study and by 27% during the second year. The level of dollar spot suppression provided by TX-1 alone, however, was not acceptable for golf course turf and only plots that had been treated with the combination of TX-1 and fungicides or fungicides alone provided acceptable control. The TX-1 delayed dollar spot in iprodione and propiconazole-treated plots, thus extending the residual control provided by those fungicides for seven to ten days in one of the two study years.

Hardebeck et al. (2004) conducted three field experiments in Indiana to assess dollar spot control by TX-1 when applied through an irrigation system using the Bioject. These studies attempted to determine if there were an interaction between the amounts of

N or fungicides applied on the level and length of dollar spot control in creeping bentgrass. Two rates of N (146 and 244 kg $ha^{-1}$ $year^{-1}$) from either SCU or urea were evaluated. The TX-1 was applied nightly through the irrigation system to 'Crenshaw' creeping bentgrass. As much as 37% reduction in dollar spot was observed in 1998, when compared to non-TX-1- treated plots. In 1999, however, TX-1 had no effect on dollar spot severity. Hardebeck et al. (2004) observed that when environmental conditions were optimal for dollar spot development, TX-1 provided little dollar spot control. In general, when disease pressure was low, the efficiency of fungicides increased by 32% and the duration of dollar spot control increased by 2.6 days when fungicides were combined with TX-1. Fungicides and fertilizers generally had little or no effect on TX-1's ability to control dollar spot. Like Davis and Dernoeden (2001), Hardebeck et al. (2004) also concluded that the level of dollar spot control provided by TX-1 was both erratic and unacceptable for golf course turf.

Dernoeden et al. (2000) evaluated the bacterium *Bacillus subtilis* (Serenade™) applied to 'Southshore' creeping bentgrass maintained as a fairway for curative dollar spot control. The bacteria were applied weekly at two rates and were compared to commonly used fungicides (thiophanate methyl (dimethyl [1, 2-phenylene-bis(iminocarbonothioyl)]bis[carbamate]; dimethyl 4,4'-*o*-phenylenebis[3-thioallophanate]) and chlorothalonil + thiophanate methyl) applied on 14 day intervals. On one of five rating dates, the bacteria reduced dollar spot severity, when compared to the untreated control. The fungicides provided significantly better dollar spot control than the bacterium on all rating dates. Butler and Tredway (2003), also evaluated *B. subtilis* for its ability to control dollar spot on a 'Crenshaw' creeping bentgrass putting green when applied alone, in rotations or in tank-mixes with propiconazole. Dollar spot pressure was severe at the North Carolina site. On all rating dates, plots treated with *B. subtilis* had levels of dollar spot equal to untreated plots. The influence of *B. subtilis* in rotations and tank-mixes with propiconazole could not be determined because the fungicide provided excellent dollar spot control throughout the trial (Butler and Tredway, 2003).

Strains within a population that have a reduced ability to cause disease are called hypovirulent. The cause of hypovirulence in fungi often is associated with double-stranded RNA (dsRNA) from a mycovirus. Zhou and Boland (1997), found a significant interaction between hypovirlence in *S. homoeocarpa* and double-stranded RNA. The study evaluated 132 isolates of *S. homoeocarpa* for the presence of the dsRNA trait using electrophoresis. They found 15 isolates that contained dsRNA and these *S. homoeocarpa* isolates caused smaller lesions on detached, inoculated creeping bentgrass leaves. Zhou and Boland (1997), hypothesized that the transmission of these mycoviruses into the field could potentially be used as a biological approach for the management of dollar spot. The practicality of dollar spot reduction on a large scale in the field using *S. homoeocarpa* strains of dsRNA isolates is unknown and would require extensive work to be proven effective.

Plant growth regulators (PGR) have been investigated for their impact on dollar spot severity. Burpee et al. (1996) evaluated three commonly used PGR's as follows: paclobutrazol [(2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl)pentan-3-ol)] applied at 0.16 kg a.i. $ha^{-1}$; flurprimidol [(a-(1-methylethyl)-a-[4-(trifluoromethoxy)phenyl]-5-pyrimidinemethanol] applied at 0.33 kg a.i. $ha^{-1}$; and trinexapac-ethyl [(ethyl 4-cyclopropyl(hydroxy)methylene-3,5-dioxocyclohexanecarboxylate)] applied at 0.19 kg a.i. $ha^{-1}$. *In vitro* studies were performed to assess the effective concentration of these PGR's for reducing *S. homoeocarpa* mycelial growth by 50% ($EC_{50}$). The $EC_{50}$ for paclobutrazol and flurprimidol were 0.10 and 0.21 µg $ml^{-1}$, respectively, while it was 15.89 µg $ml^{-1}$ for trinexapac-ethyl. In their field studies, the aforementioned PGR's were applied to 'Penncross' creeping bentgrass either alone or as a pre-treatment four days before fungicide applications were made. The fungicides evaluated were chlorothalonil, iprodione, propiconazole and thiophanate methyl applied at 9.6, 3.1, 0.4, 3.1 kg a.i. $ha^{-1}$, respectively. This study found that both paclobutrazol and flurprimidol had direct fungistatic effects on *S. homoeocarpa* when applied alone, probably because these materials are chemically related to triazole fungicides. Trinexapac-ethyl, however, was significantly less fungistatic in the *in vitro* test, when compared to the aforementioned PGR's and provided no dollar spot suppression when applied alone in the field. In general, flurprimidol and paclobutrazol pretreatments significantly enhanced the level of dollar spot control provided by the fungicides. Pre-treatments with trinexapac-ethyl enhanced dollar spot control from chlorothalonil, iprodione and propiconazole in one of the two study years. When applied alone, flurprimidol and paclobutrazol significantly suppressed (40-55%) dollar spot, when compared to the untreated control. These plant growth regulators also suppress turf growth, which limits the removal of fungicide due to less frequent mowing. Therefore, plant growth regulators may assist fungicides by limiting the amount of chemical removed by mowing.

Golembieski and Danneberger (1998) conducted a two-year field study to evaluate the influence of PGR's, creeping bentgrass cultivars and N fertility on dollar spot severity. 'Crenshaw' creeping bentgrass was seeded alone or in a 50:50 blend with 'Penncross' creeping bentgrass and maintained at fairway height (13 mm). Sulfur coated urea was applied at 0, 24.4 or 48.8 kg N $ha^{-1}$ on 30 day intervals for a total of 0,122, 244 kg N $ha^{-1}$ $year^{-1}$, respectively. Trinexapac-ethyl was applied four times at 3.0 kg a.i. $ha^{-1}$ on 30 day intervals. Fertilizer treatments were applied alone or in combination with trinexapac-ethyl. The 'Crenshaw' + 'Penncross' blend had less dollar spot at the onset of disease, when compared to the 'Crenshaw' monostand. The blend, however, did not exhibit less total disease over the two study years. Trinexapac-ethyl reduced dollar spot severity each month (25-47%), when compared to the untreated control. Nitrogen fertilization (48.8 kg N $ha^{-1}$) also reduced dollar spot severity (38-86%) during the entire study period, when compared to plots that received no N. In plots treated with the combination of N and trinexapac-ethyl, dollar spot became less severe as the rate of N increased. The combination of trinexapac-ethyl with the high rate of N only improved dollar spot control by 2%, when compared to the high rate of N applied alone. The authors concluded that both trinexapac-ethyl and N, as well as blending of cultivars, should be incorporated into a dollar spot management program.

Zhang and Schmidt (2000) investigated the influence of trinexapac-ethyl and propiconazole on 'Penncross' creeping bentgrass enzyme antioxidant levels and photochemical activity under two fertility regimes in a field and greenhouse study. The antioxidant superoxide dismutase (SOD) has been associated with stress tolerance in creeping bentgrass. Photochemical activity was measured by fluorescence emission of chlorophyll. The ratio of variable fluorescence to maximum fluorescence (Fv/Fm) (maximum quantum efficiency) in photosystem II represents the efficiency of the photosystem. As the value of the Fv/Fm increases the chlorophyll content increases. In a field study, Zhang and Schmidt (2000) evaluated the effects of trinexapac-ethyl (0.44 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) applied monthly from May through November in Virginia under two N fertility regimes (20.0 and 44.0 kg N $ha^{-1}$ from urea applied seven times $year^{-1}$). Trinexapac-ethyl and propiconazole increased SOD activity, increased Fm730/Fm690 ratio and reduced dollar spot under both N levels, when compared to untreated plots. No interaction was observed between N levels and trinexapac-ethyl or propiconazole. A greenhouse study was conducted to assess the effects of both chemicals on creeping bentgrass under low soil moisture under the two aforementioned N levels. Plugs (10 cm diameter and 2 cm deep) from the field that had been exposed to the N, trinexapac-ethyl and propiconazole treatments were placed in plastic containers with native soil 10 cm deep and dried to 5% soil moisture. Soil moisture was maintained at that level for the duration of the study. The plants were examined weekly for disease and chlorophyll fluorescence for a total of six weeks. Nitrogen alone did not influence SOD activity in the greenhouse study. Trinexapac-ethyl and propiconazole grown under the two N levels, however, promoted SOD activity under low soil moisture conditions. The authors concluded that the increase in bentgrass photosynthetic capacity provided by propiconazole and trinexapac-ethyl may have played a partial role in reducing dollar spot.

Lickfeldt et al. (2001) evaluated the implications of long term repeated applications of trinexapac-ethyl on Kentucky bluegrass mowed to a height of 3.2 cm.

Trinexapac-ethyl was applied at 0.17, 0.23 or 0.29 kg a.i. $ha^{-1}$ five times every four weeks or at 0.23, 0.29, or 0.34 kg a.i. $ha^{-1}$ for four times every six weeks over three growing seasons. Treatments were begun in May of each year. Trinexapac-ethyl was applied at 0.29 kg a.i. $ha^{-1}$ every four weeks and reduced dollar spot severity 48%, when compared to the untreated control (1.2 compared to 2.3 severity rating; where 1= no dollar spot and 5=maximum dollar spot severity). No other rates or timings reduced disease severity. Lickfeldt et al. (2001) speculated that the mechanism for dollar spot reduction by trinexapac-ethyl was related to the increase in SOD level as reported by Zhang and Schmidt (2000).

Currently, many projects are being conducted to evaluate other approaches to obtain extended levels of dollar spot suppression in the field. Preventive fungicide applications may be the most effective method of dollar spot control. Dwyer and Vargas (2004) reported that extended levels of dollar spot control can be achieved in Michigan by applying triadimefon early in the spring (May), prior to the appearance of disease symptoms (no date of occurrence given), and before environmental conditions are optimal for disease. A single May application of triadimefon provided a significant reduction in dollar spot until the middle of August in the same year. This extended period of control may be due to a reduction in inoculum in response to a fungicide application early in the spring. Conversely, curative fungicide applications likely result in a build-up of inoculum, making control more difficult.

## <u>Fungicide Resistance to *Sclerotinia homoeocarpa* and Reduced Residual Dollar Spot Control</u>

Chemicals have been used from the earliest reports of dollar spot management (Monteith, 1932), and today fungicides are considered to be the most cost-effective approach to the control of this disease (Vargas, 2004). More time, effort and money are spent managing dollar spot than any other turfgrass disease (Vargas, 2004). Many chemical control options are available on both preventive and curative bases. Problems with *S. homoeocarpa* resistance to fungicides have risen, as fungicide use has increased (Burpee, 1997).

Resistant strains of *S. homoeocarpa* have been reported to most classes of fungicides that penetrate plant tissue (Smiley et al., 2005). Due to the mutli-site, biochemical processes that are blocked by contact fungicides, these chemicals often are relied upon to help prevent or delay the onset of resistance. Due to repeated applications of penetrant fungicides with similar modes-of-action, problems with resistant *S. homoeocarpa* populations have become more widespread. Two classes of fungicides with single-site activity including benzimidazoles (thiophanate-methyl), and demethylation inhibitors (DMI; propiconazole, triadimefon) have had reported cases of resistance to *S. homoeocarpa* in the United States (Warren et al., 1974; Detweiler and Vargas, 1982; Vargas et al., 1992 and Golembieski et al., 1995). Resistance problems with DMI fungicides were reported in Canada by Hsiang et al. (1997). Dicarboximide fungicides are reported to have multi-site activity, but have developed resistance to *S. homoeocarpa* and other pathogens. Although unknown, dicarboximide fungicides may have only single site activity on specific pathogens (Smiley et al., 2005).

Demethylation inhibitor fungicides commonly are used by golf course managers to control dollar spot. Golembieski et al. (1995) evaluated *S. homoeocarpa* isolates from

Michigan golf courses that had never used a DMI and from courses that reported little or no control from these fungicides. An *in vitro* study evaluated the $EC_{50}$ values of fungicide-amended potato dextrose agar (PDA). Fifty isolates from each golf course were exposed to PDA amended with varying levels of triadimefon, fenarimol and propiconazole. Reduced sensitively to the three DMI fungicides were observed and all triadimefon-resistant isolates of *S. homoeocarpa* were cross-resistant to fenarimol and propiconazole. Field trials were conducted to assess the influence of triadimefon, fenarimol, propiconazole, iprodione, chlorothalonil and tank-mixes of triadimefon with either chlorothalonil or iprodione. The fungicide treatments were applied on 10 or 21 day intervals to a site where DMI resistant strain(s) of *S. homoeocarpa* were known to exist. In two of the three study years, plots treated with DMI fungicides and iprodione provided little or no dollar spot control. The combination of triadimefon and chlorothalonil reduced dollar spot severity, when compared to the untreated control. The level of control provided by the combination, however, was unacceptable (average severity rating for the three years =2.0, on a 0 to 9 scale with 0 = 0 to 9% and 9=90-100% of plot area blighted). When data were averaged over the three years, no statistically significant differences were observed when compared to the other treatments applied alone. In all three study years, chlorothalonil gave complete dollar spot control when applied alone on a 10-day interval. All other fungicide treatments had disease ratings equal to the untreated plots.

Burpee (1997) examined in the field and lab the effectiveness of chlorothalonil, iprodione, fluazinam (3-chloro-*N*-[3-chloro-2, 6-dinitro-4-(trifluoromethyl) phenyl]-5-(trifluoromethyl)-2-pyridinamine), propiconazole, and thiophanate-methyl on isolates of *S. homoeocarpa* that were either sensitive or resistant to both DMI and benzimidazole fungicides. The lab study was conducted by amending PDA with varying concentrations (0.01 to 100 ug $ml^{-1}$) of the fungicides and placing 6-mm diameter mycelial plugs of *S. homoeocarpa* into the center of the dish. The colonies were measured after 72 hours of incubation. Data showed that some isolates that were resistant to DMI fungicides also were resistant to benzimidazole fungicides. Chlorothalonil gave good control in the field, however, reduced sensitivity was observed in the laboratory. Miller et al. (2002), reported from a study looking at field and lab resistance that when reduced field sensitivity to propiconazole, myclobutanil (alpha-butyl-alpha-(4-chlorophenyl)-1*H*-1, 2, 4-triazole-1-propanenitrile) or triadimefon was observed, reduced sensitivity also was observed in laboratory settings.

Jo et al. (2002), conducted an *in vitro* study to assess $EC_{50}$ concentrations of thiophanate-methyl and propiconazole needed to reduce mycelial growth of *S. homoeocarpa*. Dual fungicide resistance (resistance to more than one class [i.e. DMI and benzimidazole]), was shown to be 2.5 times more common than single resistance (resistant to only one class and still sensitive to another) in *S. homoeocarpa* isolates from Ohio (Jo et al., 2002). Despite efforts to induce *S. homoeocarpa* resistance to propiconazole through the repeated transfer of isolates to the fungicide-amended PDA, resistance did not develop (Burpee, 2001). Therefore, Burpee (2001) suggested that the mechanism of *S. homoeocarpa* resistance to fungicides in the field was due to a selection of the naturally existing resistant biotypes. In a greenhouse study with ‘L-93’ creeping bentgrass plants, however, isolates of *S. homoeocarpa* that had been exposed to repeated exposure to propiconazole developed reduced levels of sensitivity, when compared to isolates that had not received repeated propiconazole exposures (Miller et al., 2002).

Another potential reason for poor or short residual control may be due to rapid microbial degradation of the fungicide. Apparently, some microbes are capable of using a fungicide as an energy source. Little is known about the nature, scope and overall importance of this phenomenon in turf. In Italy, only iprodione and propiconazole are labeled for the control of dollar spot (Mocioni et al., 2001). As a result of repeated applications, Mocioni et al. (2001) reported reduced residual effectiveness of iprodione on Italian golf courses. Laboratory study revealed that poor field control provided by iprodione was due to enhanced microbial degradation of the fungicide and not due to the selection of resistant strains of *S. homoeocarpa*. The phenomenon was dependent on soil physical-chemical properties (i.e. number of previous iprodione applications, soil pH and organic matter content). Enhanced degradation of iprodione following repeated applications to control *Sclerotinia* spp. in onions (*Allium cepa*) and lettuce (*Papaver somniferum*) was reported earlier by Martin et al., 1990 and Walker, 1987.

## Genetics of *S. homoeocarpa* and Its Hosts

Powell and Vargas (2000) assessed vegetative compatibility groups (VCG) among isolates of *S. homoeocarpa* collected during two epidemic periods in one year. Vegetative compatibility is the ability of hyphae of two strains of fungi to fuse and form a stable heterokaryon. For this to happen, the fungi must share identical alleles at a particular set of loci. If strains are not genetically the same, they will not fuse together and no heterokaryon will be formed. Vegetative compatibility groups are useful in identifying subpopulations and members of the same VCG that are genetically similar (Kohn et al., 1991). As previously mentioned, it is believed that *S. homoeocarpa* may not be the correct taxon or that there may be more than one casual agent. After examination of over 1,300 isolates, Powell and Vargas (2000) concluded that the two epidemics occurring in Michigan were the result of a single rather than multiple pathogen species.

Viji et al. (2004), examined the genetic diversity among *S. homoeocarpa* isolates from different geographic regions and different turfgrass species [i.e. creeping bentgrass, annual bluegrass (*Poa annua* L.), bermudagrass (*Cynodon dactylon* L.) and perennial ryegrass (*Lolium perenne* L.)] and identified eleven VCG's. Over half of the isolates belonged to one VCG, which were found in different geographic regions including Canada, Delaware, Illinois, New Jersey, New York, North Carolina, Pennsylvania and Virginia. In a virulence test, it was determined that there was a relationship between the VCG and an isolates' ability to damage turfgrass (Viji et al., 2004).

Other studies have assessed the genetic variation and host specialization of *S. homoeocarpa* (Raina et al., 1997; Hsiang et al., 1999; and Hsiang et al., 2000). From these experiments, it was determined that within a population of *S. homoeocarpa* some level of variation in a local population during a dollar spot epidemic exists; however, in the broad picture there was very little variation. Hsiang et al. (1999), surveyed the genetic variability of 191 isolates of *S. homoeocarpa* from Ontario and Japan using restriction fragment length polymorphisms (RFLP) of the intergenic spacer region of rDNA and random amplified polymorphic DNA (RAPD). From the isolates evaluated, the genetic similarity among isolates from Japan and Ontario was 66% and 86%, respectively (Hsiang et al., 1999). When the Ontario isolates were compared to the Japan isolates, there was a high level of genetic diversity (51%). From these studies, it was concluded that within a population there is a high degree of genetic similarity, however, among different populations from different geographic locations there was a lot of diversity.

Hsiang et al. (2000) assessed the host specialization of fifty *S. homoeocarpa* isolates from five turfgrass [annual bluegrass, creeping bentgrass, Kentucky bluegrass, perennial ryegrass and tall fescue (*Festuca arundinacea* L.)] hosts using RAPD analysis. These analyses showed significant genetic differentiation among isolates from different host species. Data indicated that there was a weak level of host specialization by *S. homoeocarpa* (Hsiang et al., 2000). Limited variation within the *S. homoeocarpa* genome may be due to the lack of apothecia production in nature. Without sexual reproduction, there would be no chance for sexual recombination and therefore less diversity would be expected within an *S. homoeocarpa* population.

Bonos et al. (2003) evaluated 265 creeping bentgrass clones and five different isolates of *S. homoeocarpa* in the field. Quantitative inheritance is when the clones and progeny show varying levels of resistance and none show complete resistance. All clones and progeny exhibited varying levels (10-60%) of disease severity and none was immune to *S. homoeocarpa*. They concluded that the distribution of phenotypes for clones and progeny for dollar spot resistance may be quantitatively inherited. Belanger et al. (2004) suggested that the use of interspecific hybrids (*Agrostis stolonifera* x *Agrostis capillaris* L.) could be a tool for developing cultivars resistant to dollar spot. *Agrostis capillaris* (colonial bentgrass) exhibits some natural resistance to *S. homoeocarpa* when compared to creeping bentgrass, however, it is more susceptible to brown patch (*Rhizoctonia solani* Kühn). It will take many years of screening to develop *S. homoeocarpa* resistant cultivars.

Bonos et al. (2004) identified resistant creeping bentgrass clones that showed a significant increase in turfgrass density and reduction in the size of the *S. homoeocarpa* infection centers. The mechanism for conferring smaller-sized infection centers is unknown. Trichome size was associated with less dollar spot, because resistant clones had larger trichomes than susceptible clones. Bonos et al. (2004) concluded that the large trichomes may be a physical hinderance to infection by *S. homoeocarpa*.

Fu et al. (2005) introduced a rice thaumatin-like protein (TLPD34) into creeping bentgrass in an attempt to improve the host resistance to fungal diseases including brown patch and dollar spot. The gene was introduced into ‘Crenshaw’ creeping bentgrass using *A. tumefaciens* strain LBA4404 in concert with the plasmid pUbiTLP, which carried the necessary TLPD34 gene and selection marker. Transgenic plants were screened using glufosinate-ammonium at the tissue culture stage and in the greenhouse. The expression of the TLPD34 gene was confirmed using PCR amplification. To assess the level of fungal disease resistance in the transgenic creeping bentgrass, the plants were exposed to *R. solani* and *S. homoeocarpa* in the greenhouse and field, respectively. Field test with *S. homoeocarpa* showed that the TLPD34 transgenic plants had improved dollar spot resistance in the field (40%), however, increased susceptibility to brown patch under greenhouse evaluations (Fu et al., 2005).

Previous research has identified cultural, genetic, and biological approaches to reduce dollar spot incidence and severity. No single practice will provide for complete control or can be relied upon to reduce disease severity to within an acceptable level for golf course greens, tees and fairways. Therefore, fungicides continue to be relied upon, but they have their own problems. Resistance problems seem to be on the rise, as are field reports of less residual control being provided by fungicides. Due to current restrictions on application rates and intervals, and the potential removal of various fungicides from the market, ways to use these materials more efficaciously need to be investigated.

**Gray leaf spot** Gray leaf spot is incited by *Pyricularia grisea* (Cooke) Sacc. [teleomorph *Magnaporthe oryzae* (B. Couch) and *M. grisea* (T.T. Herbert) Barr]. DNA sequencing and mating research with the pathogen has led it to be divided into two species, *M. grisea* and *M. oryzae* (Couch and Kohn, 2002). *Magnaporthe grisea* is used to describe isolates from *Digitaria* spp., while M. *oryzae* is used to describe isolates from rice (*Oryza sativa* L.) and turfgrasses. Smiley et al. (2005) noted that until a formal name change is adopted by the International Committee of Fungal Nomenclature, *P. grisea* and *M. grisea* likely will continue to be referenced.

Turfgrass species damaged by gray leaf spot include: annual ryegrass (*Lolium mulitflorum* Lam.) perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov.) and St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze). The primary host for *P. grisea* in the mid-Atlantic region is perennial ryegrass. The earliest reports of gray leaf spot outbreaks in perennial ryegrass occurred in Pennsylvania in 1992 and Maryland in 1995 (Landschoot and Hoyland, 1992; Dernoeden, 1996). The disease since has been reported in various regions of the United States including the mid- Atlantic, northeastern, mid-west, and California (Harmon et al., 2000; Pederson et al., 2000 Schumann and Jackson, 1999; Uddin et al., 2002a). Gray leaf spot of perennial ryegrass has become a disease of significant economic importance, particularly in the mid-Atlantic and transition zone regions. Uddin et al. (2003b), reported that an average golf course with perennial ryegrass fairways has had to increase their fungicide budget by greater than 5% since 1995 to address gray leaf spot.

Harmon and Latin (2001) found that the pathogen survives unfavorable environmental conditions in plant debris as dormant mycelium. Once spring environmental conditions become favorable for the growth of dormant mycelium, conidia are produced on necrotic tissues and dispersed on air currents. The release cycle of spores and infection processes are still misunderstood (Uddin et al., 2003a). The symptoms of gray leaf spot appear in mid-to-late summer and can continue into the late autumn if the proper environmental conditions exist (Harmon and Latin, 2005).

Disease symptoms on perennial ryegrass first appear as small, water- soaked lesions with grayish borders on leaf margins. These lesions often appear to be round or oval in shape, grayish brown or dark brown in color and sometimes they have a yellow halo. Infected leaves may have a twisted or "fish-hook" appearance. Leaf lesions, however, can be diverse in color and shape and may not be a reliable diagnostic aid. Conidia develop quickly on infected tissue, and form a dense mat in early morning hours that gives infected tissue a grayish color and/or a felted appearance. The conidia are dispersed by wind, equipment and people to infect other perennial ryegrass plants. This disease can be rapid acting and has the ability to destroy large areas of perennial ryegrass in a few days (Dernoeden, 1996). Severely affected stands often have a purple-gray or wilt-like appearance, and when the disease is allowed to progress the turf will collapse, die and turn a tan color. *Pyricularia grisea* is not known to be pathogenic to other grasses or weeds in the mid-Atlantic region. Hence, other grasses and weeds remain following a gray leaf spot epidemic. Once disease symptoms become pronounced, gray leaf spot easily can be confused with other diseases including leaf spot and net-blotch (i.e. *Bipolaris* spp., *Curvularia* spp., *Drechslera* spp.,), brown patch (*Rhizoctonia* spp.), dollar spot (*Sclerotinia homoeocarpa*) and Pythium blight (*Pythium* spp.). The potential for a misdiagnosis can complicate fungicide selection and give *P. grisea* more time to be destructive. To positively confirm gray leaf spot, it is necessary to examine blighted tissue for conidia.

Gray leaf spot on tall fescue begins as small, round or oval, tan-brown leaf lesions with a dark purple margin. Individual lesions are small (<5 mm) and can coalesce, however, tall fescue usually is able to recover from infections. (Smiley et al. 2005). In St. Augustinegrass, gray leaf spot symptoms initially appear as small, brown to red lesions on leaves and stolons. Lesions quickly become oblong with enlarged necrotic centers. Once lesions become necrotic, they appear grayish-tan in the center and have brown to red borders. *Pyricularia grisea* can quickly cause immature stands of St. Augustinegrass to thin out and decline, however, older stands rarely incur significant damage (Atilano and Busey, 1983). In both tall fescue and St. Augustinegrass, diseased stands may appear scorched, as if they were suffering from drought stress (Smiley et al. 2005).

## Environmental Conditions Favoring Gray Leaf Spot Development

High summer temperatures and dry soil conditions appear to predispose plants to leaf infection by *P. grisea*. The disease, however, can appear during cool and wet conditions and frequently becomes active in September and can persist into November. Nightly watering is a common practice during periods of drought. Nightly watering results in long periods of leaf wetness, which allows for huge numbers of *P. grisea* spores to be produced overnight (Dernoeden, 1999). Uddin et al. (2003a) reported that conditions conducive for gray leaf spot development often occur in late summer or early autumn when the average air temperature is = 28ºC (Uddin et al.,2003a). High relative humidity, extended periods of leaf wetness (12 to 15 hours), and moderately warm temperature (=20ºC) conditions increased the chances for gray leaf spot development in a greenhouse model. Uddin et al. 2003a, found that gray leaf spot did not develop in perennial ryegrass plants that were air dried immediately after spraying the leaves with a conidial suspension. The authors concluded that free moisture is required for gray leaf spot development in ryegrass. Therefore, temperature and period of leaf wetness are highly dependent on each other.

Harmon and Latin (2005) documented outbreaks of gray leaf spot in perennial ryegrass and winter survival of *P. grisea* (*M. oryzae)* in Indiana. Gray leaf spot was observed in central Indiana in the last week of August or the first week of September during all three study years. By capturing conidia, it was observed that in only one of the three study years, disease progress followed conidia release. Peak conidia capture, however, was in September of each year. In another study, four different environmental regimes (three artificial greenhouse environments and one field) were evaluated for the over-wintering survival of the pathogen. The three artificial treatments were constant temperatures of 4, -20 ºC and alternating 24 hour periods of 4 and -20ºC. The field regime was completed by placing *P. grisea* infested perennial ryegrass residue in an envelope inside a large stand of perennial ryegrass from November to May. Alternation of temperatures and the -20ºC treatments resulted in the least pathogen viability when compared to the field sample and the constant 4 ºC treatments. Harmon and Latin (2005) concluded that when winter temperatures are low (< -20ºC), the pathogen population is reduced thus resulting in less disease the following summer.

## Cultural Practices and Fertility Influences on Gray Leaf Spot

Vaiciunas and Clarke (2001) evaluated the impact of N rate, mowing height and clipping removal on the incidence and severity of gray leaf spot for three years in New Jersey. The N rates evaluated were 0, 24.4, 48.8, and 97.6 kg N $ha^{-1}$ from urea. In one study year, when disease pressure was low, gray leaf spot severity decreased between 22 and 69% of the plot area blighted with increasing N rate. During the other two years, they observed that gray leaf spot severity increased as N rate increased, especially at rates greater than 24.4 kg N $ha^{-1}$. Plots mowed at 12 mm had 52, 66, and 45% less gray leaf spot when compared to those mowed at 89 mm during all three study years, respectively. In one year, removal of clippings reduced gray leaf spot by as much as 41%, however, disease pressure was low in that year. During the two other study years, clipping removal had no influence on gray leaf spot. Clarke and Vaiciunas (2001) noted that water-soluble N sources (sources not given in abstract) increased disease severity, while slow release N sources had no effect on gray leaf spot, when compared to non-fertilized plots.

Uddin et al. (2001) evaluated ammonium nitrate (35-0-0), ammonium sulfate (21-0-0), urea (46-0-0), IBDU (isobutylidene urea; (31-0-0) and Milorganite (6-2-0) at 24.5 and 49 kg N $ha^{-1}$ for their effects on gray leaf spot in perennial ryegrass in Pennsylvania. Plots treated with ammonium nitrate, ammonium sulfate and urea exhibited greater disease severity than plots treated with IBDU, Milorganite or the untreated control. These findings support those of Clarke and Vaiciunas (2001).

Williams et al. (2001) investigated the effects of mowing height and N level on the severity of gray leaf spot in a two-year field study in Kentucky. Mowing treatments were 1.9 and 6.4 cm and there were two N levels from urea (183 and 366 kg $ha^{-1}$ $year^{-1}$).

The N treatments were applied monthly between April and August. No interactions between N-level and mowing height were observed. Plots treated with the highest N rate had significantly more gray leaf spot (32%) than those treated with the lowest N rate (18%). The authors suggested that applications of water-soluble N prior to the onset or during environmental condition favorable for gray leaf spot development should be avoided (Williams et al., 2001).

Uddin et al. (2004) evaluated the effect of the herbicide ethofumesate (2-ethoxy-2, 3-dihydro-3, 3-dimethyl-5-benzofuranyl methanesulfonate), which is used to control annual bluegrass in perennial ryegrass turf, for its effects gray leaf spot. They found that when ethofumesate was applied in the spring it increased the severity of gray leaf spot. Autumn applications (disease not active) of ethofumesate, however, had no effect on disease severity in the following year. Summer applications of ethofumesate were not evaluated. Clark and Vaiciunas (2001), observed that the herbicide dithiopyr (*S,S*'-dimethyl 2-difluoromethyl-4-isobutyl-6-trifluoromethylpyridine-3,5-dicarbothioate), which is used for preemergence crabgrass (*Digitaria* spp.) control, also increased gray leaf spot severity.

## **Biological Control of Gray Leaf Spot**

Viji et al. (2002) conducted experiments with spent mushroom substrate (SMS) as a possible biological control approach for gray leaf spot. In laboratory studies, isolates of *Pseudomonas aeruginosa* from the SMS were found to be antagonistic to *P. grisea*. Foliar applications of the bacteria at various timings (preventively) were made to ‘Pennfine’ perennial ryegrass in a greenhouse and field study. The *P. aeruginosa* suppressed gray leaf spot equally when it was applied at 1, 3 and 7 days prior to inoculation with *P. grisea* in the controlled experiment and in potted ryegrass plants maintained in the field. The authors suggested that *P. aeruginosa* may be a potential biocontrol agent for gray leaf spot management when used preventively.

Silicon exists in the soil solution as mono silicic acid (Si $(OH)_4$). Silicon has been shown to reduce levels of several important diseases of rice (*Oryza sativa* L.), including rice blast (*P. grisea*). Silicon is the second most abundant element in the earth's crust and generally most soils are comprised of 5 to 40% silicon. Silicon is absorbed readily by plant roots, however, repeated years of cropping can reduce silicon levels to a point where it is no longer available to plants. Other soils, however, contain little plant-available silicon. Previous research has shown that foliar and soil incorporated applications of silicon to soils that are silicon-deficient dramatically reduces the severity of rice blast and other rice diseases (Datnoff et al., 2001). In rice, there appears to be no benefit for using silicon in soils with silicon levels greater than 19 ppm (Korndorfer et al. 2001). Little is known about the critical levels for silicon in soils where turfgrasses are grown, however, preliminary research indicates that these values (i.e. 19 ppm) are similar to those of rice (L. E. Datnoff, personal communication).

Nanayakkara et al. (2004) evaluated the effects of silicon on the severity of gray leaf spot in perennial ryegrass grown in two different soils in a greenhouse. The soils were a peat:sand mix with a silicon level of 5 ppm and a Hagerstown silt loam soil with a silicon level of 70 ppm. Each soil received applications of Wollastonite (mineral calcium silicate, $CaSiO_3$) and calcium silicate slag at rates of 454, 907, 4536 and 9072 kg $ha^{-1}$ (0.0, 0.5, 1.0, 5 and 10 tons $ha^{-1}$). Nine-week –old perennial ryegrass plants grown in the silicon-treated soil were inoculated with *P. grisea*. Disease incidence and severity as well as silicon levels in plants were evaluated. Two weeks after inoculation, silicon levels in plant tissue significantly increased with increasing levels of silicon. No differences were observed in disease level and amount of silicon in the plants grown in the two soils (peat:sand mix and Hagerstown silt loam) evaluated. Disease incidence and severity were reported to be significantly lower in plants grown in both silicon-amended soils (no data shown).

Brecht et al. (2000) conducted a greenhouse study that evaluated the effect of soil incorporated silicon on gray leaf spot in 20 genotypes of St. Augustinegrass. Data were obtained twice each week for a month and converted to an area under disease progress curve (AUDPC) value. Leaf tissue was analyzed for percent silicon at the end of experiment. The addition of silicon reduced AUDPC values in all genotypes, some by as much as 78%. Generally, silicon reduced disease the most in genotypes that were very susceptible to gray leaf spot. The researchers recommended the use of silicon to protect plants from gray leaf spot, particularly in genotypes that have low levels of disease resistance and in soils that are low in soluble silicon.

### **Chemical Gray Leaf Spot Control and Resistance Problems with *P. grisea***

The potential for major damage to perennial ryegrass fairways from gray leaf spot has resulted in increased fungicide costs throughout the mid-Atlantic and transition zone regions in the USA. In severe cases, total renovation of fairways and roughs may be required (Uddin et al., 2003b). Fungicides that are relied upon for gray leaf spot management in perennial ryegrass include: azoxystrobin (methyl (*E*)-2-{2-[6-(2-cyanophenoxy)pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate); thiophanate-methyl (dimethyl 4,4'-*o*-phenylenebis[3-thioallophanate), propiconazole (1-[[2-(2, 4-

dichlorophenyl)-4-propyl-1, 3-dioxolan-2-yl] methyl]-1H-1, 2, 4-triazole); trifloxystrobin (methyl (*E*)-methoxyimino-{(*E*)-a-[1-(a,a,a-trifluoro-*m*-tolyl)ethylideneaminooxy]-*o*-tolyl}acetate); pyraclostrobin (methyl *N*-{2-[1-(4-chlorophenyl)-1*H*-pyrazol-3-yloxymethyl]phenyl}(*N*-methoxy)carbamate); mancozeb (manganese ethylenebis dithiocarbamate; and chlorothalonil (tetrachloroisophthalonitrile) (Vincelli et al. 2001, Uddin et al. 2002b, Dernoeden et al. 2002). These fungicides are most efficacious when applied before the disease becomes active.

Three strobilurin- class fungicides (quinol-oxiding inhibitor, $Q_oI$), are labeled for gray leaf spot control in perennial ryegrass turf (trifloxystrobin, Compass®; azoxystrobin; Heritage®, and pyraclostrobin; Insignia®). These fungicides inhibit the cytochrome $bc_1$ respiratory complex in mitochondria and have proven to be very effective against *P. grisea*. Vincelli and Dixon (2001) reported isolates of *P. grisea* resistant to azoxystrobin and trifloxystrobin from golf courses in Kentucky and Illinois in 2000. *In vitro* studies to assess the $EC_{50}$ for both azoxystrobin and trifloxystrobin to suspected-resistance and baseline isolates were conducted. All suspected- resistant isolates required significantly higher concentrations (690 times more azoxystrobin and 827 times more trifloxystrobin) than the baseline isolates to provide suppression of conidial germination.

Kim et al. (2003) amplified the cytochrome b gene from $Q_oI$ resistant *P. grisea* isolates (QoI-treated turf) and from baseline isolates. Isolates that were $Q_oI$ resistant fungicides carried a single point mutation in two different nucleotide positions (F129L and G143A), and neither of these mutations was found in the baseline population. An *in vitro* study assessed the sensitivity to azoxystrobin and trifloxystrobin from $Q_oI$ resistant isolates of *P. grisea* from Indiana and Maryland. This study assessed conidia germination in various fungicide dilutions in Petri dishes. It was found that *P. grisea* isolates possessing the G143A mutation were significantly more resistant to azoxystrobin and trifloxystrobin, than those possessing the F129 L mutation. From DNA fingerprinting of these resistant isolates, it was concluded that it only took a small number of ancestral mutations for field resistance to occur (Kim et al., 2003).

St. Augustinegrass is the primary lawn grass grown from southern California to the Gulf Coast States (Brecht et al. 2004). In St. Augustinegrass, fungicides are relied upon to manage *P. grisea*. Some of the same chemistries used in perennial ryegrass (i.e. chlorothalonil, propiconazole, azoxystrobin and pyraclostrobin), effectively control gray leaf spot in St. Augustinegrass plants (Datnoff et al. 2003).

Brecht et al. (2004) evaluated the use of silicon applied as calcium silicate (20%) to suppress gray leaf spot in St. Augustinegrass. Calcium silicate slag (1,000 kg Si $ha^{-1}$) was incorporated into the soil at 5 metric tons $ha^{-1}$ to three sites with silicon deficient soils prior to sprigging 'Floratam' St. Augustinegrass. The three treatments included soil incorporated silicon (calcium silicate-incorporated at 1,000 kg Si $ha^{-1}$), foliar sprays of chlorothalonil (7.6 kg a.i. $ha^{-1}$), and a combination of foliar chlorothalonil applications and calcium silicate-incorporated. Chlorothalonil treatments were applied every 10 days after sprigging. All treatments equally and significantly reduced gray leaf spot, when compared to untreated turf. Final St. Augustinegrass coverage ratings were increased by 17 and 34% at two of three sites where calcium silicate was incorporated into plots, when compared to untreated plots. The level of silicon in leaves of calcium silicate-incorporated plots was 1.2 to 1.3 %, while it was 0.6 to 0.7% in leaves from untreated plots. It was not determined if the increase in St. Augustinegrass coverage by calcium silicate was due to a reduction in disease, a physiological growth response from increased uptake of silicon, or both. It was suggested, however, that gray leaf spot in St. Augustinegrass can be more effectively managed with combinations of silicon and fungicides (Brecht et al., 2004).

Two studies examined the use of an amino-acid containing product (i.e. Macro-sorb Foliar) and a surfactant (i.e. Break-Thru) applied alone and in combination with fungicides (triadimefon, for there effects on gray leaf spot in perennial ryegrass (Vincelli et al. 2001, Uddin et al. 2002b). Neither material enhanced the level of control provided by the fungicides or had any effect on gray leaf spot when applied alone.

## Genetic Research with Gray Leaf Spot and *P. grisea*

Hofmann and Hamblin (2000) evaluated the reaction of 49 perennial ryegrass cultivars and experimental lines in Illinois to field inoculation of *P. grisea*. A spore solution (concentration of $10^4$ to $10^5$ conidia per ml) was applied weekly from 13 June until 27 July. When rated on 29 September, all perennial ryegrass plots had significant damage (> 20% plot area blighted). There were significant differences in the level of susceptibility among cultivars, since some plots had been blighted by nearly 80%. Windstar, Brightstar and Cathedral were three of the cultivars that were damaged substantially by *P. grisea*; whereas, Morningstar, SR 4200, and Pick F3 were damaged least (< 27%).

Bonos et al. (2004) evaluated perennial ryegrass cultivars (65 in 2001 and 73 in 2002) for resistance to *P. grisea*. Cultivars that showed improved natural resistance were selected, interpollinated and then seeded. These plants then were evaluated for two growing seasons for gray leaf spot resistance. They observed uniform and consistent blighting and most cultivars had greater than 50% of the plot area blighted during both study years.  Some cultivars had similar levels of gray leaf spot during both years, while other cultivars exhibited improved resistance.  Offsprings developed from parents that showed some initial natural resistance to gray leaf spot exhibited greater resistance in the second year. Cultivars showing even minor levels of resistance recovered more rapidly once air temperatures cooled.  It was noted that 50% of the cultivars that showed some levels of *P. grisea* resistance were from Eastern Europe, where perennial ryegrass is indigenous.  They concluded that the best opportunity to find resistant germplasm is to collect germplasm from Eastern Europe.

No highly resistant perennial ryegrass cultivars are currently available, and fungicide use remains the only approach to effectively manage gray leaf spot.  Hence, knowledge of cultural management programs to reduce gray leaf spot incidence and severity are warranted.

## II. Dollar Spot and Gray Leaf Spot Severity As Influenced by Irrigation, Paclobutrazol, Chlorothalonil and a Wetting Agent

Synopsis

The most commonly grown turfgrass species on fairways in the mid-Atlantic region of the United States are creeping bentgrass (*Agrostis stolonifera* L. var *palustris* (Huds.) Farw.) and perennial ryegrass (*Lolium perenne* L.). Creeping bentgrass and perennial ryegrass are susceptible to dollar spot (*Sclerotinia homoeocarpa* F. T. Bennett) and gray leaf spot (*Pyricularia grisea* (Cooke) Sacc.) diseases, respectively. This field study assessed the influence of two irrigation regimes (light and frequent versus deep and infrequent) on dollar spot and gray leaf severity over a three year period. Within each irrigation regime, seven chemical treatments also were evaluated. The chemical treatments included: chlorothalonil, paclobutrazol (PB), wetting agent (WA), chlorothalonil + PB, chlorothalonil + WA, chlorothalonil + PB + WA, and an untreated control. Data revealed that dollar spot became more severe in mid-to-late summer in creeping bentgrass that received infrequent irrigation, when compared to frequent irrigation in 2002 and 2004. Chlorothalonil generally provided an acceptable level of dollar spot control, even at a reduced rate in 2004. Paclobutrazol suppressed dollar spot 40 to 60% and the WA suppressed dollar spot 30 to 50% on several rating dates over the seasons (PB, n=11; WA, n=7). On numerous rating dates in 2004, chlorothalonil, PB, WA, and chlorothalonil + PB provided better dollar spot suppression in frequently irrigated versus infrequently irrigated turf. Gray leaf spot was severe in 2002 and 2004, but the disease did not develop in 2003. In 2002, gray leaf spot rapidly and severely damaged even the fungicide-treated plots, and no significant irrigation effects or chlorothalonil treatment differences were observed. Gray leaf spot was more severe in frequently irrigated blocks, when compared to infrequently irrigated blocks in 2004. Chlorothalonil provided effective gray leaf spot control in 2004, but only in the infrequently irrigated blocks where disease pressure was less. Neither PB or WA had any effect on gray leaf spot, and no benefit was observed from tank-mixing chlorothalonil with either PB or WA. Results from this study suggest that maintaining soil moisture levels above 25 $cm^3$ $cm^{-3}$ reduced dollar spot severity in mid-to-late summer and improved the ability of chlorothalonil, PB, and WA to suppress the disease. This study also showed that gray leaf spot was very destructive under periods of very high disease pressure and an ineffective fungicide application interval (14 day), regardless of soil moisture level. Chlorothalonil effectively controlled gray leaf spot when applied on an eight-day rather than a fourteen-day spray interval, but only in infrequently irrigated blocks in 2004. This information will help golf course superintendents better manage dollar spot and gray leaf spot by adjusting their irrigation practices and by using plant protection chemicals more effectively.

Introduction

Golf course fairways normally comprise between 10 and 14 hectares of highly managed fairway turf, which represent approximately of 20% of the overall area of an entire golf course (Beard, 2002). Fairways are extremely important to the playability of the entire golf course. Throughout the mid-Atlantic region of the United States, the most common cool-season turfgrass species grown on fairways are creeping bentgrass (*Agrostis stolonifera* L. var *palustris* (Huds.) Farw.) and perennial ryegrass (*Lolium perenne* L.). Although both turfgrass species provide excellent fairway surfaces, each can be seriously affected by at least one major summer disease. Creeping bentgrass is very susceptible to dollar spot (*Sclerotinia homoeocarpa* F. T. Bennett) and perennial ryegrass is very susceptible to gray leaf spot (*Pyricularia grisea* (Cooke) Sacc.). Economically, dollar spot is one of the most important diseases affecting golf courses and more money is spent on managing this disease than any other (Vargas, 2004). Additionally, Uddin et al. (2003b) reported that an average golf course with perennial ryegrass fairways has had to increase their fungicide budget by greater than 5% since 1995 to address gray leaf spot.

During summer months, water from irrigation is applied frequently to fairways to maintain turf health and promote vigor. There are two distinct approaches to irrigating fairways during summer months in the mid-Atlantic region. These approaches are light and frequent and deep and infrequent irrigation. Frequent irrigation is a common summer practice for numerous golf course managers, primarily because of aesthetic reasons. Frequent irrigation promotes wet soils and dew formation, which are important in the development of several turf diseases. Deep and infrequent irrigation is performed for playability and agronomic reasons, and involves maintaining the soil as dry as possible until symptoms of wilt are observed. Deep and infrequent irrigation typically is recommended as a cultural disease management tool as one would predict that dry soil conditions are less conducive for plant infection by most foliar pathogens (Couch, 1995; Vargas, 2004; Watschke et al., 1995). A greenhouse study demonstrated that low soil moisture levels enhanced dollar spot in mature Kentucky bluegrass (*Poa pratensis* L.) plants (Couch and Bloom, 1960). In that study, soil moisture levels = 75% of field capacity resulted in a 45 to 55% increase in dollar spot severity, when compared to plants maintained at field capacity. Jiang et al. (1998), however, found that dollar spot in fairway height perennial ryegrass was enhanced by 50% when it received daily irrigation in one year of a two year field study in Kansas. Jiang et al. (1998), also observed an increase in clipping weights in the frequently irrigated plots. They suggested that as clippings were removed from the study site, nitrogen was depleted, which promoted the increased blighting. Watkins et al. (2001) studied the influence of two irrigation regimes on dollar spot in creeping bentgrass in Nebraska. In that field study, turf was irrigated daily at 100% or 60% (between April to mid-June) to 80% (between mid-June and 9 September) of potential evapotranspiration. Dollar spot severity was not affected by either irrigation regime. Rainfall, however, was above the 14-year average during both study years. These results and those of Jiang et al. (1998) do not support the earlier findings of Couch and Bloom (1960). The influence of irrigation frequency on dollar spot in the mid-Atlantic region has not been assessed in the field. There are no field studies that have investigated the influence of soil moisture on gray leaf spot severity. Previous research, however, has demonstrated that both dollar spot and gray leaf spot are more prevalent during periods that favor increased leaf wetness durations (Couch, 1995, Hall, 1984, Uddin et. al, 2003a, Williams et al., 1996).

In addition to cultural practices, many golf course managers use a variety of chemicals to maintain fairways at the desired quality level. Some of these chemicals include plant growth regulators (PGR's), wetting agents and fungicides. Paclobutrazol (4-chlorophenyl) m ethyl-alpha (1-1 dimethyl) -1h-1, 2, 4 triazole-1 ethanol) is a PGR that is commonly applied to manage excess clippings, improve turfgrass color and density, and to suppress annual bluegrass (*Poa annua* L.) populations. Paclobutrazol belongs to the triazole class of chemicals and has fungistatic effects on *S. homoeocarpa* in creeping bentgrass (Burpee et. al 1996, Dernoeden et al., 2002). Little information exists on the effect that paclobutrazol may have on gray leaf spot or on dollar spot in turf managed under different irrigation regimes.

Wetting agents are commonly used on fairways to improve water infiltration and to alleviate hydrophobic soil conditions associated with localized dry spots and fairy rings. Primer Select® (polymeric polyoxyalkylene 95% oxoalkonyl hydroxyl polyoxlalkane diyl 5%; Aquatrols Corporation of America, Paulsboro, NJ) is a non-ionic surfactant that is commonly used on golf courses and has been shown to suppress dollar spot (Dernoeden et al., 2002). On mornings following an application of most wetting agents, there is displacement of dew from the turfgrass canopy. Williams et al. (1996) reported that early morning displacement of leaf surface exudates by mowing reduced dollar spot severity (53 to 81%). Liu et al. 1995b, reported that the tank-mix of the wetting agent Aqua-Gro® (95% polyoxyethylene ester and 50% polyoxyethylene ether of cyclic acid and alklated phenols with silicone anti-foam emulsion; Aquatrols Corporation of America, Paulsboro, NJ) with the fungicide benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate) reduced dollar spot severity, when compared to benomyl applied alone. They hypothesized that the benomyl rate could be reduced by 30% when tank-mixed with Aqua-Gro and immediately watered-in. The effect of dew displacement by a wetting agent on gray leaf spot severity is unknown.

Chlorothalonil (tetrachloroisophthalonitrile) is perhaps the most widely used fungicide on turfgrasses and it effectively controls dollar spot and gray leaf spot (Mitkowski et al., 2005; Dernoeden et al., 2005). Chlorothalonil is an extremely important fungicide for use in disease resistance management programs. Because of its broad spectrum activity, there have been no reported cases of pathogen resistance to chlorothalonil, but there have been resistance problems with other fungicides used to control dollar spot and gray leaf spot in turf (Burpee, 1997; Vargas, 2004; Vincelli, 2001). Furthermore, the United States Environmental Protection Agency (E.P.A) placed restrictions on the use of chlorothalonil in 2002 (Appendix B. Table 1). These restrictions have created the need to elucidate approaches to increasing the longevity of chlorothalonil. The effects of irrigation on chlorothalonil performance are unknown. Therefore, since chlorothalonil, paclobutrazol and wetting agents and various tank-mixes are widely used as part of fairway management programs, research regarding their use under relatively wet or dry irrigation regimes is warranted.

The purpose of this three year field study was to evaluate the influence of two irrigation regimes (light and frequent versus deep and infrequent) and three commonly used chemicals (chlorothalonil, paclobutrazol, wetting agent) and various tank-mixes of these materials on fairway height creeping bentgrass and perennial ryegrass for their impact on dollar spot and gray leaf spot incidence and severity.

Materials and Methods

## Site Descriptions

This study was conducted at the University of Maryland Paint Branch Turfgrass Research Facility in College Park, MD. Soil was a Keyport silt loam (fine, mixed, semiactive, mesic Aquic Hapludult) with a pH ranging from 5.8 to 6.2 and 12 to 20 mg of organic matter/g soil.

**2002.** In April 2002, the soil in eight, 3.0 m x 10.5 m blocks was tilled and leveled by hand raking. These blocks will be described further in the irrigation protocol to follow. Blocks were split (1.5 m x 10.5 m) and 'Crenshaw' creeping bentgrass and 'Figaro' perennial ryegrass were separately seeded into each half block at 49 and 292 kg seed $ha^{-1}$, respectively. Following the mid- April seeding, the soil was raked and firmed by rolling. 'Crenshaw' was chosen based on its known high susceptibility of dollar spot and 'Figaro' because of its susceptibility to gray leaf spot (T. R. Turner, personal communication). The study area received a total of 120 kg N $ha^{-1}$ during the 2002 study period from either a 16-4 -8 or 19-0-19 fertilizer (Appendix A. Table 2). All plots were mowed three times $week^{-1}$ to a height of 19 mm with a reel mower and clippings were removed. Treatments were initiated on 17 June and the final applications were made on 26 August 2002. Neither dollar spot or gray leaf spot were visually active at the time the study was initiated.

**2003.** The 2002 site was renovated using glyphosate (N-(phosphonomethyl)glycine) in October 2002. The site was vertical cut and seeded (49 kg seed $ha^{-1}$) with 'Crenshaw' creeping bentgrass on 12 October 2002. Similarly, 'Brightstar' perennial ryegrass was seeded (440 kg seed $ha^{-1}$) on 5 May 2003. A spring seeding was chosen because immature perennial ryegrass turf generally is more susceptible to gray leaf spot. 'Figaro' was rapidly and severely damaged by *P. grisea* in 2002, and there were few differences among treatments. Therefore, 'Brightstar' was substituted in 2003 in anticipation that it was not as susceptible as 'Figaro'. Creeping bentgrass and perennial ryegrass plots were mowed two to three times $week^{-1}$ to a height of 19 and 21 mm, respectively. Higher mowing was required for the perennial ryegrass because of poor stand development. During all study years, chemical applications were periodically made to the plot areas to manage weeds and diseases (Appendix A. Table 1). Flutalonil (N-[3-(1-methylethoxy) phenyl ]-2-(trifluoromethyl) benzamid) was used to control brown patch (*Rhizoctonia solani* Kuhn) and mefenoxam (R)-20[2, 6-dimethylphenyl)-methoxyacetylamino]-propionic) targeted Pythium blight (*Pythium* spp.). These aforementioned fungicides would not be expected to greatly affect dollar spot or gray leaf spot (Dernoeden et al., 2001). Creeping bentgrass received a total of 60 kg N $ha^{-1}$, while the perennial ryegrass received a total of 146 kg N $ha^{-1}$ from either of the aforementioned fertilizers or urea during the study period (Appendix A. Table 2).

Originally, treatments were initiated in the creeping bentgrass on 6 June and repeated on 19 June 2003. Dollar spot became a problem in the creeping bentgrass 12 June (Appendix A. Table 5), especially in plots that did not contain a chlorothalonil treatment. This was prior to the time when the perennial ryegrass plants were mature enough to impose treatments. On 16 June, dollar spot activity was intense in the bentgrass and infection centers had coalesced by 27 June. On 27 June, all bentgrass plots were treated with chlorothalonil (10.2 kg a.i. $ha^{-1}$) to control dollar spot and to allow time for infection centers to heal so that irrigation treatments could be imposed simultaneously on both species. To speed recovery from dollar spot in bentgrass, 24.4 kg

N ha$^{-1}$ from urea were applied on 27 June. Treatments finally were re-initiated in both species on 10 July and continued every 14 days until 21 August.

**2004.** The 2003 site was treated with glyphosate on 17 September 2003 and reseeded as previously described. Irrigation blocks were reversed and the frequently irrigated blocks became infrequently irrigated blocks and vice versa. Similarly, the perennial ryegrass and creeping bentgrass were reversed in each block. On 15 October 2003, 'Crenshaw' creeping bentgrass was seeded (78 kg seed ha$^{-1}$) as previously described. Because there was no gray leaf spot damage to 'Brightstar', 'Figaro' was seeded (370 kg seed ha$^{-1}$) on 3 October. On 10 November, both sites were fertilized with 48.8 kg N ha$^{-1}$ from a complete fertilizer. Both stands were fertilized with 24.5 kg N ha$^{-1}$ from a complete fertilizer on 19 April 2004. The study area received 85.7 kg N ha$^{-1}$ from 20-20-20 or urea during the 2004 study period (Appendix A. Table 2). Both species were mowed to a height of 19 mm three times week$^{-1}$ with a reel mower and clippings were removed.

Chemical and irrigation treatments were initiated 1 June 2004. The rate of chlorothalonil was reduced in 2004 in the creeping bentgrass to 4.5 kg a.i. ha$^{-1}$, which is the low label rate. Treatments were initiated 1 June and reapplied to the bentgrass on 15 and 29 June, 15 and 30 July and 16 August. Initially, chlorothalonil was applied to the perennial ryegrass at 4.5 kg a.i. ha$^{-1}$. The 2002 data suggested that the 8.0 kg a.i. ha$^{-1}$ applied on a fourteen day interval would not be expected to effectively control gray leaf spot once the disease had become active, the rates and application intervals were adjusted as noted below. Perennial ryegrass plots received chlorothalonil (4.5 kg a.i. ha$^{-1}$) treatments on 15 and 29 June, and 15 July 2004. Gray leaf spot became active in the perennial ryegrass plots on 20 July 2004. Thereafter, chlorothalonil (8.0 kg a.i. ha$^{-1}$) was applied to the all perennial ryegrass plots that were to receive chlorothalonil either alone or in a tank-mix on 20 and 28 July, and 6 and 16 August. Paclobutrazol and Primer Select®-alone- treatments were applied on a 14 day interval beginning 1 June and ending 16 August.

### Irrigation Treatments

In autumn 2001, eight (3.0 x 10.5 m) independently irrigated blocks were outfitted with pop-up, matched precipitation spray irrigation heads (Weathermatic Model 5520; Weathermatic Irrigation Company; Dallas, TX.) which delivered 22.3 L minute$^{-1}$ to each block. This is equivalent to a precipitation rate of 0.15 mm water minute$^{-1}$. To assess the main effects of two irrigation regimes consisting of i) infrequent irrigation to a soil depth of 6 to 8 cm and ii) light (on average 5.0 mm water) and frequent (daily) irrigation. The irrigation treatments were applied to four, randomly assigned blocks. Throughout the study, rainfall events were recorded using a rain gauge (Rain Gauge, Spectrum Technologies, Inc. Plainfield, IL.).

Infrequently and frequently irrigated blocks were irrigated between 6:00 and 8:00 hours and 21:00 hours, respectively. These times were chosen based on the practices of many golf course managers. Typically, a golf course manager that irrigates frequently will water during the night (21:00-23:00 hours). Frequent, nighttime irrigation is not a recommended cultural practice, but is still common because infrequent irrigation during the morning hours takes significantly more time and labor to complete prior to turf maintenance practices and golfer use. When golf course managers are watering infrequently, typically they will assess dew patterns early in the morning hours (6:00 hours) and determine if the turf is likely to wilt that day. The infrequently irrigated blocks only received water when visible drought stress symptoms were observed or when soil moisture measurements indicated that the soil had fallen well below field capacity (i.e. < 17 $cm^3$ $cm^{-3}$ soil moisture). Both irrigation regimes were adjusted based on weather patterns and irrigation was withheld if rainfall were forecasted or had recently occurred (> 6.0 mm).

Overall, approximately 25 to 38 mm of water from irrigation or rainfall $week^{-1}$ were applied to both frequently and infrequently irrigated plots in 2002, which was a drought year. Due to frequent rain in 2003 (47.6 cm precipitation during study period), there were only a few dates when supplemental irrigation was applied to the frequently irrigated blocks. The 2004 season was another wet year (51.4 cm precipitation during the study period) and tarps (3.3 x 11 m) were used to cover infrequently irrigated blocks prior to the onset of rain. Tarps were slightly wider than individual blocks and were constructed from 12 mil black/white reinforced polyethylene sheeting; Model 12 BW; Integra Plastics, Madison, SD). Tarps only were used on the infrequently irrigated plots to promote soil drying and to better assess the effect of irrigation and soil moisture on the diseases being assessed. The white side of the tarps faced up and they usually were removed within 15 minutes after weather had cleared. Tarps were used on 14 occasions between 4 June and 21 August. The frequently irrigated blocks received water daily at the aforementioned amounts and times of day. The frequently irrigated blocks received an average of 64 mm water $week^{-1}$, while the infrequently irrigated plots received 21 mm $week^{-1}$ from either irrigation or rainfall during 2004. The frequently irrigated blocks received substantially more water due to frequent rainfall, which there was no control over.

## Chemical Treatments

In 2002 and 2003, seven chemical subplot (1.5 x 1.5 m) treatments were applied as follows: chlorothalonil at 8.0 kg a.i. $ha^{-1}$; paclobutrazol (PB) at 0.13 kg a.i. $ha^{-1}$; Primer Select® (WA) at 6.3 L product $ha^{-1}$; chlorothalonil + PB; chlorothalonil + WA; chlorothalonil + PB + WA; and an untreated control. Rates for the tank-mix treatments were the same as for each chemical applied alone. As previously noted, the rate of chlorothalonil was reduced to 4.5 kg a.i. $ha^{-1}$ in the bentgrass in 2004 because no dollar spot differences were observed among these treatments in 2002 and 2003. Chemical treatments were applied on the dates described above and footnoted in the data tables. Chemical treatments were applied using a $CO_2$ pressurized sprayer (262 kPa) equipped with an 8004E flat fan nozzle and calibrated to deliver 468 L $ha^{-1}$. On treatment days, chlorothalonil and WA were allowed to completely dry on foliage and irrigation was applied to the entire area with a minimum of 6.4 mm of water eight to ten hours after application for PB uptake by roots.

## Dew Measurements

In 2004 only, dew measurements were obtained 1, 3, 5 and 7 days after application of treatments when paclobutrazol and WA were included to determine the duration and amount of dew displaced by the these treatments. Measurements were taken separately on each species. Two replications of each species and irrigation regime were assessed to obtain an average. Canopy dew measurements were performed as described by Williams et al. (1998). Briefly, four white, unscented Kimwipe tissues (Kimberly-Clark Corp, Rosewell GA.) were placed into a zip-lock bag and weighted. Prior to dew removal, the four tissues were removed from the bag and blotted over 120

$cm^2$ area of an untreated control plot using a wooden frame as a template. Blotting was carefully performed to accurately measure canopy dew and not to absorb any moisture from the thatch layer. Tissues then were placed into the same bag and immediately weighed. The gain in weight was used to calculate the amount of dew present on the canopy. Data were converted from grams 120 $cm^{-2}$ to millimeters of moisture as previously described by Williams et al. (1998). Dew amounts (mm) then were converted into L $ha^{-1}$.

### Soil Moisture Measurements

In all years, volumetric soil moisture was recorded two to three times $week^{-1}$ using time domain reflectometry (TDR) (Soil Moisture Equipment Corp., CA). The TDR technique has been shown to be a viable method for determining water content in soils that are homogenous (Topp et al., 1982). The two probes of the TDR were 15 cm in length and pushed into the soil so that the top of the probes were flush with the thatch layer. The TDR takes the average of the dielectric constant within those 15 cm and records the values as $cm^3$ $cm^{-3}$. Seven measurements were taken randomly in each perennial ryegrass and creeping bentgrass block. Soil moisture measurements then were averaged for each irrigation regime and species. Significantly different means were separated at P=0.05 using Fischer's least significant difference (LSD test). Soil moisture measurements then were charted over the course of each study year with $1^{+}_{-}$ standard error (SE) bars shown. (Figures 1 and 2).

### Soil Temperature

To determine the effects of the two different irrigation regimes on soil temperature, four continuous data logging probes (Stowaway Tidbit Temperature Logger, Onset Computer Corp., Pocasset, MA.) were installed 6.5 cm below the soil surface. One probe was placed in two perennial ryegrass and two creeping bentgrass blocks subjected to either frequent or infrequent irrigation. Soil was compacted over top and around probes to ensure accuracy. Probes were capable of storing temperature data for 55 days and measurements were recorded every 15 minutes. Loggers were checked weekly and downloaded into Box Car software system, (Onset Computer Corp. Pocasset, MA.) on a laptop computer. The Box Car system is a computer program that tracks and plots changes in soil temperature over time. Logger installation and removal dates were 28 June and 2 November 2002; 11 June and 11 September 2003; 26 May and 26 October 2004. Loggers were checked weekly throughout the study period. During 2003 and 2004, the loggers were occassionaly struck by lightening and did not record data. Soil temperature data will not be discussed, but can be found in Appendix A. Figures 2 - 4.

### Ratings and Statistical Analyses.

Plots were rated for disease severity and turfgrass quality. Dollar spot was assessed by counting the number of infection centers plot$^{-1}$ until they had coalesced. Depending on disease pressure, *S. homoeocarpa* infection centers typically coalesce when more than 3% of the plot area became blighted. Thereafter, plots were rated visually on a linear 0 to 100% scale where 0=no disease and 100=entire plot area blighted. An acceptable threshold was judged to be 8 to 10 *S. homoeocarpa* infection centers plot$^{-1}$ or 0.5 % plot area blighted. Gray leaf spot was assessed using the same visual linear scale. Area under the disease progress curve (AUDPC) is a way to integrate data from a study period into a single value for each treatment. Hence, AUDPC values allow one to assess the total amount of disease within a treatment over a specified time period. The AUPDC values were calculated for dollar spot and gray leaf spot data according to Campbell and Madden (1990) using the formula ∑ (sum of) $[y_i + y_{i+1})/2$ $[t_{i+1}-t_i]$ where i=1, 2, 3….n-1, $y_i$ is the amount of disease (either infection centers or percent of plot area blighted) and $t_i$ is the time of the $i^{th}$ rating. For dollar spot, AUDPC values were calculated separately for early season (i.e., infection center data) and late season (i.e., percent plot area blighted data) data collection periods. The AUDPC values shown in the data tables represent a sum value, where the larger number represents a greater amount of disease. Because these treatments were evaluated over the same time period each year, there is no need to standardize or normalize the data. The 2002, 2003 and 2004 % PAB AUDPC (dollar spot) values include ratings taken 32, 24, and 42 days after the last fungicide application, respectively. he unit of measure for an AUDPC value is disease x time, since disease would be shown on the y-axis (either IC or % plot area blighted) and time (days) on the x-axis of a figure. Turfgrass quality was rated visually on a 0 to 10 scale where 0=brown turf; 7.5=minimum acceptable level of quality for a golf course fairway, and 10=optimum greenness and density. Turf quality data are not discussed, but can be found in Appendix A.

Treatment structure was a 2 (irrigation treatments) x 7 (6 chemical treatments and one untreated control) factorial with four replications. Data were subjected to a one-way analysis of variance (ANOVA) in SAS MIXED (SAS version 9.1, SAS Institute; Cary, NC). When an interaction was observed, data were subjected to a two-way ANOVA in SAS GLM to separate treatments and include a Tukey's LSD test to separate treatments P= 0.05) (Steel et al., 1997). Disease data were analyzed using a square-root transformation to normalize the data.  Turf quality data were separated using the protected less conservative Fisher's LSD test (P= 0.05).

Results

## Dollar Spot

**2002.** Treatments initially were applied on 17 June, but dollar spot was very slow to develop (Table 1, Appendix A. Table 3). June and July were marked by prolonged periods of dry weather (Table 9). Soil moisture levels initially were similar, but began to separate during the last week of June. By 9 July, infrequently and frequently irrigated plots had a mean soil water content ranging from 16 to 28 $cm^3$ $cm^{-3}$, respectively (Figure 1). Except on 10 August, soil moisture levels in the infrequently irrigated blocks (15.5-26.0 $cm^3$ $cm^{-3}$) were lower than those in the frequently irrigated blocks (27.0-35.2 $cm^3$ $cm^{-3}$) for the entire study period. Dollar spot pressure peaked on 3 September, when untreated plots had an average of 109 *S. homoeocarpa* infection centers $plot^{-1}$ (IC's). Thereafter, dollar spot severity was rated by assessing the percent of plot area blighted (% PAB). It should be noted that the acceptable threshold for dollar spot control in fairway height turf was judged to be 8 to 10 IC's $plot^{-1}$ or 0.5 % PAB.

From 19 July to 16 August, no differences in the level of dollar spot control were observed between irrigation regimes (Table 1; all data not shown). There were, however, differences in the level of dollar spot control among the chemical treatments (Table 1). Dollar spot was first observed in the paclobutrazol (PB)-alone and untreated plots on 19 July. By 29 July, chlorothalonil-alone, chlorothalonil + PB, and chlorothalonil + PB + wetting agent (WA) reduced dollar spot, when compared to all other treatments (data not shown). On 7 August, only the tank-mix of chlorothalonil + PB provided complete dollar spot control. By 16 August, all chemical treatments, except the WA (4.4 IC's), had reduced dollar spot, when compared to the untreated control (8.5 IC's). On 22 August, infrequently irrigated plots had an average of 15.5 IC's, while frequently irrigated plots had 3.3 IC's, and there was a significant interaction between chemical treatment and irrigation regime (Table 1). On that date, the WA applied to frequently irrigated plots had provided a level of dollar spot control equal to all other chemical treatments. Conversely, the WA applied to infrequently irrigated plots had dollar spot levels equal to the untreated control. Similarly, on 26 August plots treated with the WA-alone in the infrequent irrigation regime had 62 IC's, while plots receiving the WA in the frequent irrigation regime had 5.8 IC's. When each irrigation regime was examined independently on 26 August, the WA applied to plots in the infrequent irrigation regime had IC's equal to the untreated control. The WA applied to plots in the frequent irrigation regime, however, had dollar spot levels equal to all other chemical treatments, which were lower than those levels observed in the untreated control. On 3 September, no significant interactions were observed among treatments or irrigation regimes.

The IC AUDPC values revealed significant interactions between irrigation regime and chemical treatments (Table 1). In both irrigation regimes, plots treated with chlorothalonil-alone or tank-mixed with WA and PB had less dollar spot, when compared to plots treated with WA and PB alone and the untreated control. Within the frequently irrigated blocks, PB and WA-treated plots had dollar spot levels equal to the untreated control. In the infrequently irrigated regime, PB-alone-treated plots had less dollar spot than plots treated with WA-alone or the untreated control. Except for chlorothalonil+ PB + WA, chlorothalonil and the tank-mixes, provided effective dollar spot control within both irrigation regimes.

By 5 September, *S. homoeocarpa* infection centers had coalesced and thereafter disease severity was rated as %PAB. On 5 and 13 September, no dollar spot differences were observed between irrigation regimes (Table 2). On 5 September, PB (0.2% PAB) and WA (6.2% PAB) reduced dollar spot, when compared to the untreated control, but they were not as effective as chlorothalonil or the tank-mix treatments (<0.1% PAB). On 13 September, dollar spot in WA-treated plots had increased substantially to 8.4% PAB, however, this was still less disease than was observed in the untreated control (20.8% PAB). Paclobutrazol applied to infrequently irrigated blocks provided better dollar spot suppression (1.3% PAB) than the WA (8.4% PAB), however, it was not as effective as the chlorothalonil treatments (0.0% PAB). On 23 September, frequently irrigated plots had an average of 5.4% PAB, while those that received infrequent irrigation had nearly three times as much disease (13.1% PAB). A significant irrigation by chemical treatment interaction also was observed on 23 September. Both PB and WA performed differently in each irrigation regime. In frequently irrigated blocks, PB and WA reduced dollar spot when compared to untreated plots, however, they were not as effective as treatments containing chlorothalonil. In the infrequently irrigated regime, the WA was not as effective as chlorothalonil treatments or PB, however, dollar spot levels in the WA-treated plots were less than those observed in the untreated control. In frequently irrigated blocks on 1 October, WA (20.5% PAB) and PB (20.5% PAB) provided the same level of dollar spot suppression. However, in the infrequently irrigated blocks PB (18.8% PAB) provided better dollar spot suppression than the WA (40.3% PAB). On most rating dates, all chlorothalonil treatments provided the same level of dollar spot control in each irrigation regime.

The AUDPC values for PAB data revealed that infrequently irrigated blocks had higher dollar spot levels (124.3% PAB x time), when compared to the frequently irrigated blocks (72.4% PAB x time). When each irrigation regime was independently examined, PB-treated plots had lower dollar spot levels in both irrigation regimes, when compared to WA-treated plots and the untreated control (Table 2). Plots treated with WA had lower dollar spot levels versus the untreated control in both irrigation regimes. All plots treated with chlorothalonil-alone or in a tank-mix had low levels of dollar spot throughout 2002 and few differences were observed among those treatments.

**2003.** The year was marked by heavy dollar spot pressure, unseasonably cool temperatures, and frequent rainfall (Table 9). Although there were soil moisture differences between irrigation regimes, soil moisture in the infrequently irrigated blocks never fell below 19 $cm^3\ cm^{-3}$ in 2003 (Appendix A. Figure 1). Furthermore, soil moisture levels in both irrigation regimes were similar during the entire study period. Chemical treatments initially were applied to the bentgrass on 6 and 19 June 2003, however, dollar spot damage in most treated plots quickly exceeded the threshold (data not shown, Appendix A. Table 5). On 27 June, chlorothalonil (8.0 kg a.i. $ha^{-1}$) was applied to all bentgrass plots. After a period of recovery, all chemical and irrigation treatments were re-implemented on 10 July. Ratings were taken as percent of plot area blighted, since patches had rapidly coalesced.

When dollar spot reactivated in the study area on 24 July, there were no dollar spot differences between the irrigation regimes (Table 3). Among chemical treatments on 24 July, plots treated with chlorothalonil and all tank-mixes were disease-free. Paclobutrazol-treated plots (2.9% PAB) had lower dollar spot levels, when compared to the WA (6.2% PAB) and untreated control (9.0% PAB) on 24 July. By 31 July, dollar spot was observed in plots treated with chlorothalonil + PB and chlorothalonil + WA, but no dollar spot was observed in plots treated with chlorothalonil-alone or chlorothalonil + WA + PB. Paclobutrazol and WA-treated plots had dollar spot levels equal to the untreated control on 31 July. On 6 August, all plots treated with chlorothalonil were dollar spot-free, but untreated plots were severely damaged (18.8% PAB). Dollar spot levels were above the threshold (>0.5% PAB) in WA-alone (9.8% PAB) and PB-alone (4.3% PAB)-treated plots, but these disease levels were less than those observed in the untreated control (18.8% PAB) on 6 August. Dollar spot severity peaked on 13 August and there were high levels of disease in the untreated plots (23% PAB) and WA-alone-treated plots (17.8% PAB), which were statistically similar. Paclobutrazol-alone (6.3% PAB) reduced dollar spot, when compared to the WA-alone (17.8% PAB). All chlorothalonil treatments provided complete control, which was significantly better than all other treatments on 13 August.

By late August, plots had begun to recover and little or no dollar spot was observed in plots receiving the chlorothalonil treatments. Dollar spot levels among WA, PB and untreated control plots were similar at this time (data not shown; Appendix A. Table 6). Beginning in early September soil moisture measurements in the infrequently irrigated blocks had dropped due to less frequent rainfall in mid-to-late August (Appendix A. Figure 1 and Table 9). On 5 September, a significant chemical by irrigation treatment interaction was observed (Table 3). Within the frequent irrigation regime, all treatments had equal levels of dollar spot. In the infrequently irrigated blocks, plots treated with PB-alone had less dollar spot than WA-treated plots and the untreated control. Similarly, on 15 September there was a chemical by irrigation interaction. In the infrequently irrigated blocks, plots treated with chlorothalonil and the tank-mixes had less dollar spot, when compared to plots treated with WA and PB or the untreated control on 15 September.

The AUDPC for PAB values showed that chlorothalonil-alone and tank-mix treatments provided the best level of dollar spot control. Although plots treated with PB-alone were severely damaged by dollar spot, PB- treated plots had less disease, when compared to WA-treated plots and the untreated control. There were no significant effects between irrigation regimes in 2003. This likely was due to frequent rainfall, since no agronomically important differences in soil moisture levels between the regimes during the peak period of disease activity occurred.

Dollar spot in the perennial ryegrass was controlled curatively with iprodione (6.1 kg a.i. $ha^{-1}$), but on a few occasions in 2003 disease injury was evaluated (Table 4). All plots treated with chlorothalonil, chlorothalonil tank-mixes or PB-alone had less dollar spot, when compared to the untreated control on 6 August. The perennial ryegrass blocks were treated with iprodione (6.1 kg a.i. $ha^{-1}$) on 6 August and dollar spot reactivated on 21 August. Dollar spot progressed until 28 August, before the perennial ryegrass was again treated with iprodione. Chlorothalonil-alone, the tank-mixes and PB-alone provided an equal level of dollar spot control on 28 August. There was a non-significant trend on all rating dates in August indicating that dollar spot levels were higher in perennial ryegrass blocks that had received infrequent versus frequent irrigation.

**2004**. Due to frequent rainfall in 2003, tarps were used on 14 occasions in 2004 to achieve variation in soil moisture levels between irrigation regimes. Soil moisture in frequently irrigated blocks remained above 30 $cm^3$ $cm^{-3}$ between 10 June and 12 September (Figure 2). Except between 29 July and 18 August, infrequently irrigated blocks had soil moisture levels below 25 $cm^3$ $cm^{-3}$. On three occasions during mid-to-late August, wilt was observed in at least one infrequently irrigated block. Irrigation and chemical treatments were initiated on 1 June, and dollar spot became active on 29 June. The chlorothalonil rate was reduced from 8.0 kg a.i. $ha^{-1}$ to the low label rate of 4.5 kg a.i. $ha^{-1}$ in 2004.

Plots were evaluated for dollar spot 16 times during 2004 (all data not shown; Appendix A. Tables 8 and 9). There were no dollar spot differences among irrigation or chemical treatments when trace levels of disease were first observed on 29 June (data not shown; Appendix A. Table 8). On 6 July, plots treated with WA-alone (8.8 IC's) had dollar spot levels equivalent to the untreated control (6.6 IC's), but there were no differences among all other treatments (data not shown, Appendix A. Table 8). By 13 July, all treated plots had active dollar spot, but only plots treated with chlorothalonil + PB (0.3 IC's) had levels lower than the untreated control (6.9 IC's; data not shown; Appendix A. Table 8). There was a significant chemical by irrigation interaction on 21 July (Table 5). Plots treated with WA-alone (10.8 IC's) and PB-alone (6.0 IC's) in frequently irrigated blocks had dollar spot levels equivalent to the untreated control (10.3 IC's, Table 5). In infrequently irrigated blocks, PB-alone (0.0 IC's), but not WA-alone (8.5 IC's), provided a level of dollar spot control equivalent to all chlorothalonil-treatments. There were no irrigation by chemical interactions on 2 and 10 August (Table 5). Plots treated with PB-alone (22.4 IC's) had dollar spot levels less than plots treated with WA-alone (60.8 IC's) and untreated plots (60.8 IC's) on 2 August. Chlorothalonil-alone (5.6 IC's)-treated plots had less dollar spot than plots treated with PB-alone (22.4 IC's). Chlorothalonil + PB (0.6 IC's) and chlorothalonil + PB + WA (0.5 IC's) provided a higher level of dollar spot, when compared to chlorothalonil-alone (5.6 IC's) on 2 August (Table 5). On 10 August, plots treated with PB-alone (35.1 IC's) had less dollar spot, when compared to plots treated with WA-alone (95.1 IC's) and the untreated control (100.9 IC's). Chlorothalonil + PB (1.1 IC's) and chlorothalonil + PB + WA (1.1 IC's) provided better dollar spot control, when compared to all other treatments.

The IC AUDPC data showed that plots treated with WA-alone had dollar spot levels equivalent to the untreated control (Table 5). Plots treated with PB-alone (441.6 IC's x time) had less dollar spot than plots treated with WA-alone (1292 IC's x time). Chlorothalonil + PB (19.2 IC's x time) and chlorothalonil + PB + WA (25.6 IC's x time) provided a higher level of dollar spot control, when compared to chlorothalonil-alone (115.2 IC's x time) or chlorothalonil + WA (134.4 IC's x time). There were no dollar spot differences between irrigation regimes during this period.

During mid-to-late August, soil moisture measurements in the infrequently blocks were at the lowest point for the year and dollar spot pressure increased throughout the month (Figure 3). Paclobutrazol-alone (1.9% PAB) provided better dollar spot suppression versus WA-alone (4.1% PAB), however, chlorothalonil and tank-mix treatments provided the highest level of control on 17 August (data not shown, Appendix A. Table 9). From 24 August to 27 September, significant interactions were observed (Table 6). On all three rating dates between 30 August and 27 September there was less dollar spot in frequently irrigated blocks (4.1-11.5%) versus infrequently irrigated blocks (9.2-24.0%, Table 6, all data not shown; Appendix A. Table 9). There were, however, few dollar spot differences among chemical treatments, except WA-alone, on 24 and 30 August and 3 September (Table 6). During the aforementioned period, WA-alone-treated plots had dollar spot levels equivalent to the untreated control in both irrigation regimes. Within frequently irrigated blocks on 17 September, plots treated with chlorothalonil-alone (9.8% PAB), chlorothalonil + WA (12.8% PAB), and WA-alone (16.5% PAB) had dollar spot levels equivalent to the untreated control (18.5 % PAB, Table 6). All other treatments in the frequently irrigated blocks on 17 September, which contained PB reduced dollar spot, when compared to the untreated control (18.5% PAB). All chemical treatments in the infrequently irrigated blocks had less dollar spot than the untreated control at this time. The highest level of dollar spot control was provided by chlorothalonil + PB (4.1% PAB) and chlorothalonil + PB + WA (12.8% PAB), when compared to all other treatments (13.0-63.3% PAB) within the infrequently irrigated blocks on 17 September. Within frequently irrigated blocks, there were few dollar spot differences among chemical-treated plots and the untreated control on 22 September (data not shown, Appendix A. Table 9) and 27 September (Table 6). In the infrequently irrigated blocks, however, plots treated with PB-alone, chlorothalonil-alone and the tank-mixes had less dollar spot, when compared to the WA-alone and the untreated control (Table 6).

The PAB AUDPC values showed that more dollar spot developed in infrequently irrigated blocks (1685% PAB x time), when compared to frequently irrigated blocks (857% PAB x time, Table 6). In both irrigation regimes, WA-treated plots had dollar spot levels equivalent to the untreated control and plots treated with PB-alone had less dollar spot than plots treated with WA-alone. There were no differences in the level of dollar spot control provided by PB-alone (869% PAB x time), chlorothalonil-alone (389% PAB x time) and tank-mixes (279 to 480%PAB x time) in the frequently irrigated blocks. In the infrequently irrigated blocks, however, chlorothalonil + PB (209% PAB x time) and chlorothalonil + PB + WA (213 % PAB x time) provided better dollar spot control, when compared to PB-alone (882% PAB x time, Table 6).

## Gray Leaf Spot

**2002.** The 2002 summer was marked by prolonged periods of drought and heat stress. Chemical treatments were initiated on 17 June, and gray leaf spot became active on 3 July. Gray leaf spot was assessed as a percent of plot area blighted (% PAB) by *P. grisea.*

All treated plots, except chlorothalonil + PB, had active gray leaf spot (0.1-1.4% PAB) on 3 July, but there were no disease differences among irrigation and chemical treatments (data not shown, Appendix A. Table 11). By 19 July, gray leaf spot had progressed and plots treated with PB-alone (3.1% PAB), WA-alone (5.1% PAB) and the untreated control (4.8% PAB) had similar levels of blighting (Table 7). Only plots treated with chlorothalonil + PB (0.1% PAB) had less disease, when compared to the untreated control on 19 July. By 29 July, plots treated with PB-alone (37.3% PAB), WA-alone (30.6% PAB) and the untreated control (26.9% PAB) were blighted severely. All chlorothalonil-treated plots (0.8-3.4% PAB) continued to suppress gray leaf spot, but disease levels would likely be high enough to warrant a curative fungicide application to golf course fairways. Gray leaf spot intensified between late July and early August and again no disease differences among plots treated with PB-alone (72.6% PAB), WA-alone (66.0% PAB) and the untreated control (62.4% PAB) were observed on 8 August. Gray leaf spot also intensified in all chlorothalonil-treated plots between 8 and 16 August. There were no differences among chlorothalonil-treated plots at these times, but blight levels (2.9-20.0% PAB) would be considered unacceptable by most golf course managers. On 22 August, there was a significant interaction between irrigation and chemical treatments. There was more blighting in infrequently irrigated blocks (57.9% PAB) versus frequently irrigated blocks (46.8% PAB) on 22 August. Although data cannot be statistically compared, blight levels were higher in chlorothalonil-treated plots subjected to infrequent irrigation (20.5- 33.6% PAB), when compared to those in the frequently irrigated blocks (5.5-12.0% PAB). Data collected 29 August and 5 September were similar to those observed on 22 August, except the blight levels were higher.

Gray leaf spot AUDPC value data showed that there was a significant ($P$=0.05) interaction between irrigation and chemical treatments (Table 7). There was, however, no significant irrigation effect. The AUDPC values suggested that plots treated with chlorothalonil + PB + WA (1030% PAB x time) in the frequently irrigated block had a higher level of gray leaf spot, when compared to plots treated with chlorothalonil-alone (671% PAB x time), chlorothalonil + PB (660%PAB x time) and chlorothalonil + WA (690% PAB x time). The AUDPC values for both irrigation regimes showed that PB-alone, WA-alone had no effect on gray leaf spot. Except as previously noted, there were no differences in gray leaf spot levels among plots treated with chlorothalonil-alone (939% PAB x time) and the tank-mix treatments (762- 1183% PAB x time).

**2003 and 2004.** In 2002, ‘Figaro’ perennial ryegrass was rapidly blighted by *P. grisea*. Therefore, in 2003 ‘Brightstar’ perennial ryegrass was substituted in anticipation that it would not be as susceptible, which may have allowed for better assessment of potential differences among chemical treatments. The 2003 study year, however, was marked by cool temperatures and frequent rainfall and gray leaf spot did not develop in the 'Brightstar'. Therefore, in 2004 'Figaro' perennial ryegrass again was evaluated and the rate and application interval for chlorothalonil treatments were adjusted. Prior to the time gray leaf spot became visually active in the study area, the rate and application interval for all chlorothalonil treatments were 4.5 kg a.i $ha^{-1}$ and 14 days, respectively. On 20 July, when gray leaf spot became visually active, the chlorothalonil rate was increased to 8.0 kg a.i. $ha^{-1}$ and the application interval was reduced to 8 days.

Trace levels of gray leaf spot were observed in untreated (0.1% PAB) and WA-alone-treated plots (0.1% PAB) on 20 July (data not shown, Appendix A. Table 12). All plots within the infrequently irrigated blocks were disease-free on 27 July, but the highest disease level in frequently irrigated blocks was only 0.2% PAB (data not shown, Appendix A. Table 12). On 2 August, there were no significant irrigation effects or interactions, but chlorothalonil-treated plots were disease free (data not shown, Appendix A. Table 12). Gray leaf spot did not intensify until 10 August, when blight levels increased to between 3.3 and 6.3% PAB in plots treated with PB-alone, WA-alone and untreated control (Table 8). Similar blight levels were observed on 17 August (data not shown, Appendix A. Table 12). On 24 August, the disease had dramatically intensified and there was a significant interaction. There were greater disease levels in frequently irrigated blocks (11.4% PAB), when compared to infrequently irrigated blocks (3.3% PAB) on 24 August (Table 8). All chlorothalonil-treated plots were disease-free, but plots treated with PB-alone and WA-alone were more severely blighted in the frequently irrigated blocks. Similar results were observed on 30 August. On 30 August and 3 and 22 September, frequently irrigated blocks (27.5-52.0% PAB) were more severely blighted than infrequently irrigated blocks (9.9-40.1% PAB). All chlorothalonil-treated plots (last treated on 16 August) were disease-free on 3 September, but had 2.3 to 3.4% PAB on 13 September. By 22 September, gray leaf spot severity had increased substantially in all chlorothalonil-treated plots (15.0-18.8% PAB) in the frequently irrigated blocks. In infrequently irrigated blocks, however, blight levels only ranged from 0.5 to 2.5% PAB in chlorothalonil-treated plots. Similarly on 27 September and 4 October, gray leaf spot was more severe in frequently irrigated (52.0-57.8% PAB) versus infrequently irrigated (40.2-41.5% PAB) blocks. Chlorothalonil-treated plots in infrequently irrigated blocks (1.3-8.8% PAB) continued to exhibit far less blighting than was observed in frequently irrigated blocks (13.8-28.3% PAB) between 27 September and 4 October. No gray leaf spot differences, however, were observed among plots treated with chlorothalonil-alone and the tank-mixes on any rating date in 2004 (Table 8).

The AUDPC values confirmed that there was less damage in infrequently irrigated blocks (1140% PAB x time), when compared to frequently irrigated blocks (1809% PAB x time) throughout the season (Table 8). There was, however, no interaction between chemical and irrigation treatments. As was observed in 2002, plots treated with PB-alone (43.1% PAB x day), WA-alone (41.1% PAB x day) had gray leaf spot levels equivalent to the untreated control (38.5% PAB x day). There were no AUDPC value differences among chlorothalonil-alone and tank-mix treatments.

Discussion

**Dollar Spot.**

This field study assessed the influence of seven chemical treatments and two irrigation regimes on dollar spot severity over a three year period. In a greenhouse study, Couch and Bloom (1960) found that as soil moisture decreased, dollar spot became more severe. Jiang et al. (1998) and Watkins et al. (2001) assessed the effects of irrigation frequency on dollar spot severity in field studies and were unable to corroborate the findings of Couch and Bloom (1960). In this study, dollar spot was shown to be more severe in infrequently versus frequently irrigated creeping bentgrass in late summer in two (2002 and 2004) of the three study years. Hence, these results support the findings of Couch and Bloom (1960).

From the time that soil moistures levels consistently fell below 23 $cm^3$ $cm^{-3}$ in late summer of 2002 and 2004, dollar spot became more severe in the infrequently irrigated blocks. In 2002, soil moisture averaged 15.5 $cm^3$ $cm^{-3}$ in the infrequently irrigated blocks on 10 July and dollar spot developed in those blocks on 19 July (Figure 1). Dollar spot pressure increased during late August and early September in 2002, when 109 IC's were observed in untreated plots. Soil moisture levels during this period ranged from 22.5 to 24.0 $cm^3$ $cm^{-3}$. Because of frequent rainfall in 2003, soil moisture levels in both irrigation regimes were similar (20 to 34 $cm^3$ $cm^{-3}$) during most of the study period and no blighting differences between irrigation regimes were observed. Soil moisture levels fell to close to 20 $cm^3$ $cm^{-3}$ on three occasions in 2004 (8 June, 19 July and 5 September; Figure 2.). A significant irrigation effect, however, was not observed until 30 August 2004, when soil moisture averaged 23.5 $cm^3$ $cm^{-3}$ in infrequently irrigated blocks. On 3 September 2004, soil moisture in the infrequently irrigated blocks averaged 19 $cm^3$

$cm^{-3}$, and a significant irrigation effect was observed. Dollar spot pressure in 2004 peaked in the infrequently irrigated untreated control (63.3% PAB) plots on 17 September, at which time soil moisture averaged 23 $cm^3$ $cm^{-3}$. On the same day in the frequently irrigated untreated control plots, soil moisture averaged 36 $cm^3$ $cm^{-3}$ and only 18.5% PAB was observed. Hence, when moisture levels for this soil approached a range of 20 to 23 $cm^3$ $cm^{-3}$ in late summer, dollar spot became more severe in the creeping bentgrass. Low soil moistures levels in a similar range (15.5-22.9 $cm^3$ $cm^{-3}$) occurring earlier in the season, however, were not associated with increases in dollar spot severity. It is conceivable that when soil moisture levels were low earlier in the season, *S. homoeocarpa* inoculum levels were not sufficient to incite severe blighting. Indeed, it was only early in the season when IC's could be counted since disease pressure was low, and IC AUDPC values from 2002 and 2004 between irrigation regimes were not significantly different. Another important factor to consider is that 'Crenshaw' creeping bentgrass was the host. Dollar spot generally is more severe in other bentgrass cultivars in Maryland in late spring or early summer. Typically, however, peak dollar spot activity in 'Crenshaw' often occurs in late-summer in Maryland (Bigelow et al., 2002; Dernoeden and Kaminski, 2000). Hence, these results may only apply to situations in which severe outbreaks of dollar spot occur in late summer.

The mechanism by which low soil moisture conditions in mid-to-late summer predispose creeping bentgrass to more severe damage from *S. homoeocarpa* is unknown. Some theories would include: 1) low soil moisture levels predispose plants to infection due to stress; 2) high soil moisture levels may enhance microbial competition and/or antagonism with *S. homoeocarpa*; 3) frequent irrigation may physically remove *S.*

*homoeocarpa* mycelia from plant surfaces; and 4) high soil moisture levels increase organic matter mineralization thus increasing N availability to plants. It is possible that *S. homoeocarpa* is more competitive under conditions of low soil moisture or that drought and other summer stresses weaken plants, rendering them more susceptible to the pathogen. Furthermore, turf managed under low soil moisture levels or drought stress grows more slowly and is less likely to recover rapidly from damage caused by *S. homoeocarpa*. It also is possible in soils with high moisture levels that there is an increase in microbial populations, which antagonize, compete with or in some way reduce the capacity of *S. homoeocarpa* to infect plants. Finally, more N may be available to plants due to an increase in mineralization in warm and wet soils. The availability of more N can stimulate recovery from blighting caused by *S. homoeocarpa* (Couch, 1995).

Fidanza and Dernoeden (1996), conducted a two year field study that evaluated the effects of two irrigation practices on brown patch (*Rhizoctonia solani* Kühn) in perennial ryegrass. They found that brown patch severity was consistently reduced with morning irrigation, when compared to evening irrigation. They hypothesized that frequent morning irrigation may have physically removed *R. solani* mycelia from the canopy, thus preventing and/or delaying the onset or expression of the disease. Williams and coworkers (1996 and 1998), found that dew displacement before 0400 hours would not reduce the leaf wetness duration, and that early morning dew displacement speeds canopy drying and reduces dollar spot severity. In this study, water was applied to frequently irrigated blocks at 2100 hours, before most dew or foliar *S. homoeocarpa* mycelium would have formed in the canopy. Therefore, it is unlikely that significant amounts of *S. homoeocarpa* mycelium were removed as a result of irrigation at 2100 hours. Dew generally begins to form in creeping bentgrass at about 2000 hours during summer in Maryland. It is possible that irrigation at 2100 hours could have increased the leaf wetness duration in the frequently irrigated creeping bentgrass. Regardless, the time of irrigation (i.e. 2100 hours) did not appear to play a role in the dollar spot differences observed in this study. Obviously, more research is needed to elucidate mechanism(s), which enable *S. homoeocarpa* to be more damaging under conditions of decreasing soil moisture. It is likely, however, that other environmental and host-pathogen interaction factors are involved and that a soil moisture level below 23 $cm^3$ $cm^{-3}$ in mid-to-late summer is not the only factor involved.

In this study, dollar spot was evaluated early in each year by counting IC's, but as the epidemic progressed plots were evaluated as a percent PAB. The threshold at which a golf course manager would likely apply a fungicide curatively was subjectively established at 8 to 10 IC's or 0.5% PAB. Over the three years, chlorothalonil-alone provided acceptable dollar spot control on 15 of 16 rating dates early in the season, when IC data were collected. In both irrigation regimes and over the three years, however, late season PAB data showed that chlorothalonil-alone only provided an acceptable level of control on 12 of 23 rating dates. It is important to note that on nine PAB rating dates, data were obtained fourteen or more days after chlorothalonil was last applied. When a chemical by irrigation interaction was observed, however, chlorothalonil-alone provided better dollar spot control on 9 of 13 ratings in the frequently irrigated blocks than was observed in infrequently irrigated blocks. Conversely, on only 4 of 13 rating dates when interactions were observed, chlorothalonil-alone provided better dollar spot in infrequently irrigated blocks, when compared to the frequently irrigated blocks. Hence, chlorothalonil, even at the reduced rate evaluated in 2004, generally provided acceptable dollar spot control in frequently irrigated turf late in the season, when disease pressure was greatest.

The AUDPC values showed that PB-alone reduced dollar spot levels, when compared to the untreated control in all three years. On six occasions over the three years when the threshold had been exceeded in untreated plots, PB-alone provided acceptable dollar spot control. In 2002 and 2004, when interactions were observed, PB-alone provided better dollar spot control in the frequently irrigated blocks on 9 of 13 rating dates, when compared to the infrequently irrigated blocks. On 4 of 13 rating dates, however, PB-alone provided better dollar spot control in the infrequently irrigated blocks, when compared to frequently irrigated blocks. Over the three years, PB-alone reduced dollar spot blighting by 40 to 60% on eleven rating dates and by greater than 60% on twenty rating dates, when compared to the untreated control. It should be noted that the PB rate evaluated (0.12 kg a.i. $ha^{-1}$) was a low label rate. Results from this study support those of Burpee et al. (1996), corroborating that PB-applied alone (0.16 kg a.i. $ha^{-1}$) does provide an agronomically significant level of dollar spot suppression.

As previously noted, early morning displacement of dew would be expected to reduce dollar spot severity in fairway turf (Williams et al. 1996). The WA-alone only was able to provide acceptable dollar spot suppression on one occasion when the disease exceeded the IC threshold in the untreated control. However, the WA provided better dollar spot suppression in the frequently irrigated blocks, when compared to the infrequently irrigated blocks on 13 of 14 rating dates over the three years. This may have been due to the capacity of the WA to more effectively displaced dew in the frequently irrigated blocks, where disease pressure was generally less. On seven dates over the three years, the WA reduced dollar spot by as much as 30 to 50%, when compared to the untreated control. When examining all AUDPC values (AUDPC IC's=3; AUDPC PAB=3), however, the WA-alone only reduced dollar spot levels twice, when compared to the untreated control.

When chlorothalonil-alone treated plots had exceeded the threshold (IC and PAB data), the mixtures of chlorothalonil + PB and chlorothalonil + PB + WA provided acceptable dollar spot control on only three rating dates over the three year period. In 2004, the rate of chlorothalonil was reduced and IC AUDPC values for that year (i.e., early season data) indicated that the tank-mix of chlorothalonil + PB provided a higher level of dollar spot control, when compared to chlorothalonil-alone, chlorothalonil + WA and chlorothalonil + PB + WA. The 2004 PAB AUDPC data (i.e., late season data), however, showed that there were no dollar spot differences among plots treated with chlorothalonil-alone or a tank-mix. On two 2004 rating dates (2 and 10 August), chlorothalonil + PB and chlorothalonil + PB + WA provided a higher level of dollar spot control, when compared to chlorothalonil-alone and chlorothalonil + WA. Hence, data indicated that PB, which was applied at a low label rate, was more effective in suppressing dollar spot when disease pressure was low early in the season. The AUDPC values for each rating type (i.e., IC and PAB) showed that plots treated with chlorothalonil + WA generally had dollar spot levels equivalent to plots treated with chlorothalonil-alone. Hence, there was a benefit from applying a combination of chlorothalonil + PB, but there was no benefit provided by tank-mixing chlorothalonil + WA. Except for the 2004 IC AUDPC data, all other AUDPC values calculated during the three study years detected few differences among chlorothalonil-alone and tank-mix treatments.

Data from this study have shown that maintaining moisture levels above 25 $cm^3$ $cm^{-3}$ for this soil in late summer through frequent irrigation can reduce dollar spot severity and improve the ability of chlorothalonil, PB, and WA to suppress the disease in fairway height creeping bentgrass. Although neither PB and WA can be expected to provide an acceptable level of dollar spot control, on several rating dates over the three years each material reduced dollar spot levels, when compared to untreated plots. Hence, in creeping bentgrass fairways where dollar spot is a chronic problem the use of PB and WA may help to reduce dollar spot levels as well as provide other important agronomic benefits. In 2002 and 2004, the chlorothalonil treatments preformed better in turf that had been subjected to frequent irrigation, when compared to infrequent irrigation. Furthermore, on two ratings dates in 2004, chlorothalonil (reduced rate of 4.5 kg a.i. $ha^{-1}$) + PB provided a higher level of dollar spot control, when compared to all other chlorothalonil treatments. Because the rate and application intervals for chlorothalonil are restricted, these data will help golf course superintendents use chlorothalonil to manage dollar spot more efficiently. Since environmental conditions are widely variable among regions, these finding and conclusion may only apply to creeping bentgrass grown in a transition zone climate in the mid-Atlantic region.

**Gray Leaf Spot.**

Gray leaf spot was severe in 2002 and 2004, but the disease did not develop in 2003. There was no irrigation effect on gray leaf spot in 2002. Chlorothalonil treatments provided an acceptable level of gray leaf control on only 2 of 8 rating dates in 2002, and there were no disease differences among chlorothalonil treatments. The AUDPC values for 2002 showed that there were no gray leaf spot differences among chlorothalonil treatments in the infrequently irrigated blocks. Within the frequently irrigated blocks, plots treated with chlorothalonil + PB + WA (1030% PAB x time) had a higher AUDPC value in 2002, when compared to chlorothalonil-alone, chlorothalonil + WA and chlorothalonil + PB (671-690% PAB x time). This likely was due to an error in application, since one of the four replicates was blighted disproportionately. The WA and PB applied had no impact on gray leaf spot. Data indicated that the fungicide spray interval was too long to provide effective gray leaf spot control.

The application interval for all chlorothalonil treatments was reduced to eight days and the rate was increased from 4.5 to 8.0 kg a.i. $ha^{-1}$ after gray leaf spot was observed in 2004. The AUDPC values showed that gray leaf spot was more severe in frequently irrigated blocks (1809% PAB x time), when compared to infrequently irrigated blocks (1139% PAB x time). The threshold at which a golf course manager would likely apply a fungicide curatively to control gray leaf spot was subjectively established at 0.5 to 1.0% PAB. The chemical treatments provided an acceptable level of gray leaf spot control on 8 of 13 rating dates in 2004. On 3 of 13 rating dates in 2004, when interactions were observed, plots treated with chlorothalonil in frequently irrigated blocks (13.8-28.3% PAB) exhibited substantially more blighting, when compared to the same treatments applied in infrequently irrigated blocks (0.5-8.8% PAB). As was observed in 2002, plots treated with WA and PB-alone had gray leaf spot levels equivalent to the untreated control and no gray leaf spot differences among chlorothalonil treatments were observed.

In 2002, the application interval and/or chlorothalonil rate were not sufficient to effectively control gray leaf spot, which rapidly and severely damaged even the fungicide-treated plots. As a result, no significant irrigation effects or chlorothalonil treatment differences were observed in 2002. Throughout the 2004 season, however, chlorothalonil-treated plots in frequently irrigated blocks were more severely blighted, when compared to chlorothalonil-treated plots in the infrequently irrigated blocks. The difference between 2002 and 2004 was due to less disease pressure in infrequently irrigated plots in 2004, which resulted in a greatly improved level of gray leaf spot control provided by chlorothalonil in those blocks. While no benefit was observed from tank-mixing PB or WA with chlorothalonil, there also did not appear to be any negative effects when using these chemicals during a gray leaf spot epidemic.

These studies showed that under conditions of high disease pressure, and insufficient use of fungicides, gray leaf spot was very destructive, regardless of soil moisture level. Using a closer spray interval, however, chlorothalonil did effectively control gray leaf spot, but only under conditions of less frequent irrigation, which resulted in lower soil moisture ($= 26.0\ cm^3\ cm^{-3}$). Gray leaf spot occurs during periods of moderate to warm weather that is accompanied by periods of prolonged leaf wetness (Couch, 1995; Uddin et al. 2003). Large number by *P. grisea* conidia undoubtedly were alighting on leaves of infrequently irrigated perennial ryegrass, but may have had a reduced capacity to germinate and infect leaves due to a shorter leaf wetness duration. Less frequent irrigation would have reduced the number of wetting and drying cycles and contributed to generally drier soil conditions, which may have reduced the capacity of the pathogen to sporulate and blight. Other environmental and biological factors probably contributed to the inability of *P. grisea* to more severely blight perennial ryegrass in the infrequently irrigated blocks in 2004. Additional research is needed to better understand the relationship between irrigation practices and the incidence and severity of gray leaf spot.

Table 1. Number of *Sclerotinia homoeocarpa* infection centers in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent applications, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 16 August | 22 August | | 26 August | |
|---|---|---|---|---|---|---|
| | | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | No. of *S. homoeocarpa* infection centers $plot^{-1}$ | | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.5 b[‡] | 0.0 b | 2.0 b | 0.5 b | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.8 b | 1.0 b | 1.0 b | 3.5 b | 5.5 b |
| Primer Select (WA) | 6.3 L prod. | 4.4 a | 3.3 b | 46.8 a | 5.8 b | 62.0 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.1 b | 0.0 b | 0.0 b | 0.8 b | 0.3 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.1 b | 0.0 b | 0.0 b | 0.0 b | 0.8 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.6 b | 0.0 b | 0.4 b | 1.0 b | 0.0 b |
| Untreated | --- | 8.5 a | 18.5 a | 56.8 a | 29.8 a | 87.3 a |
| Irrigation | | | | | | |
| Frequent | | 1.2 a | 3.3 b | | 5.9 b | |
| Infrequent | | 3.0 a | 15.5 a | | 22.3 a | |
| ANOVA | | | | | | |
| Irrigation (I) | | NS[§] | ** | | ** | |
| Chemical (C) | | *** | *** | | *** | |
| I*C | | NS | *** | | *** | |

[†] Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in a column followed by the same letter are not significantly different at $P < 0.05$ according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 1 (Cont'd). Number of *Sclerotinia homoeocarpa* infection centers in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent applications, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 3 September | AUDPC | |
|---|---|---|---|---|
| | | | Frequent | Infrequent |
| Chemical | | —— No. of *S. homoeocarpa* infection centers—— | —— disease x time | —— |
| Chlorothalonil | 8.0 kg a.i. | 4.8 b[‡] | 7.1 c | 13.2 c |
| Paclobutrazol (PB) | 0.12 kg a.i. | 50.1 a | 277.6 ab | 230.5 b |
| Primer Select (WA) | 6.3 L prod. | 96.0 a | 437.1 a | 1072.8 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 b | 6.8 c | 3.3 c |
| Chlorothalonil + WA | 8.0 kg a.i. +6.3 L | 1.6 b | 4.1 c | 24.4 c |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 12.5 b | 108.1 bc | 12.1 c |
| Untreated | --- | 108.8 a | 702.1 a | 1439.8 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 37.3 a | 220.4 a | |
| Infrequent | | 40.9 a | 399.5 a | |
| ANOVA | | | | |
| Irrigation (I) | | NS[§] | NS | |
| Chemical (C) | | *** | *** | |
| I*C | | NS | *** | |

[†] Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in a column followed by the same letter are not significantly different at $P < 0.05$ according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 2. Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent applications, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 5 September | 13 September | 23 September Frequent | 23 September Infrequent |
|---|---|---|---|---|---|
| Chemical | | % of plot area blighted | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.1 c[‡] | 0.0 d | 0.0 c | 0.1 d |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.2 b | 1.3 c | 8.0 b | 12.5 c |
| Primer Select (WA) | 6.3 L prod. | 6.2 b | 8.4 b | 9.3 b | 31.3 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 c | 0.0 d | 0.0 c | 0.0 d |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 c | 0.0 d | 0.0 c | 0.1 d |
| Chlorothalonil + PB +WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 c | 0.0 d | 0.0 c | 0.0 d |
| Untreated | - | 14.3 a | 20.8 a | 20.8 a | 47.8 a |
| Irrigation | | | | | |
| Frequent | | 2.0 a | 4.1 a | 5.4 b | |
| Infrequent | | 4.4 a | 4.6 a | 13.1 a | |
| ANOVA | | | | | |
| Irrigation (I) | | NS[§] | NS | ** | |
| Chemical (C) | | *** | *** | *** | |
| I*C | | NS | NS | *** | |

[†] Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 2 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent applications, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 1 October | | AUDPC | |
|---|---|---|---|---|---|
| | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | % of plot area blighted | | % blighted x time | |
| Chlorothalonil | 8.0 kg a.i. | 0.3 c[‡] | 2.8 d | 0.2 d | 0.4 d |
| Paclobutrazol (PB) | 0.12 kg a.i. | 20.5 b | 18.8 c | 66.9 c | 74.3 c |
| Primer Select (WA) | 6.3 L prod. | 20.5 b | 40.3 b | 142.9 b | 260.0 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.3 c | 0.0 d | 0.0 d | 0.5 d |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.3 c | 1.4 d | 0.0 d | 1.15 d |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.2 c | 0.0 d | 0.0 d | 0.0 d |
| Untreated | - | 34.8 a | 55.8 a | 296.8 a | 533.3 a |
| Irrigation | | | | | |
| Frequent | | 11.0 a | | 72.4 b | |
| Infrequent | | 17.0 a | | 124.3 a | |
| ANOVA | | | | | |
| Irrigation (I) | | NS[§] | | * | |
| Chemical (C) | | *** | | *** | |
| I*C | | *** | | *** | |

[†] Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 3. Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent applications, 2003.

| Treatment[†] | | 24 July | 31 July | 6 August | 13 August |
|---|---|---|---|---|---|
| Chemical | Rate $ha^{-1}$ | % of plot area blighted | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 c[‡] | 0.0 c | 0.0 c | 0.0 c |
| Paclobutrazol (PB) | 0.12 kg a.i. | 2.9 b | 1.8 abc | 4.3 b | 6.25 b |
| Primer Select (WA) | 6.3 L prod. | 6.2 ab | 9.1 a | 9.8 b | 17.8 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 c | 1.0 bc | 0.0 c | 0.0 c |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 c | 0.1 bc | 0.0 c | 0.0 c |
| Chlorothalonil + PB +WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 c | 0.0 c | 0.0 c | 0.0 c |
| Untreated | - | 9.0 a | 7.4 ab | 18.8 a | 23.0 a |
| Irrigation | | | | | |
| Frequent | | 2.3 a | 2.7 a | 4.7 a | 7.4 a |
| Infrequent | | 2.8 a | 2.7 a | 4.7 a | 6.0 a |
| ANOVA | | | | | |
| Irrigation | | NS[§] | NS | NS | NS |
| Chemical | | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS |

[†] Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 3 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Crenshaw' creeping bentgrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent applications, 2003.

| Treatment[†] | | 5 September | | 15 September | | |
|---|---|---|---|---|---|---|
| | Rate $ha^{-1}$ | Frequent | Infrequent | Frequent | Infrequent | AUDPC |
| Chemical | | % of plot area blighted | | | | % blighted x time |
| Chlorothalonil | 8.0 kg a.i. | 0.5 a[‡] | 0.0 c | 1.2 ab | 0.5 a | 6.1 c |
| Paclobutrazol (PB) | 0.12 kg a.i. | 1.8 a | 3.7 b | 2.0 ab | 3.9 b | 153.5 b |
| Primer Select (WA) | 6.3 L prod. | 2.3 a | 5.7 a | 3.0 a | 6.1 b | 334.4 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.3 a | 0.0 c | 0.9 ab | 0.2 a | 10.5 c |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.2 a | 0.0 c | 1.0 ab | 0.4 a | 17.8 c |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 a | 0.0 c | 0.5 ab | 0.3 a | 2.3 c |
| Untreated | - | 2.7 a | 6.9 a | 2.7 ab | 6.2 b | 413.5 a |
| | | | | | | |
| Irrigation | | 1.1 a | | 1.6 a | | 127.3 a |
| Frequent | | 2.3 a | | 2.5 a | | 140.7 a |
| Infrequent | | | | | | |
| ANOVA | | | | | | |
| Irrigation | | NS[§] | | NS | | NS |
| Chemical | | *** | | *** | | *** |
| I*C | | *** | | *** | | NS |

[†] Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 4. Number of *Sclerotinia homoeocarpa* infection centers in 'Brightstar' perennial ryegrass fairway turf as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent applications, 2003.

| Treatment | Rate ha $^{-1}$ | 6 August | 21 August | 28 August |
|---|---|---|---|---|
| Chemical[†] | | No. of *S. homoeocarpa* infection centers plot$^{-1}$ | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 b[‡] | 0.0 c | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 4.0 b | 2.3 bc | 5.9 b |
| Primer Select (WA) | 6.3 L prod. | 27.4 a | 9.7 a | 30.4 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 2.2 b | 1.3 c | 3.0 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 5.2 b | 0.3 c | 1.4 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 b | 0.0 c | 0.0 b |
| Untreated | - | 31.3 a | 6.3 ab | 24.8 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 8.5 a | 1.2 a | 5.8 a |
| Infrequent | | 13.6 a | 5.2 a | 15.5 a |
| ANOVA | | | | |
| Irrigation | | NS[§] | NS | NS |
| Chemical | | *** | *** | *** |
| I*C | | NS | NS | NS |

[†] Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 5. Number of *Sclerotinia homoeocarpa* infection centers in ‘Southshore’ creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$ | 21July |  | 2 August | 10 August | AUDPC |
|---|---|---|---|---|---|---|
|  |  | Frequent | Infrequent |  |  |  |
| Chemical |  | Number of *S. homoeocarpa* infection centers $plot^{-1}$ |  |  |  | disease x time |
| Chlorothalonil | 4.5 kg a.i. | 0.0 a[‡] | 2.0 ab | 5.6 c | 11.1 c | 115.2 cd |
| Paclobutrazol (PB) | 0.12 kg a.i. | 6.0 bc | 0.0 a | 22.4 b | 35.1 b | 441.6 b |
| Primer Select (WA) | 6.3 L prod. | 10.8 c | 8.5 bc | 67.3 a | 95.1 a | 1292.8 a |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 0.0 a | 2.0 a | 0.6 d | 1.1 d | 19.2 e |
| Chlorothalonil + WA | 4.5 kg a.i. +6.3 L | 1.3 ab | 0.0 a | 6.6 c | 11.3 c | 134.4 c |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.3 ab | 0.0 a | 0.5 d | 1.1 d | 25.6 d |
| Untreated | - | 10.3 c | 19.0 c | 60.8 a | 100.9 a | 1305.6 a |
| Irrigation |  |  |  |  |  |  |
| Frequent |  | 4.0 a |  | 23.4 a | 32.7 a | 467.2 a |
| Infrequent |  | 4.5 a |  | 23.4 a | 40.4 a | 486.4 a |
| ANOVA |  |  |  |  |  |  |
| Irrigation |  | NS[§] |  | NS§ | NS | NS |
| Chemical |  | *** |  | *** | *** | *** |
| I*C |  | *** |  | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 6. Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Southshore' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$ | 24 August | | 30 August | |
|---|---|---|---|---|---|
| | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | % of plot area blighted | | | |
| Chlorothalonil | 4.5 kg a.i. | 0.5 bc[‡] | 0.3 bc | 1.0 b | 1.5 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 2.0 ab | 1.8 b | 2.9 b | 2.6 b |
| Primer Select (WA) | 6.3 L prod. | 7.4 a | 16.0 a | 11.7 a | 27.5 a |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 0.2 c | 0.1 c | 0.5 b | 0.3 b |
| Chlorothalonil + WA | 4.5 kg a.i. +6.3 L | 0.6 bc | 0.4 bc | 0.9 b | 1.5 b |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.3 c | 0.4 bc | 0.5 b | 1.5 b |
| Untreated | - | 8.5 a | 16.5 a | 11.4 a | 29.3 a |
| Irrigation | | | | | |
| Frequent | | 2.8 a | | 4.1 b | |
| Infrequent | | 5.1 a | | 9.2 a | |
| ANOVA | | | | | |
| Irrigation | | NS[§] | | * | |
| Chemical | | *** | | *** | |
| I*C | | ** | | *** | |

[†]Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, NS and refer to significant at the 0.05, 0.01, 0.001, non-significant, respectively.

Table 6 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Southshore' creeping bentgrass as influenced by irrigation regime, chlorothalonil, paclobutrazol and a wetting agent, 2004.

| Treatment[†] | Rate ha $^{-1}$ | 3 September | | 17 September | |
|---|---|---|---|---|---|
| | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | % of plot area blighted | | | |
| Chlorothalonil | 4.5 kg a.i. | 2.0 b[‡] | 3.9 b | 9.8 abc | 13.0 c |
| Paclobutrazol (PB) | 0.12 kg a.i. | 3.9 b | 4.4 b | 9.5 bc | 15.8 c |
| Primer Select (WA) | 6.3 L prod. | 17.8 a | 35.8 a | 16.5 ab | 46.3 b |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 1.4 b | 0.8 b | 6.5 c | 4.1 d |
| Chlorothalonil + WA | 4.5 kg a.i. +6.3 L | 2.1 b | 3.7 b | 12.8 abc | 13.0 c |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.9 b | 3.7 b | 7.0 c | 12.8 d |
| Untreated | - | 18.6 a | 37.0 a | 18.5 a | 63.3 a |
| | | | | | |
| Irrigation | | | | | |
| Frequent | | 6.7 b | | 11.5 b | |
| Infrequent | | 12.8 a | | 24.0 a | |
| ANOVA | | | | | |
| Irrigation | | *[§] | | ** | |
| Chemical | | *** | | *** | |
| I*C | | * | | *** | |

[†]Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, NS and refer to significant at the 0.05, 0.01, 0.001, non-significant, respectively.

Table 6 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in Southshore creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent, 2004.

| Treatment[†] | Rate ha $^{-1}$ | 27 September | | AUDPC | |
|---|---|---|---|---|---|
| | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | % of plot area blighted | | % blighted x time | |
| Chlorothalonil | 4.5 kg a.i. | 9.5 a[‡] | 21.3 c | 389.5 b | 627.3 bc |
| Paclobutrazol (PB) | 0.12 kg a.i. | 9.1 a | 18.5 cd | 869.2 b | 881.5 b |
| Primer Select (WA) | 6.3 L prod. | 11.0 a | 45.0 b | 1783.5 a | 4325.5 a |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 10.5 a | 10.1 d | 295.2 b | 209.1 c |
| Chlorothalonil + WA | 4.5 kg a.i. +6.3 L | 14.0 a | 19.0 cd | 479.7 b | 639.6 bc |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 9.0 a | 12.3 cd | 278.8 b | 213.2 c |
| Untreated | - | 12.5 a | 63.8 a | 1898.3 a | 4924.1 a |
| | | | | | |
| Irrigation | | | | | |
| Frequent | | 14.4 b | | 856.9 b | |
| Infrequent | | 28.0 a | | 1685.1 a | |
| ANOVA | | | | | |
| Irrigation | | **[§] | | * | |
| Chemical | | *** | | *** | |
| I*C | | *** | | *** | |

[†] Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, NS and refer to significant at the 0.05, 0.01, 0.001, non-significant, respectively.

Table 7. Percent of plot area blighted by *Pyricularia grisea* in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent, 2002.

| Treatment[†] | Rate ha$^{-1}$ | 19 July | 29 July | 8 August | 16 August |
|---|---|---|---|---|---|
| | | % plot area blighted | | | |
| **Chemical** | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.9 ab[‡] | 1.6 b | 6.3 b | 9.8 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 3.1 a | 37.3 a | 72.6 a | 96.4 a |
| Primer Select (WA) | 6.3 L prod. | 5.1 a | 30.6 a | 66.0 a | 95.6 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.1 b | 0.8 b | 2.9 b | 5.3 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.9 ab | 1.4 b | 5.4 b | 12.4 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 1.5 ab | 3.4 b | 10.5 b | 20.0 b |
| Untreated | - | 4.8 a | 26.9 a | 62.4 a | 91.4 a |
| **Irrigation** | | | | | |
| Frequent | | 4.3 a | 14.1 a | 37.7 a | 44.5 a |
| Infrequent | | 0.4 a | 15.0 a | 26.5 a | 50.0 a |
| **ANOVA** | | | | | |
| Irrigation (I) | | NS[§] | NS | NS | NS |
| Chemical (C) | | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS |

[†] Treatments were applied on a 14 day interval beginning on 17 June and ending 26 August, 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 7 (cont'd). Percent of plot area blighted by *Pyricularia grisea* in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | | 22 August | | |
|---|---|---|---|---|
| | Rate $ha^{-1}$ | Frequent | Infrequent | 29 August |
| Chemical | | % plot area blighted | | |
| Chlorothalonil | 8.0 kg a.i. | 5.5 b[‡] | 29.8 b | 43.8 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 96.5 a | 99.5 a | 99.0 a |
| Primer Select (WA) | 6.3 L prod. | 97.5 a | 99.5 a | 99.0 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 10.5 b | 20.5 b | 42.5 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 6.5 b | 26.0 b | 42.3 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 12.0 b | 33.6 b | 51.3 b |
| Untreated | - | 96.8 a | 96.8 a | 96.9 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 46.8 b | | 66.0 a |
| Infrequent | | 57.9 a | | 69.6 a |
| ANOVA | | | | |
| Irrigation (I) | | *[§] | | NS |
| Chemical (C) | | *** | | *** |
| I*C | | ** | | NS |

[†] Treatments were applied on a 14 day interval beginning on 17 June and ending 26 August, 2002.
[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 7 (cont'd). Percent of plot area blighted by *Pyricularia grisea* in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 5 Sept | AUDPC Frequent | AUDPC Infrequent |
|---|---|---|---|---|
| Chemical | | % plot area blight | % blighted x day | |
| Chlorothalonil | 8.0 kg a.i. | 53.1 b[‡] | 670.9 c | 939.6 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 99.0 a | 3536.6 a | 3522.9 a |
| Primer Select (WA) | 6.3 L prod. | 98.5 a | 3489.8 a | 3354.2 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 54.4 b | 659.8 c | 762.1 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 55.6 b | 689.5 c | 970.9 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 61.9 b | 1029.5 b | 1183.1 b |
| Untreated | - | 97.8 a | 3504.1 a | 3070.6 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 72.6 a | 1940.3 a | |
| Infrequent | | 76.0 a | 1971.9 a | |
| ANOVA | | | | |
| Irrigation (I) | | NS[§] | NS | |
| Chemical (C) | | *** | *** | |
| I*C | | NS | * | |

[†] Treatments were applied on a 14 day interval beginning on 17 June and ending 26 August, 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P*=0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 8. Percent of plot area blighted by *Pyricularia grisea* in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment† | Rate ha$^{-1}$† | 10 August | 24 August | | 30 August | |
|---|---|---|---|---|---|---|
| | | | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | % plot area blighted | | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 b‡ | 0.0 b | 0.0 b | 0.0 b‡ | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 6.3 a | 35.0 a | 9.4 a | 72.5 a | 22.8 a |
| Primer Select (WA) | 6.3 L prod. | 4.2 a | 23.5 a | 7.9 a | 66.3 a | 23.0 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 b | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 b | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 b | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Untreated | - | 3.3 a | 21.5 a | 5.8 a | 53.8 a | 24.0 a |
| Irrigation | | | | | | |
| Frequent | | 2.6 a | 11.4 a | | 27.5 a | |
| Infrequent | | 1.3 a | 3.3 b | | 9.9 b | |
| ANOVA | | | | | | |
| Irrigation (I) | | NS§ | * | | * | |
| Chemical (C) | | *** | *** | | *** | |
| I*C | | NS | ** | | *** | |

† All chlorothalonil treatments were applied at 4.5 kg a.i. ha$^{-1}$ on 1, 15 and 29 June and 15 July, 2004. On 20, 28 July and 6 and 16 August 2004, all chlorothalonil treatments were applied at 8.0 kg a.i. ha$^{-1}$. Paclobutrazol and wetting agent-alone were applied on a 14 day interval beginning 1 June and ending 16 August.

‡ Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 8 (cont'd). Percent of plot area blighted by *Pyricularia grisea* in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$[†] | 3 September | | 13 September | 22 September | |
|---|---|---|---|---|---|---|
| | | Frequent | Infrequent | | Frequent | Infrequent |
| Chemical | | % plot area blighted | | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 b[‡] | 0.0 b | 2.8 b | 18.8 b | 2.5 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 86.3 a | 30.3 a | 84.8 a | 98.0 a | 94.8 a |
| Primer Select (WA) | 6.3 L prod. | 80.0 a | 35.0 a | 78.8 a | 98.0 a | 94.0 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 b | 0.0 b | 2.3 b | 18.8 b | 0.5 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 b | 0.0 b | 3.4 b | 17.5 b | 1.5 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 b | 0.0 b | 3.3 b | 15.0 b | 1.0 b |
| Untreated | - | 76.3 a | 31.3 a | 71.6 a | 98.0 a | 86.5 a |
| Irrigation | | | | | | |
| Frequent | | 34.6 a | | 42.6 a | 52.0 a | |
| Infrequent | | 13.8 b | | 27.9 b | 40.1 b | |
| ANOVA | | | | | | |
| Irrigation (I) | | **[§] | | ** | ** | |
| Chemical (C) | | *** | | *** | *** | |
| I*C | | *** | | NS | *** | |

[†] All chlorothalonil treatments were applied at 4.5 kg a.i. $ha^{-1}$ on 1, 15 and 29 June and 15 July 2004. On 20, 28 July and 6 and 16 August 2004, all chlorothalonil treatments were applied at 8.0 kg a.i. $ha^{-1}$. Paclobutrazol and wetting agent-alone were applied on a 14 day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 8 (cont'd). Percent of plot area blighted by *Pyricularia grisea* as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment† | Rate $ha^{-1}$† | 27 September | | 4 October | | |
|---|---|---|---|---|---|---|
| | | Frequent | Infrequent | Frequent | Infrequent | AUDPC |
| Chemical | | ——% plot area blighted—— | | | | % blighted x day |
| Chlorothalonil | 8.0 kg a.i. | 13.8 b‡ | 3.0 b | 25.0 b | 6.0 b | 205.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 98.0 a | 92.8 a | 96.0 a | 90.0a | 3315.3 a |
| Primer Select (WA) | 6.3 L prod. | 98.5 a | 94.3 a | 96.8 a | 92.5 a | 3188.7 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 15.8 b | 1.8 b | 28.3 b | 3.0 b | 194.2 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 20.8 b | 3.8 b | 36.3 b | 8.8 b | 250.8 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 20.8 b | 1.3 b | 28.0 b | 2.5 b | 206.3 b |
| Untreated | - | 97.0 a | 88.3 a | 96.0 a | 87.5 a | 2961.4 a |
| Irrigation | | | | | | |
| Frequent | | 52.0 a | | 57.8 a | | 1809.3 a |
| Infrequent | | 40.2 b | | 41.5 b | | 1139.8 b |
| ANOVA | | | | | | |
| Irrigation (I) | | **§ | | * | | ** |
| Chemical (C) | | *** | | *** | | *** |
| I*C | | *** | | ** | | NS |

† All chlorothalonil treatments were applied at 4.5 kg a.i. $ha^{-1}$ on 1, 15 and 29 June and 15 July 2004. On 20, 28 July and 6 and 16 August 2004, all chlorothalonil treatments were applied at 8.0 kg a.i. $ha^{-1}$. Paclobutrazol and wetting agent-alone were applied on a 14 day interval beginning 1 June and ending 16 August.

‡ Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

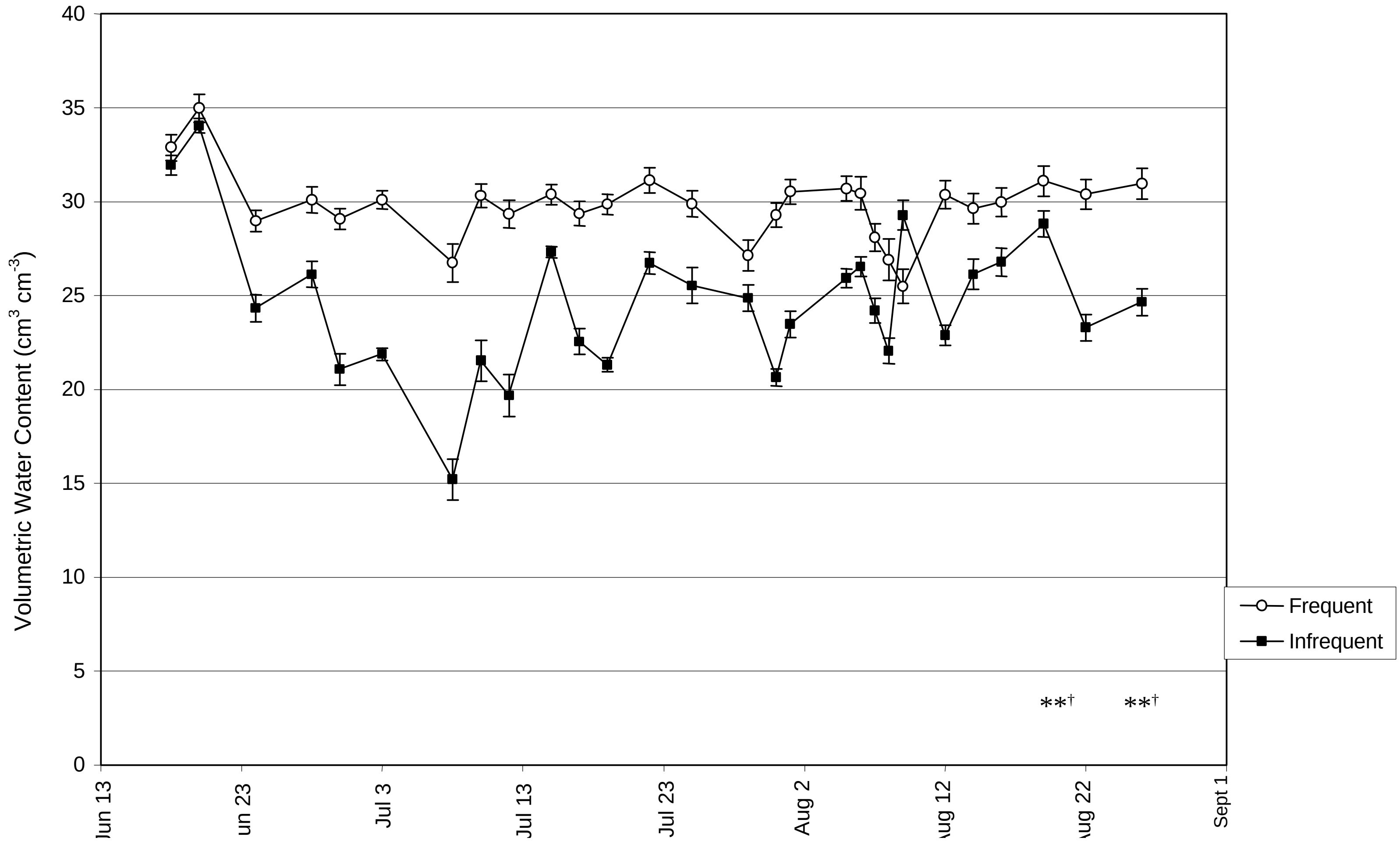
§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 9. Precipitation at the experimental site during the study period in 2002, 2003, and 2004.

| Month | Total precipitation (mm)[†] |
|---|---|
| 2002 | |
| June | 53 |
| July | 49 |
| August | 78 |
| September | 82 |
| Total | 262 |
| 2003 | |
| June | 167 |
| July | 156 |
| August | 101 |
| September | 177 |
| Total | 601 |
| 2004 | |
| June | 127 |
| July | 296 |
| August | 91 |
| September | 115 |
| Total | 629 |

[†] Precipitation was measured using a rain gauge at the site.

**Figure 1. Soil Moisture Measurements, 2002.†**

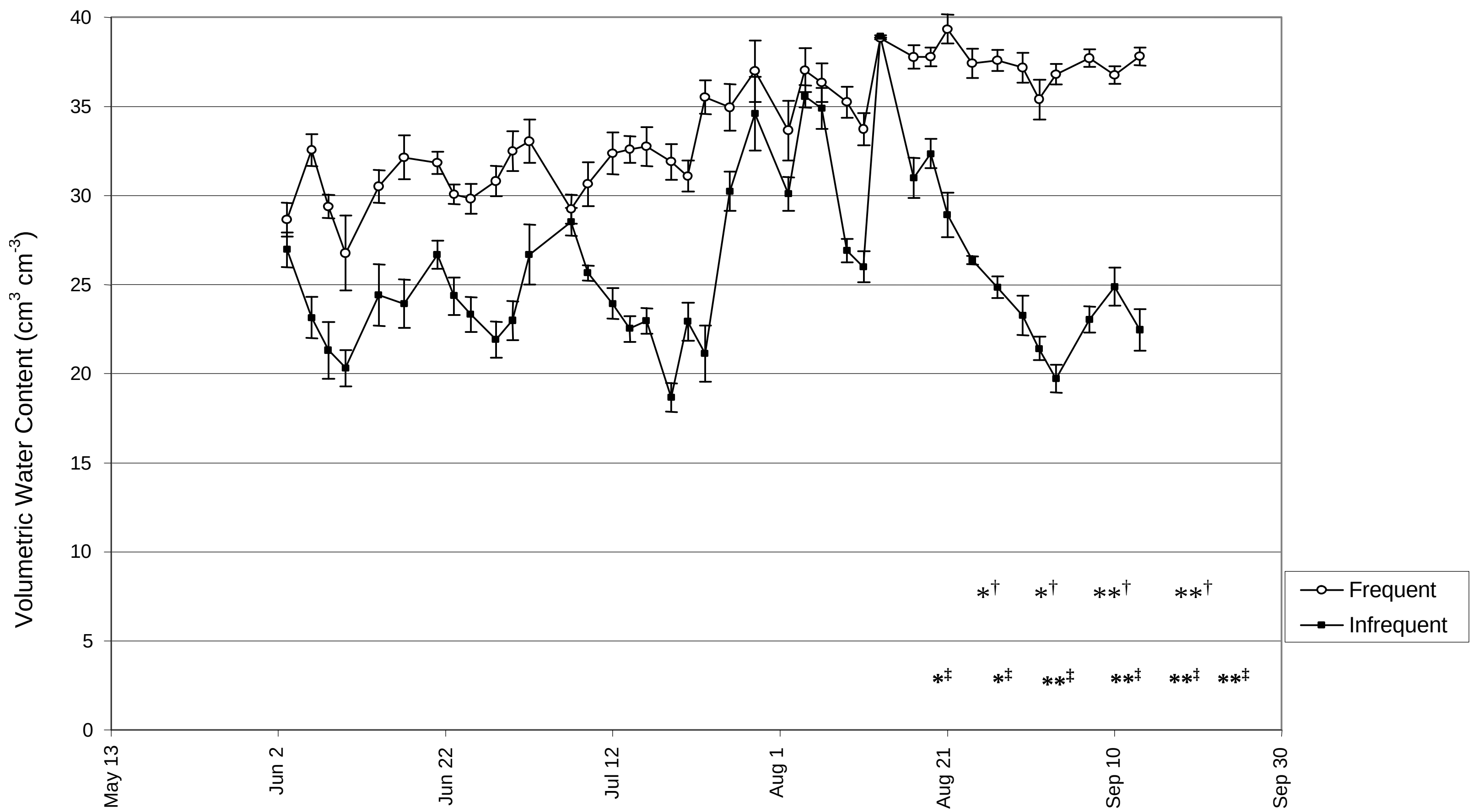



Vertical bars represent +- 1 standard error of the mean (SE).

† In creeping bentgrass, *, **, ***, and NS refer to a significant irrigation effect on dollar spot at the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

§ If there is no symbol for rating date (6/17 to 8/16), there was a non-significant irrigation (NS) effect.

**Figure 2. Soil Moisture Measurements, 2004†‡**




Vertical bars represent +- 1 standard error of the mean (SE).

† In creeping bentgrass, *, **, ***, and NS refer to a significant irrigation effect on dollar spot at the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

‡ In perennial ryegrass, ***, **, ***,** and **NS** refer to a significant irrigation effect on gray leaf spot at the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

§ If there is no symbol for rating date (6/7 to 8/16), there was a non-significant irrigation (NS) effect.

## III. Dollar Spot Control In Creeping Bentgrass As Influenced by Fungicide Spray Volume and Application Timing

Synopsis

Dollar spot (*Sclerotinia homoeocarpa* F. T Bennett) is a difficult disease to control in creeping bentgrass (*Agrostis stolonifera* L. var *palustris* (Huds.) Farw.). To maximize fungicide performance, more information is needed regarding proper delivery timing and water dilution or spray volume. In these field studies, a contact (chlorothalonil) and a penetrant (propiconazole) fungicide were evaluated. The objectives of this field study were to: (1) assess the influence of two spray volumes (468 and 1020 L water $ha^{-1}$); and (2) evaluate the impact of the presence or absence of dew at the time of application on the ability of the aforementioned fungicides to control dollar spot in fairway height creeping bentgrass. Only chlorothalonil (8.0 kg a.i. $ha^{-1}$) was assessed in 2002, but chlorothalonil (4.5 kg a.i. $ha^{-1}$), propiconazole (1.65 to 3.3 kg a.i. $ha^{-1}$), and a tank-mix of chlorothalonil (4.5 kg a.i. $ha^{-1}$) + propiconazole (1.65 to 3.3 kg a.i. $ha^{-1}$) were evaluated in 2003 and 2004. Treatments were applied in two spray volumes with dew present or displaced in the AM and again in the PM. In all three study years, chlorothalonil provided better dollar spot control when applied in 468 versus 1020 L water $ha^{-1}$ and in the PM, when compared to AM. In 2004 only, chlorothalonil gave better dollar spot control on several dates in plots treated with the dew displaced, when compared to plots treated with dew present. Few differences in spray volume and application timing were observed with propiconazole and the tank mix treatments. The tank-mix, however, generally provided a longer duration and higher level of dollar spot control, when compared to propiconazole-alone. Evidentially, chlorothalonil performance was reduced as a result of being diluted or washed from foliar surfaces in

the higher water volume or diluted by dew; whereas, the penetrant propiconazole was able to effectively penetrate tissue without loss of effectiveness. Since both fungicides perform well when applied in 468 L water $ha^{-1}$, golf course managers can use the lower spray volume to save time, labor and fuel.

**Introduction**

Dollar spot (*Sclerotinia homoeocarpa*) continues to be a difficult disease to control in creeping bentgrass (*Agrostis stolonifera* L. var *palustris* (Huds.) Farw.) fairways in many regions of the world. Chlorothalonil (tetrachloroisophthalontitrile) is a contact fungicide in the nitrile class and is perhaps the most common chemical used on turf for disease control. Beginning in 2002, the United States Environmental Protection Agency mandated that the use of chlorothalonil be restricted because of its negative effects on non-target aquatic ecosystems. These restrictions (29.2 kg a.i. $ha^{-1}$ annually to fairways) have created a demand on increasing the effectiveness of chlorothalonil. Furthermore, chlorothalonil is highly valued in disease resistance management programs and methods for improving its performance need to be investigated. There have been no reported cases of pathogen resistance to chlorothalonil, but there have been resistance problems with other fungicides used to control turfgrass diseases (Burpee, 1997; Vargas, 2004; Vincelli, 2003).

Propiconazole (1-[[2-(2, 4-dichlorophenyl)-4-propyl-1, 3-dioxolan-2-yl] methyl]-1H-1, 2, 4-triazole) is a penetrant fungicide that is commonly used to control dollar spot and generally provides a longer period of control than chlorothalonil (Mitkowski et al., 2005). Propiconazole is a demethyation inhibitor (DMI), which penetrates plants. This chemical moves mostly upward (acropetal) in the grass plant after penetration has occurred. Previous research has indicated that chlorothalonil tank-mixed with a penetrant can improve the level of dollar spot control, when compared to either fungicide applied alone (Vargas, 2004; Vincelli, 2003).

Due to playability issues, pesticide exposure and demands from golfers, superintendents normally make pesticide applications early in the morning or possibly at night. The effect of the presence of dew at the time a fungicide is applied is unknown. Furthermore, there has been little study on the impact of water dilution volume or spray volume (SV) on fungicide performance. Couch (1984) evaluated triadimefon (1-(2-(2,4-dichlorophenyl) 4-propyl-1-1,3-dixolan-2-ymethyl0-1H-1,2,4- triazole) and chlorothalonil in SV's ranging from 203 to 13,033 L water $ha^{-1}$ (L $ha^{-1}$) for curative dollar spot (30% plot area blighted) control in a 'Penneagle' creeping bentgrass putting green. Couch (1984) observed that chlorothalonil (6.2 kg a.i. $ha^{-1}$) performed best in 407 L water $ha^{-1}$, when applied-alone. He also reported that triadimefon (0.76 kg a.i. $ha^{-1}$ ) performed best when applied in 815 L water $ha^{-1}$. Triadimefon is in the same chemical class as propiconazole and both fungicides have the same mode of action. Vincelli et al. (2003) evaluated the efficacy of triadimefon (0.38 kg a.i. $ha^{-1}$) and chlorothalonil (8.0 kg a.i. $ha^{-1}$) applied in 407 and 815 L $ha^{-1}$ for dollar spot control in a 'Crenshaw' creeping bentgrass fairway. One treatment was applied on a 14 day interval while another was applied curatively. Vincelli et al. (2003) reported that the use of both SV's resulted in an equivalent level of dollar spot control for both fungicides. Ashbaugh and Larson (1982), applied triadimefon, iprodione (3-(3, 5-dichlorophenyl)-N-(1-methylethyl)-2, 4,-dioxo-1-imidazolidinecarboxamide) and chlorothalonil curatively to a stand of fairway height creeping bentgrass using various SV's. They reported that there were no differences in the level of curative dollar spot control among the SV (203, 407, 1017.5 and 2035 L $ha^{-1}$)

with chlorothalonil (4.0 and 8.0 kg a.i. $ha^{-1}$), triadimefon (1.0 kg a.i. $ha^{-1}$) or iprodione (1.5 kg a.i. $ha^{-1}$). Gregos et al. (2000) reported that there were no significant differences in the length or level of dollar spot control when chlorothalonil (9.31 kg a.i. $ha^{-1}$), triadimefon (0.79 kg a.i. $ha^{-1}$) and propiconazole (0.87 kg a.i. $ha^{-1}$) were applied in 407, 815, and 1628 L water $ha^{-1}$. Hence, Ashbaugh and Larson (1982), Gregos et al. (2000) and Vincelli et al. (2003) could not corroborate the findings reported by Couch (1984).

Williams et al. (1996) showed that dew plays an important role in the development of dollar spot and that early morning dew displacement from the canopy can reduce dollar spot severity. In a separate study, Williams et al. (1998) quantified the amount of dew and plant exudates in the canopy of ‘Penncross’ creeping bentgrass maintained to a height of 19 mm. Plant exudates were measured by placing a tent on top of the turf, which prevented condensation from forming on the turfgrass canopy. Plots inside tents were blotted in the same fashion as those outside of the tent, and the difference in dew (outside the tent) and exudates (inside the tent) was determined. In both study years, plant exudates contributed substantially (33%) to total dew. The amount of dew found in the canopy ranged from 0.16 mm to 0.23 mm, with a mean of 0.195 mm (1,949 L $ha^{-1}$) when measured at 8:00 hours. It is conceivable that moisture from dew in the canopy could impact fungicide performance. No studies, however, have assessed the relationship of the presence or absence of dew on the efficacy of fungicides.

Due to conflicting research results, and varying SV’s and/or methods of application, further study is needed to evaluate the importance of SV as well as the presence or absence of dew on the ability of fungicides to control dollar spot. Furthermore, manufacturer labels often are vague and only may state that their fungicide should be applied in enough water to obtain thorough plant coverage. In general, recommended SV's range from 204 to 1868 L $ha^{-1}$, depending on the fungicide and target pathogen. For logistical reasons, however, golf course superintendent would prefer to utilize lower rather than higher SV's. Hence, an important aspect of this study was to determine if dollar spot control is diminished if a lower rather than higher water volume were utilized. The purpose of this study was to investigate the efficacy of a contact (chlorothalonil) and a penetrant (propiconazole) fungicide for their ability to control dollar spot as influenced by SV (468 and 1020 L $ha^{-1}$) and by the presence or absence of dew (AM dew present; AM dew displaced; and PM dry turf).

Materials and Methods

These studies were conducted at the University of Maryland Paint Branch Turfgrass Research Facility in College Park, MD. Soil was a Keyport silt loam (fine, mixed, semiactive, mesic Aquic Hapludult) with a pH ranging from 5.8 to 6.2 and 12 to 20 mg of organic matter/g soil. Treatments were applied with a $CO_2$ pressurized sprayer (262 kPa; 35 psi) equipped with either an 8004 (467.5 L $ha^{-1}$; low-SV) or 8010 (1019.5 L $ha^{-1}$; high-SV) flat fan nozzle. Spray volume (SV) or water dilution volume is the amount of water into which a material (active ingredient, surfactants and inert materials) is dissolved or suspended into before it is applied to a given area of turf. Treatments were not reapplied until significant levels (i.e. threshold) of dollar spot were observed so as to quantify differences among treatments. The threshold at which a golf course superintendent (or in this study) reapply a fungicide was subjectively judged to be 8 to 10 infection centers (IC's) $plot^{-1}$ or 0.5% plot area blighted, depending on the size of the infection centers and whether they had coalesced. Dollar spot developed naturally and uniformly in all years.

During all years, study sites were fertilized as typical golf course fairways (i.e. = 146 kg N $ha^{-1}$ $year^{-1}$). The N-source was urea (46-0-0) and was applied in spring and autumn of each year. Study sites were mowed three times $week^{-1}$ to a height of 12.7 mm. Generally, the study sites were mowed about 20 hours after treatments were applied. Irrigation was applied often due to frequent periods of drought stress in 2002 (218 mm rainfall during study period). In 2003 and 2004, however, irrigation was seldom needed because of frequent and abundant rainfall (305 mm and 298 mm during 2003 and 2004 study periods, respectively). In all years, the AM treatments were applied at 0800 hours and PM treatments were applied after the turf canopy was dry, typically after 1230 hours.

In 2003 and 2004, dew was displaced using the straight edge on the reverse side of an aluminum rake immediately before treatments were applied. Different sites were used each year and plots were 1.5 m x 1.5 m. In most other studies of this nature, fungicides were either applied on time or on a specific interval (i.e. 14 day). Hence, if fungicides were effectively controlling the disease, differences in spray volume may not be detected. Hence, to best elucidate potential differences among treatments, dollar spot was allowed to become active and increase to above threshold levels (i.e. ≥ 0.5 % plot area blighted) before a follow-up application was made. No fungicides were applied to the test sites in the spring prior to the initiation of each study.

**Site Descriptions**

**2002** Separate areas of 'Crenshaw' and 'L-93' creeping bentgrass were utilized in 2002. 'Crenshaw' was seeded in the spring of 2001 and 'L-93' was seeded in autumn of 2000. Treatments were arranged as a randomized complete block with the 'Crenshaw' site having five replications and the 'L-93' four replications. The treatment structure for the 2002 study was a 2 (SV's) x 2 (AM and PM) factorial. Treatments were as follows: chlorothalonil applied at 8.0 kg a.i. $ha^{-1}$ AM in the low SV (468 L $ha^{-1}$; low-SV) or the high SV (1020 L $ha^{-1}$; high-SV), and again to separate plots in the PM of the same day. This was the only year when there was a no "dew displaced" treatment. Dollar spot was active for one day before treatments initially were applied. Treatments were applied to 'Crenshaw' on 20 June, 21 July, and 23 August and to 'L-93' on 20 June and 21 July 2002. Because the 'L-93'site was severely blighted by 7 August, no further ratings were obtained thereafter.

**2003** A 'Crenshaw' creeping bentgrass site seeded in September 2001 was the 2003 study site. The rate of chlorothalonil was reduced from 8.0 to 4.5 kg a.i. $ha^{-1}$ in 2003.

Treatments were as follows: chlorothalonil applied alone in the AM in low-SV or high-SV and PM on the same day. Propiconazole was applied alone (3.3 kg a.i. $ha^{-1}$) and the tank-mix of chlorothalonil and propiconazole (same rates) were applied on the same timings as previously given for chlorothalonil-alone. The experiment was designed as a completely randomized design with four replications. The 2003 treatment structure was a 2 (SV's) x 3 (AM, AM dew displaced, and PM dry) x 4 (chlorothalonil, propiconazole, tank-mix and untreated control) factorial. The site was treated 18 August 2003 with 5.3 kg a.i. $ha^{-1}$ flutolanil (N-[3-(1-methylethoxy) phenyl] trifluoromethyl) benzamide) and 0.73 kg a.i. of mefenoxam (R)-2-[2, 6-dimethylphenyl)-methoxyactlamino]-propionic) to preventively control brown patch *(Rhizoctonia solani* Kuhn*)* and Pythium blight *(Pythium spp)*, respectively.

Dollar spot was not active at the time the 2003 study was initiated. All treatments were applied initially on 23 July 2003. Chlorothalonil- alone treatments were reapplied on 7 and 23 August. Propiconazole and tank-mix (propiconazole + chlorothalonil) treatments only were re-applied on 19 August.

**2004** **'**Southshore' creeping bentgrass, seeded in the autumn of 2002, was used for the 2004 study site. The experimental design and treatment structure were the same as described for 2003. The rate of propiconazole, however, was reduced from 3.30 to 1.65 kg a.i. $ha^{-1}$, regardless of whether it was applied alone or tank-mixed with chlorothalonil. Dollar spot was not visually active when the study began. Treatments were initiated on 12 May 2004. Chlorothalonil treatments were reapplied 4 and 23 June. Propiconazole and tank-mix treatments were reapplied on 18 June.

## Dew Measurements

Canopy dew measurements were obtained as described by Williams et al. (1998). Four white, unscented Kimwipe tissues (Kimberly-Clark Corp, Rosewell GA.) were placed into a zip-lock bag and weighted. Prior to dew removal, the four tissues were removed from the bag and blotted over 120 $cm^2$ area of an untreated control plot using a wooden frame as a template. Blotting was carefully performed to accurately measure canopy dew and not to absorb any moisture from the thatch layer. Tissues then were placed into the same bag and immediately weighed. The gain in weight was used to calculate the amount of dew present on the canopy. Data were converted from grams 120 $cm^{-2}$ to millimeters of moisture as previously described by Williams et al. (1998). Dew amounts (mm) then were converted into L $ha^{-1}$ in order to gain a better understanding of the amount of water in the canopy, which may dilute or in some way impact fungicide performance.

## Ratings and Statistical Analyses

Disease ratings were performed twice weekly during all study years. Ratings were taken by counting the number of *S. homoeocarpa* infection centers $plot^{-1}$(IC's) or by estimating the percent of plot area blighted (% PAB) once infection centers coalesced. Percent of plot area blighted was assessed visually on a 0 to 100 scale with 0= no dollar spot and 100= entire plot area blighted. All dollar spot data were square root transformed (v*x*) to correct for normality, however, actual means are shown in the data tables. Area under the disease progress curve (AUDPC) is a way to integrate data from a study period into a single value for each treatment. Hence, AUDPC values allow one to assess the total amount of disease within a treatment over a specified time period. The AUPDC values were calculated according to Campbell and Madden (1990) using the formula ∑ (sum of) $[y_i + y_{i+1})/2\ [t_{i+1}-t_i]$ where i=1, 2, 3….n-1, $y_i$ is the amount of disease (either infection centers or percent of plot area blighted) and $t_i$ is the time of the $i^{th}$ rating. Values were calculated separately for early season (i.e., infection center data) and late season (i.e., percent plot area blighted data) data collection periods. The AUDPC values shown in the data tables represent a sum value, where the larger number represents a greater amount of disease. Because these treatments were evaluated over the same time period each year, there is no need to standardize or normalize the data. The 2002 ('L-93' site), 2003 and 2004 % PAB AUDPC values include ratings taken 18, 41, and 23 days after the last fungicide application, respectively. The unit of measure for an AUDPC value is disease x time, since disease would be shown on the y-axis (either IC or % plot area blighted) and time (days) on the x-axis of a figure. Data for each year were individually subjected to analysis of variance (ANOVA) and significantly different means were separated at $P = 0.05$ by Turkey's least significant difference mean comparison test using the SAS MIXED procedure (SAS version 9.1, SAS Institute; Cary, NC). Pre-planned orthogonal contrasts in 2002 included: chlorothalonil low-SV versus high-SV and chlorothalonil AM versus PM treatments. For 2003 and 2004, the pre-planned orthogonal contrasts evaluated were: chlorothalonil applied in the low-SV versus high-SV; AM dew present versus AM dew displaced; AM dew present versus PM; AM dew displaced versus PM; and propiconazole-alone versus propiconazole + chlorothalonil (averaged over SV's and timings). The contrasts were performed using 'estimate' statements in SAS MIXED procedure.

Results

## Dollar Spot

**2002.** The 2002 study year was marked by heavy dollar spot pressure in both the 'L-93' and 'Crenshaw'. Data from each cultivar were analyzed separately because the studies were performed in different locations and had different levels of dollar spot pressure. Dollar spot became active one day prior to initiating the treatments in both sties. In 2002, no significant interactions between SV and application timing at both sites were observed (Table 1 and Appendix Table 3). Therefore, main effects and pre-planned orthogonal contrasts are discussed. The analyses of variance for application time and SV data as well as their potential interactions were conducted using only the chlorothalonil treatments in 2002. This was done because the untreated control had no time of application or SV that could be included in the analysis (Table 1 and Appendix Table 3). On certain dates, when there were significant differences among treatments, data in the tables may not indicate a significant SV effect because of inclusion of data from the untreated control (Table 2). For this reason, there were no differences in AUDPC values among chlorothalonil treatments in both sites in 2002 (all data not shown). Therefore, it is important to examine the pre-planned orthogonal contrasts to determine if differences due to SV or time of application had occurred.

## 'L-93' Site

When treatments initially were applied on 20 June, all plots had similar numbers of *S. homoeocarpa* infection centers plot$^{-1}$ (IC's, Table 2). On 28 June (eight days after treatment= 8 DAT), all treatments significantly reduced dollar spot levels, when compared to the untreated control (Table 2). At this time, the PM application of chlorothalonil in the lower SV (low-SV, 468 L ha$^{-1}$) provided better dollar spot suppression (2 IC's) than both treatments applied in the higher SV (high-SV, 1020 L $ha^{-1}$; 10 to 12 IC's, Table 3). On all rating dates in July, all chlorothalonil-treated plots had similar numbers of IC's (Table 2, all data not shown, Appendix B Table 3). Contrast statements for 17 and 19 July, however, showed that better dollar spot control was provided by chlorothalonil applied in the low-SV, when compared to the high-SV (Table 3). Eight days following re-application (i.e. 29 July), all chlorothalonil treatments reduced dollar spot levels dramatically (Table 2). Contrast statements comparing the SV's on 29 July showed that chlorothalonil applied in the low-SV provided better dollar spot control (2 to 4 IC's), when compared to treatments applied in the high-SV (6 to 10 IC's, Table 3). By 1 August, plots treated with chlorothalonil in the low-SV and both timings had lower, trace levels of dollar spot (0.0 and 0.3 IC's), when compared to treatments applied in the high-SV (3.5 IC's) and the untreated control (118 IC's, Table 2). Dollar spot pressure in the following days intensified in all chlorothalonil-treated plots. On the last rating date (7 August), chlorothalonil applied in the low-SV (16 to 20 IC's) and in the AM or PM continued to provide better dollar spot control, when compared to AM treatments applied in the high-SV (34 to 46 IC's, Table 2).

On six of the nine rating dates, SV contrast statements indicated that chlorothalonil applied in the low-SV gave better dollar spot control than when applied in the high-SV on 'L-93' creeping bentgrass (Table 3). Time of application (AM vs. PM) did not influence the performance of chlorothalonil in 'L-93'. On two dates (i.e., 28 June and 1 August), however, chlorothalonil applied in the low-SV, PM gave better dollar spot control than when applied in the high-SV, AM (Table 2).

### 'Crenshaw' Site

The 'Crenshaw' site also had active dollar spot when the study was initiated (20 June) and all plots had a similar number of IC's at this time (Table 4). Between 28 June (8 DAT) and 29 July (eight days after second application), all chlorothalonil-treated plots had similar levels of dollar spot (all data not shown; Appendix B Table 5). During the course of the study (20 June to 5 September) there were 14 rating dates and only on 29 July (P=0.05), 1 (P=0.001) and 30 August (P=0.05) were significant contrasts observed (Appendix Table 6). On 29 July, treatments applied in the low-SV (0.2 IC) gave a higher level of dollar spot control, when compared to those applied in the high-SV (2.2 to 3.2 IC's, Table 4). By 1 August, plots treated with chlorothalonil applied in low-SV had trace dollar spot levels (0.2 IC), while plots receiving both high-SV treatments had 1.6 to 2.0 IC's. Low-spray volume treatments gave better dollar spot control versus those applied in high-SV on 1 August (data not shown, Appendix Table 6). On 30 August, the contrast showed that treatments applied with the low-SV provided better curative dollar spot control, when compared to those applied in the high-SV. For example, on 30 August plots treated with chlorothalonil in the low-SV (9 to 15 IC's) remained close to the threshold, while plots treated using the high-SV had dollar spot levels above the threshold (22 and 24 IC's, Table 4). Time of application again did not appear to influence fungicide performance. However, on 1 August plots treated in the PM in the high-SV had a higher level of disease, when compared to all other chlorothalonil treatments. By 5 September, dollar spot was extremely severe and no differences were observed among chlorothalonil treatments (Table 4).

**2003.** In 2003, the rate of chlorothalonil was reduced from 8.0 to 4.5 kg a.i. $ha^{-1}$ in order to better assess differences among SV and application timing. Also, three new parameters were evaluated as follows: dew displaced, propiconazole-alone (3.3 kg a.i. $ha^{-1}$) and a tank-mix of propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$). Treatments initially were applied to 'Crenshaw' creeping bentgrass on 23 July, one week before dollar spot became visually active (data not shown, Appendix B. Table 8). Data are shown as a percent of plot area blighted by *S. homoeocarpa* (PAB), because dollar spot developed in the untreated plots and coalesced before *S. homoeocarpa* infection centers developed in fungicide-treated plots. The five, pre-planned orthogonal contrasts that were evaluated included: chlorothalonil applied in the low-SV versus high-SV; AM dew present versus AM dew displaced; AM dew present versus PM; AM dew displaced versus PM; and propiconazole-alone versus propiconazole + chlorothalonil (averaged over SV's and timings). On every rating date, except 30 July and 21 August, at least one of the five contrasts was significant (Table 7, Appendix B. Table 9). There was a significant fungicide effect on most rating dates because propiconazole and the tank-mix were providing a higher level of dollar spot control, when compared to chlorothalonil-alone (Table 5). These differences would be expected since chlorothalonil is a contact fungicide with a probable shorter period of residual effectiveness.

**Chlorothalonil-Alone, Spray Volume Treatments**

Due to a large number of observations, data from some rating dates were omitted from Tables 5, 6 and 7 and are shown in Appendix B. From 30 July to 11 August, few significant differences or interactions were observed among SV and application timing treatments (data not shown; Appendix B Table 7). On 11 August, however, the contrasts showed that chlorothalonil applied in the low-SV (0.06% PAB) gave better dollar spot control, when compared to plots treated with the high-SV (0.20% PAB, Appendix B Table 8). Dollar spot pressure peaked on 16 August when 7.9% PAB was observed in untreated plots (Table 6). On 16 August, the contrast again showed that chlorothalonil applied in the low-SV (0.1% PAB) gave slightly yet significantly better dollar spot control, when compared to plots treated with the high-SV (0.2%PAB, Table 6 and Table 7). Two days after the second application of chlorothalonil (25 Aug), treatments applied in the low-SV, PM (0.1% PAB) provided better dollar spot control than both AM treatments applied in the high-SV (>0.9% PAB, Table 6). From 29 August to 1 October, the SV contrast again revealed that chlorothalonil applied in low-SV provided better dollar spot control, when compared to treatments applied in the high-SV (Table 7, Appendix B. Table 9). Contrast statements for the two SV's showed that on 12 of the 21 rating dates chlorothalonil applied in low-SV provided better dollar spot control, when compared to chlorothalonil applied in the high-SV (Table 7; Appendix B Table 9). Contrasts for the AUDPC values also showed that chlorothalonil-alone provided better (P=0.001) dollar spot control when applied in the PM and in the low-SV, when compared to AM applications with dew present or displaced or in the high-SV (Table7).

**Chlorothalonil-Alone, Dew Treatments**

Contrast statements showed that there were no differences on any rating date between chlorothalonil applied in the AM with the dew present versus dew displaced (Table 7, Appendix B. Table 9). However, contrasts did show that plots treated with chlorothalonil in the PM provided better dollar spot control, when compared to AM applications with dew present on 6, 8, 11, 21 and 27 August (Table 7, Appendix B. Table 9). Contrasts for data collected 4, 6, 8, 11, 13 and 21 August also showed that chlorothalonil applied in the PM provided better dollar spot control, when compared to AM applications with the dew displaced (Table 7, Appendix B. Table 9).

**Propiconazole and Tank-Mix Treatments**

When comparing the propiconazole-alone treatments among themselves, few differences were observed throughout 2003 (Table 6, all data not shown, Appendix B. Table 8). When propiconazole-alone (0.6 % PAB) data were compared to those of the tank-mix (0.3% PAB), the tank-mix treatments provided better dollar spot control than propiconazole applied-alone (Table 6). Propiconazole-alone was last applied on 19 August and dollar spot was allowed to progress until 1 October. During this period, no differences among the application timing and SV treatments were observed (Table 6). Furthermore, no differences were observed among the tank-mix treatments (Table 6). When propiconazole-alone and the tank-mix were compared as a contrast, the tank-mix was shown to have provided better dollar spot control than propiconazole-alone on 9 of the 21 rating dates (Table 7, Appendix B. Table 9).

**2004**. In 2003, no differences were observed among propiconazole-alone or the tank-mix treatments. Therefore, in 2004 the rate of propiconazole was reduced from 3.30 to 1.65 kg a.i. $ha^{-1}$ for both treatments. Also, the 2004 study was conducted on 'Southshore' creeping bentgrass rather than 'Crenshaw'. All other treatments remained the same as evaluated in 2003. Treatments initially were applied on 12 May 2004, one week before dollar spot became visually active. Plots were evaluated for dollar spot 18 times during 2004 (all data not shown, Appendix B Tables 10, 11 and 12). Initially (19 May to 2 June), dollar spot was rated by counting the number of *S. homoeocarpa* infections centers $plot^{-1}$. Dollar spot pressure became severe in the first week of June and untreated plots had an average of 36 IC's. Thereafter, ratings were taken as a percent of plot area blighted by *S. homoeocarpa*.

### Chlorothalonil-Alone, Spray Volume Treatments

There were few differences among chemical treatments from 19 May to 28 May (data not shown, Appendix Table 11). On 2 June, plots treated with chlorothalonil-alone in the low-SV, PM (0.7 IC's) had less dollar spot than plots treated in low-SV, AM with dew present (8.7 IC's) or in high-SV with dew present (10.2 IC's) (Table 9). On 13 June (9 days after the second treatment), 15 and 17 June, the contrast revealed that chlorothalonil-alone applied in the low-SV provided better dollar spot control, when compared to the high-SV (Table 9). Dollar spot was allowed to progress above the threshold following the last application on 23 June. Dollar spot became very severe during the first half of July and on 9 July 18.8% PAB was observed in untreated plots. Contrast statements from 7 to 16 July again showed that chlorothalonil provided better dollar spot when applied in the low-SV versus the high-SV. Hence, on 9 of 18 rating dates in 2004, chlorothalonil applied in the low-SV provided better dollar spot control, when compared to treatments applied in the high-SV.

**Chlorothalonil-Alone, Dew Treatments**

On 2 June, the contrast statement revealed that plots treated in the AM with dew displaced had less dollar spot (4.7 IC's), when compared to plots treated in the AM with dew present (9.5 IC's, Table 9). The contrast also showed that plots treated with chlorothalonil in the PM (1.9 IC's) had less dollar spot, when compared to plots treated with chlorothalonil in the AM with dew displaced (4.7 IC's, Tables 9 and 10). On 3, 8 and 11 June, plots treated in the PM (0.0-0.3% PAB) had less dollar spot versus those plots treated in the AM (0.2-0.7% PAB) with dew present (data not shown, Appendix B. Table 11).

Chlorothalonil treatments were re-applied on 4 June, when plots had reached the threshold. From 22 June to 2 July, chlorothalonil applied in the PM (0.3-0.7% PAB) provided consistently better dollar spot control, when compared to plots treated in the AM (0.7-1.1% PAB) with the dew displaced (Table 9). During the later stages of the epidemic (7 to 16 July), few differences were observed among application timing or dew treatments (Table 9, all data not shown; Appendix B. Table 11). On 5 of 18 rating dates, chlorothalonil provided better dollar spot control when applied in the AM with the dew displaced, when compared to the AM application with the dew present. Also, on 8 of 18 rating dates, chlorothalonil provided better dollar spot control when applied in the PM, when compared to AM treatments with the dew present.

### Propiconazole-alone and Tank-mix Treatments

As experienced in 2003, no differences were observed on any rating date when propiconazole or tank-mix treatments were compared to themselves (Table 9). When dollar spot first was observed in the propiconazole and tank-mix-treated plots (8 and 11 June, data not shown, Appendix B. Table 11), the contrast revealed that the tank-mix had provided better dollar spot control than propiconazole-alone. Similar results between the tank-mix and propiconazole-alone treatments were observed from 22 June to 16 July, and significant contrast differences occurred on 11 of 18 rating dates (Table 10, all data not shown, Appendix B. Table 12).

### Dew Measurements

Dew measurements were taken on four, rain-free days between 4 June and 22 August in both 2003 and 2004. The mean amount of dew quantified was different on each date, which would be expected in view of varying temperatures, relative humidity and other environmental factors. Dew levels ranged from 982 L $ha^{-1}$ to 2,548 L $ha^{-1}$, with a mean of 1842 L $ha^{-1}$ (Figure 1). In Kentucky, Williams et al. (1998) found that the mean amount of dew on the canopy of fairway height (19 mm) creeping bentgrass was

1,945 L $ha^{-1}$. Hence, these measurements are remarkably similar to those reported by Williams et al. (1998).

Discussion

Spray volumes and application timings were evaluated over a three year period with two commonly used fungicides for dollar spot control. The magnitude of the differences in dollar spot levels among treatments in these studies was small because a reapplication threshold was established. In most golf course settings, an acceptable threshold for dollar spot damage is less than 0.5 % plot (turf) area blighted. To observe differences among treatments, however, dollar spot was allowed to become active before plots were re-treated to remain within the threshold and to avoid excessive blighting.

In all three study years, chlorothalonil-alone provided better dollar spot control when applied in 468 versus 1020 L $ha^{-1}$. Couch (1984) previously reported that chlorothalonil provided better dollar spot control using a similar SV (i.e. 407 L $ha^{-1}$), when compared to higher amounts (814, 1628, 3256, 6512 and 13,030 L $ha^{-1}$). Other researchers, however, observed that there were no differences in the level of dollar spot control provided by chlorothalonil using various SV's (Ashbaugh and Larson, 1982; Gregos et al., 2000; Vincelli et al., 2003). Applying chlorothalonil to a dry turfgrass canopy in the PM also increased efficacy, when compared to both AM (dew present and dew displaced) treatments. In 2003, there were no dollar spot differences on any rating date between AM dew present and AM dew displaced treatments using chlorothalonil. On five of sixteen rating dates in 2004, however, chlorothalonil applied in the AM with the dew displaced resulted in better dollar spot control, when compared to AM applications with the dew present. While there was no consistent benefit provided by displacing the dew between years, 2004 data suggested that displacing dew can be beneficial when using chlorothalonil-alone. In general, the 2003 and 2004 data indicate that applying chlorothalonil in the low-SV and in the PM extends the level of acceptable (i.e. threshold of < 0.5 PAB) dollar spot control by an average of 2 to 4 days, when compared to high-SV and AM treatments (all data not shown; Appendix Tables 8 and 11). As previously noted, the amount of dew present in the canopy ranged between 982 L $ha^{-1}$ and 2,548 L $ha^{-1}$. Displacement when dew levels are high may still result in large amounts of water remaining within the lower canopy or thatch, which could reduce the effectiveness of chlorothalonil. Apparently, significant amounts of chlorothalonil did not adhere to the foliage when it was applied in the higher SV or in the presence of dew. Differences in the dew displacement treatments between years (2003 and 2004) may be attributed to the amount of moisture remaining following displacement, differences in the amount of active ingredient applied, or bentgrass cultivar. Hence, to optimize chlorothalonil performance when targeting dollar spot, it should be applied to a dry canopy in 468 L $ha^{-1}$ rather than 1020 L $ha^{-1}$.

No differences were observed in the level of dollar spot control in either year among dew and SV treatments using propiconazole-alone. Evidently, SV and the presence of dew did not affect the ability of effective, fungicidal levels of propiconazole to penetrate plants and move acropetally. Couch (1984) found that the acropetal penetrant triadimefon, with the same mode of action as propiconazole, performed best when applied in 815 L $ha^{-1}$, when compared to 204, 407, 1628, 3256, 6512 and 13,030 L $ha^{-1}$. The 815 L $ha^{-1}$ SV was between the 468 and 1020 L $ha^{-1}$ SV evaluated in this study. Vincelli et al. (2003), however, found that triadimefon provided equal levels of dollar spot control in 407 and 815 L $ha^{-1}$. Difference between our results and those of Vincelli et al. (2003) and Couch (1984) could possibly be attributed to differences in disease severity, chemistry, amount of active ingredient applied, formulation, surfactants and other unknown factors. There also were no differences among dew or SV treatments with propiconazole + chlorothalonil in either study year. During 2003 and 2004 the tank-mix, however, provided better and extended levels of dollar spot control on 29 of 39 rating dates, when compared to propiconazole-alone. Hence, data generally have shown that the presence or absence of dew and the two SV's assessed did not affect the level of dollar spot control provided by either propiconazole or propiconazole + chlorothalonil.

<u>Summary</u>

This is the first reported study that evaluated the influence of both dew and SV on the level of dollar spot control provided by a contact and penetrant fungicide alone or in a tank-mix combination. Data clearly showed that golf course superintendents can effectively use 468 L $ha^{-1}$ SV for targeting dollar spot with the fungicides evaluated. This information is very important since using 1020 L $ha^{-1}$ would require about twice the amount of water. Since golf course fairways typically range between 61 and 74 ha, applying fungicides in the higher SV would require the input of substantially more time, labor, fuel and equipment. These results pertain only to dollar spot control in creeping bentgrass with chlorothalonil and propiconazole. *Sclerotinia homoeocarpa* initially attacks foliage, but can eventually infect crown tissue. Other turfgrass pathogens that primarily infect stem and/or root tissue may be more efficaciously controlled by fungicides applied in higher SV's.

Table 1. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil in 'L-93' creeping bentgrass, 2002.

| Source of variation[†] | 20 June | 28 June | 29 July | 1 Aug | 7 Aug | AUDPC |
|---|---|---|---|---|---|---|
| Application time | NS | NS | NS | NS | NS | NS |
| Spray volume | NS | * | ** | ** | * | *[§] |
| Spray volume* application time | NS | NS | NS | NS | NS | NS |

[†] Chlorothalonil was applied 20 June and 21 July 2002 at a rate of 8.0 kg a.i. ha$^{-1}$.
[§] On certain dates when significant differences between spray volumes had occurred the ANOVA may not indicate a significant spray volume effect because of inclusion of the untreated control data.
*, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively

Table 2. Number of *Sclerotinia homoeocarpa* infection centers as influenced by chlorothalonil, application timing and spray volume in 'L-93' creeping bentgrass, 2002.

| Timing | Spray volume[†] | *S. homoeocarpa* infection centers plot$^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | 20 June | 28 June | 29 July | 1 August | 7 August |
| | (L ha$^{-1}$) | (no.) | | | | |
| AM[§] | 468 | 12.3 a[‡] | 3.8 bc | 1.8 d | 0.0 c | 15.8 d |
| AM | 1020 | 14.0 a | 11.5 b | 10.3 b | 3.5 b | 45.8 b |
| PM[¶] | 468 | 11.0 a | 2.0 c | 3.5 cd | 0.3 c | 19.8 cd |
| PM | 1020 | 9.3 a | 10.0 b | 6.0 bc | 3.5 b | 33.5 bc |
| - | Untreated control | 9.3 a | 26.0 a | 120.5 a | 117.8 a | 116.5 a |
| - | P>F | 0.7883 | 0.0021 | 0.001 | 0.001 | 0.0001 |

[†] Chlorothalonil (8.0 kg a.i. ha$^{-1}$) timing and spray volume treatments were applied 20 June and 21 July 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P < 0.05$ according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[§] AM treatments were applied in early morning with dew present on the canopy.
[¶] PM treatments were applied in the afternoon to a dry canopy.

Table 3. Pre-planned orthogonal contrasts for chlorothalonil applied in two spray volumes and application timings and their effect on dollar spot in ‘L-93’ creeping bentgrass, 2002.

| Contrast | 20 June | 28 June | 17 July | 19 July | 29 July | 1 Aug | 7 Aug | AUDPC |
|---|---|---|---|---|---|---|---|---|
| Chlorothalonil[†] 468 vs. 1020 L $ha^{-1}$ | NS[‡] | * | * | * | ** | *** | ** | * |
| Chlorothalonil[†] AM vs. PM | NS | NS | NS | NS | NS | NS | NS | NS |

[†]Chlorothalonil (8.0 kg a.i. $ha^{-1}$) was applied 20 June and 21 July 2002.

[‡] *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Table 4. Number of *Sclerotinia homoeocarpa* infection centers as influenced by chlorothalonil, application timing and spray volume in ‘Crenshaw’ creeping bentgrass, 2002.

| Timing | Spray volume[†] | Number of *S. homoeocarpa* infection centers plot$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | 20 June | 29 July | 1 August | 30 August | 5 Sept | AUDPC |
| | (L ha$^{-1}$) | (no.) | | | | | |
| AM[§] | 468 | 2.8 a[‡] | 0.6 b | 0.2 c | 8.6 c | 68.2 b | 851 b |
| AM | 1020 | 3.6 a | 2.2 b | 1.6 c | 21.8 b | 87.6 ab | 1120 b |
| PM[¶] | 468 | 3.4 a | 2.0 b | 0.2 c | 15.4 bc | 70.4 b | 963 b |
| PM | 1020 | 2.4 a | 3.2 b | 2.0 b | 24.4 b | 71.0 b | 1076 b |
| - | Untreated control | 3.0 a | 30.0 a | 28.8 a | 93.2 a | 113.0 a | 2314 a |
| - | P>F | 0.776 | 0.0001 | 0.0001 | 0.0001 | 0.0414 | 0.0002 |

[†] Chlorothalonil (8.0 kg a.i ha$^{-1}$) spray volume and application treatments were applied 20 June, 21 July and 23 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P < 0.05$ according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means
[§]AM treatments were applied in early morning with dew present on the canopy.
[¶] PM treatments were applied in the afternoon to a dry canopy.

Table 5. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil, propiconazole and the propiconazole + chlorothalonil tank-mix in ‘Crenshaw’ creeping bentgrass, 2003.

| Source of variation | 16 Aug | 18 Aug | 25 Aug | 29 Aug | 4 Sept | 7 Sept | 10 Sept | 12 Sept | 22 Sept | 29 Sept | 1 Oct | AUDPC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fungicide[†] | ***[§] | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| Spray volume (SV) | *** | *** | ** | NS | *** | *** | *** | *** | *** | *** | ** | *** |
| Dew [‡] | NS | NS | NS | NS | NS | NS | NS | ** | ** | ** | NS | ** |
| Fungicide*SV | NS | NS | *** | ** | *** | *** | *** | * | NS | NS | NS | * |
| Fungicide*dew | NS | NS | NS | NS | NS | ** | NS | NS | * | NS | NS | ** |
| SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

[†]Chlorothalonil-alone (4.5 kg a.i. $ha^{-1}$) treatments were re-applied on 23 July and 7 and 23 August, 2003. Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

[‡] The dew source of variation included three variables: AM dew present, AM dew displaced and PM dry.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 6. Percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by fungicides, spray volume, and application timing where dew was either present or absent in ‘Crenshaw’ creeping bentgrass, 2003.

| | | | | Plot area blighted by *S. homoeocarpa*[¶] | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Dew/displaced /none | Timing | L $ha^{-1}$ | 16 Aug | 18 Aug | 25 Aug | 4 Sept |
| | | | | % | | | |
| Chlorothalonil [†] | Dew | AM | 468 | 0.1 de[§] | 0.3 bc | 0.5 bcd | 0.3 c |
| Chlorothalonil | Displaced | AM | 468 | 0.1 de | 0.3 bc | 0.4 bcd | 0.3 c |
| Chlorothalonil | None | PM | 468 | 0.1 e | 0.1 c | 0.1 cd | 0.2 c |
| Propiconazole [‡] | Dew | AM | 468 | 0.4 b-e | 0.4 bc | 0.0 d | 0.0 c |
| Propiconazole | Displaced | AM | 468 | 0.5 b-e | 0.4 bc | 0.0 d | 0.0 c |
| Propiconazole | None | PM | 468 | 0.5 bcd | 0.5 bc | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.2 b-e | 0.3 bc | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.1 cde | 0.2 bc | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.1 cde | 0.2 bc | 0.0 d | 0.0 c |
| Chlorothalonil | Dew | AM | 1020 | 0.3 b-e | 0.2 bc | 1.0 b | 1.1 b |
| Chlorothalonil | Displaced | AM | 1020 | 0.3 b-e | 0.6 bc | 0.9 b | 1.1 b |
| Chlorothalonil | None | PM | 1020 | 0.1 cde | 0.2 bc | 0.5 bc | 0.3 bc |
| Propiconazole | Dew | AM | 1020 | 0.6 bc | 0.7 bc | 0.0 d | 0.0 c |
| Propiconazole | Displaced | AM | 1020 | 0.8 b | 0.8 bc | 0.0 d | 0.0 c |
| Propiconazole | None | PM | 1020 | 0.6 bcd | 0.9 b | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.4 b-e | 0.6 bc | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.3 b-e | 0.3 bc | 0.0 d | 0.0 c |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.4 b-e | 0.5 bc | 0.0 d | 0.0 c |
| Untreated control | - | - | - | 7.9 a | 7.7 a | 4.0 a | 3.4 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.
[‡]Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.
[§] Means in the same column followed by the same letter are not significantly different at $P < 0.05$ according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Table 6 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by fungicides, spray volume, and application timing where dew was either present or absent in 'Crenshaw' creeping bentgrass, 2003.

| Fungicide | Dew/displaced/ none | Timing | L ha$^{-1}$ | Plot area blighted by *S. homoeocarpa*[¶] 12 Sept | 22 Sept | 1 Oct | AUDPC |
|---|---|---|---|---|---|---|---|
| | | | | % | | | % blighted x time |
| Chlorothalonil[†] | Dew | AM | 468 | 1.0 bc[§] | 2.8 ab | 4.1 abc | 2979 bc |
| Chlorothalonil | Displaced | AM | 468 | 0.8 bcd | 2.4 a-d | 3.5 a-d | 2660 c |
| Chlorothalonil | None | PM | 468 | 0.5 cde | 1.0 b-f | 3.3 a-e | 1213 cd |
| Propiconazole[‡] | Dew | AM | 468 | 0.2 ef | 0.4 def | 0.9 ef | 566 d |
| Propiconazole | Displaced | AM | 468 | 0.1 ef | 0.4 def | 1.0 def | 608 d |
| Propiconazole | None | PM | 468 | 0.1 ef | 0.3 ef | 0.8 ef | 493 d |
| Propiconazole + Chlorothalonil[‡] | Dew | AM | 468 | 0.0 f | 0.2 f | 0.9 ef | 330 d |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 f | 0.2 f | 0.8 f | 212 d |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.0 f | 0.2 f | 0.7 f | 204 d |
| Chlorothalonil | Dew | AM | 1020 | 1.7 b | 3.9 a | 6.2 a | 5233 b |
| Chlorothalonil | Displaced | AM | 1020 | 1.6 b | 5.0 a | 5.4 ab | 5200 b |
| Chlorothalonil | None | PM | 1020 | 1.1 bc | 2.0 a-e | 3.8 abc | 2506 c |
| Propiconazole | Dew | AM | 1020 | 0.4 cde | 0.9 b-f | 1.6 c-f | 1192 cd |
| Propiconazole | Displaced | AM | 1020 | 0.4 cde | 0.9 b-f | 1.5 c-f | 1147 cd |
| Propiconazole | None | PM | 1020 | 0.3 def | 0.7 b-f | 1.4 c-f | 1299 cd |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.1 ef | 0.5 c-f | 1.1 def | 577 d |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.1 ef | 0.5 def | 0.8 f | 516 d |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.0 f | 0.3 f | 0.8 f | 484 d |
| Untreated control | - | - | - | 3.4 a | 2.6 abc | 2.2 b-f | 12292 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

[‡]Propiconazole (3.3 kg a.i. ha$^{-1}$) and propiconazole (3.3 kg a.i. ha$^{-1}$) + chlorothalonil (4.5 kg a.i. ha$^{-1}$) were applied on 23 July and 19 August 2003.

[§] Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.

[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Table 7. Pre-planned orthogonal contrasts among spray volume, application timing and fungicide treatments and their effect on dollar spot control in ‘Crenshaw’ creeping bentgrass, 2003.

| | Contrast | | | | |
|---|---|---|---|---|---|
| Rating Date | Chlorothalonil 468 vs. 1020 L $ha^{-1}$ † | Chlorothalonil AM dew present vs. AM dew displaced† | Chlorothalonil AM dew present vs. PM † | Chlorothalonil AM dew displaced vs. PM † | Propiconazole vs. propiconazole + chlorothalonil‡ |
| 11 August | **§ | NS | * | * | NS |
| 13 August | NS | NS | NS | * | * |
| 16 August | ** | NS | NS | NS | *** |
| 18 August | NS | NS | NS | NS | *** |
| 7 September | *** | NS | ** | ** | * |
| 10 September | *** | NS | ** | * | * |
| 12 September | *** | NS | ** | * | *** |
| 29 September | ** | NS | ** | ** | NS |
| 1 October | ** | NS | ** | ** | NS |
| AUDPC | *** | NS | *** | *** | ** |

† Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July and 7 and 23 August 2003.

‡ Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 8. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil, propiconazole and the propiconazole + chlorothalonil tank-mix in 'Southshore' creeping bentgrass, 2004.

| Source of variation | 13 June | 15 June | 17 June | 22 June | 25 June | 2 July | 9 July | 12 July | 16 July | PAB AUDPC |
|---|---|---|---|---|---|---|---|---|---|---|
| Fungicide[†] | NS[§] | *** | *** | ** | *** | *** | *** | *** | *** | *** |
| Spray volume (SV) | ** | NS | NS | ** | ** | NS | ** | ** | *** | *** |
| Dew[¶] | NS | NS | NS | NS | NS | * | * | NS | NS | * |
| Fungicide*SV | NS | * | NS | NS | NS | NS | * | ** | *** | * |
| Fungicide*dew | NS | NS | NS | NS | NS | * | NS | * | NS | * |
| SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

[†]Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004. Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.
[¶] The dew source of variation included three variables: AM dew present, AM dew displaced and PM dry.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 9. Number of *Sclerotinia homoeocarpa* infection centers and percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by fungicides, spray volumes and application timings where dew was either present or absent in 'Southshore' creeping bentgrass, 2004.

| Fungicide | Dew/displaced/ none | Timing | L ha$^{-1}$ | IC's 2 June | Plot area blighted by S. homoeocarpa[¶] 22 June | 25 June | 2 July |
|---|---|---|---|---|---|---|---|
| | | | | no. | % | | |
| Chlorothalonil [†] | Dew | AM | 468 | 8.7 b[§] | 0.6 b | 0.9 bc | 1.0 b |
| Chlorothalonil | Displaced | AM | 468 | 5.6 bc | 0.3 b | 0.6 b-e | 0.5 b-e |
| Chlorothalonil | None | PM | 468 | 0.7 cde | 0.3 b | 0.4 b-f | 0.4 b-f |
| Propiconazole [‡] | Dew | AM | 468 | 0.1 de | 0.4 b | 0.2 ef | 0.1 c-g |
| Propiconazole | Displaced | AM | 468 | 0.0 e | 0.4 b | 0.2 def | 0.1 efg |
| Propiconazole | None | PM | 468 | 0.0 e | 0.7 b | 0.3 c-f | 0.3 b-g |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.0 e | 0.3 b | 0.2 ef | 0.0 fg |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 e | 0.3 b | 0.1 f | 0.0 fg |
| Propiconazole + Chlorothalonil | None | P M | 468 | 0.0 e | 0.3 b | 0.1 f | 0.0 g |
| Chlorothalonil | Dew | AM | 1020 | 10.2 b | 0.7 b | 1.0 b | 1.1 b |
| Chlorothalonil | Displaced | AM | 1020 | 3.8 bcd | 0.5 b | 0.8 bcd | 0.7 bc |
| Chlorothalonil | None | PM | 1020 | 3.1 b-e | 0.4 b | 0.8 bc | 0.7 bcd |
| Propiconazole | Dew | AM | 1020 | 0.0 e | 0.7 b | 0.4 b-f | 0.2 c-g |
| Propiconazole | Displaced | AM | 1020 | 0.0 e | 0.6 b | 0.4 b-f | 0.1 d-g |
| Propiconazole | None | PM | 1020 | 0.0 e | 0.5 b | 0.3 c-f | 0.2 c-g |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.0 e | 0.4 b | 0.2 ef | 0.1 efg |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.1 de | 0.4 b | 0.2 def | 0.0 efg |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 0.0 e | 0.4 b | 0.1 ef | 0.0 fg |
| Untreated control | - | - | - | 36.2 a | 3.0 a | 3.3 a | 4.4 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.

[‡] Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.

[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.

[¶] Dollar spot was rated visually on a 0 to 100 scale with 0= no blighting, 0.5= the acceptable threshold for dollar spot control in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Table 9 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by fungicides, spray volumes and application timings where dew was either present or absent in 'Southshore' creeping bentgrass, 2004

| Fungicide | Dew/ displaced/ none | Timing | L $ha^{-1}$ | Plot area blighted by *S. homoeocarpa*[¶] 9 July | 12 July | 16 July | AUDPC |
|---|---|---|---|---|---|---|---|
| | | | | % | % | % | % blighted x time |
| Chlorothalonil [†] | Dew | AM | 468 | 2.1 bcd[§] | 2.0 bcd | 2.2 b-e | 42 bc |
| Chlorothalonil | Displaced | AM | 468 | 1.8 b-f | 1.6 b-e | 2.0 b-e | 31 b-e |
| Chlorothalonil | None | PM | 468 | 1.6 b-f | 1.5 b-e | 1.5 b-e | 26 c-f |
| Propiconazole [‡] | Dew | AM | 468 | 1.2 c-g | 1.0 cde | 1.4 b-e | 20 c-f |
| Propiconazole | Displaced | AM | 468 | 1.0 d-h | 1.0 cde | 1.0 de | 19 c-f |
| Propiconazole | None | PM | 468 | 1.4 b-f | 1.5 b-e | 1.5 b-e | 27 b-f |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.3 gh | 0.5 e | 0.8 e | 11 ef |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.2 h | 0.4 e | 0.9 e | 9 f |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.4 fgh | 0.7 de | 0.9 e | 12 ef |
| Chlorothalonil | Dew | AM | 1020 | 3.0 b | 2.9 b | 3.5 b | 58 b |
| Chlorothalonil | Displaced | AM | 1020 | 1.9 b-e | 1.9 bcd | 2.7 bcd | 29 bcd |
| Chlorothalonil | None | PM | 1020 | 2.5 bc | 2.3 bc | 3.1 bc | 44 bc |
| Propiconazole | Dew | AM | 1020 | 1.3 c-f | 1.2 b-e | 1.5 b-e | 26 c-f |
| Propiconazole | Displaced | AM | 1020 | 1.0 d-h | 1.2 b-e | 1.4 cde | 24 c-f |
| Propiconazole | None | PM | 1020 | 1.4 b-f | 1.0 cde | 1.4 cde | 23 c-f |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.4 fgh | 0.6 de | 0.9 e | 14 ef |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.4 fgh | 0.7 de | 0.8 e | 14 ef |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.8 e-h | 0.8 cde | 0.9 e | 15 def |
| Untreated control | - | - | - | 18.8 a | 12.5 a | 10.6 a | 267 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

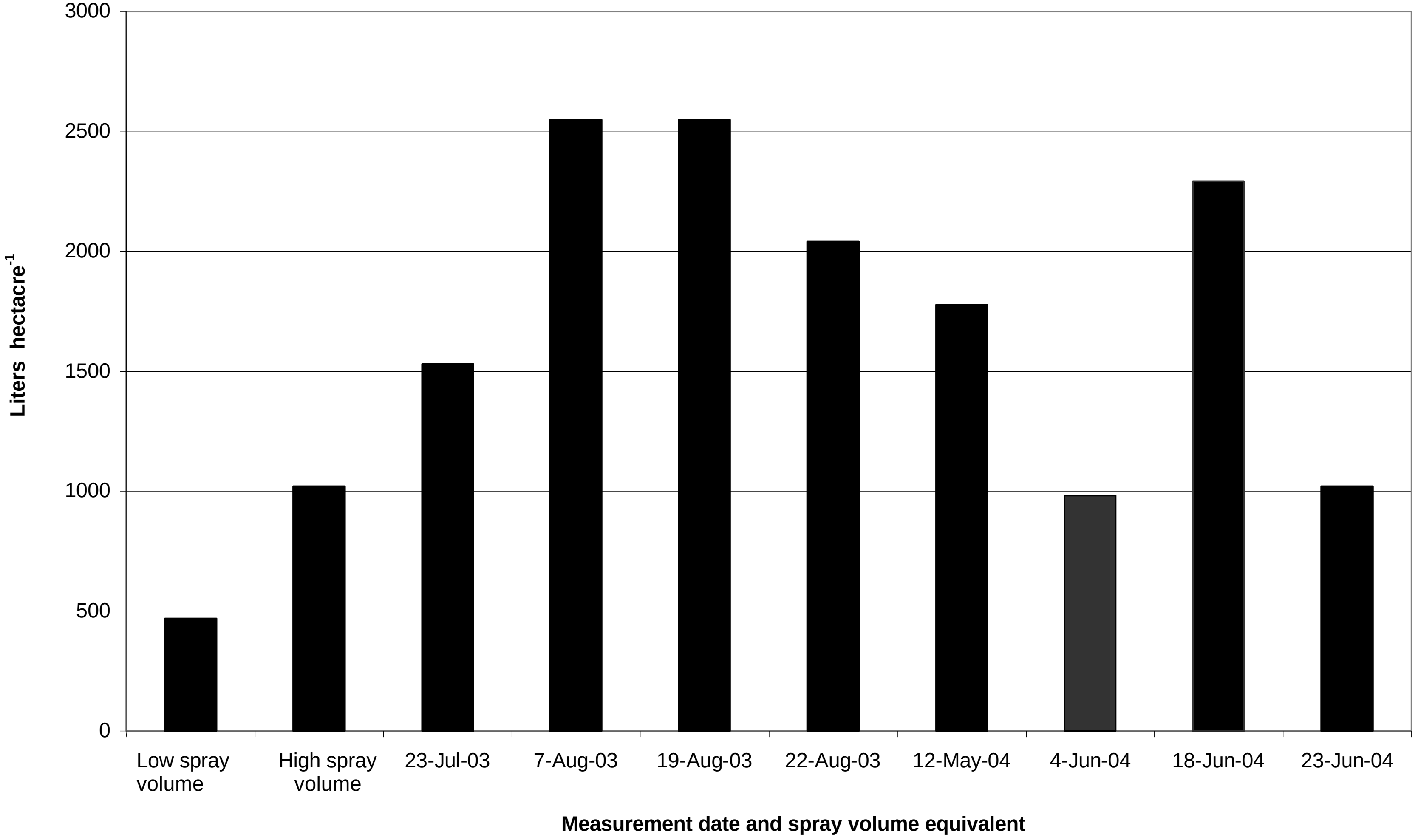
[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.
[‡] Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.
[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Table 10. Pre-planned orthogonal contrasts among spray volume, application timing and fungicide treatments and their effect on dollar spot control in 'Southshore' creeping bentgrass, 2004.

| | Contrast | | | | |
|---|---|---|---|---|---|
| Date | Chlorothalonil 468 vs. 1020 L ha$^{-1}$ [†] | Chlorothalonil AM dew present vs. AM dew displaced [†] | Chlorothalonil AM dew present vs. PM [†] | Chlorothalonil AM dew displaced vs. PM [†] | Propiconazole vs. propiconazole + chlorothalonil [‡] |
| 24 May | NS | NS | NS | * | NS |
| 2 June | NS | ** | *** | * | NS |
| 3 June | NS | NS | ** | NS | NS |
| 8 June | NS | NS | * | NS | * |
| 11 June | NS | NS | * | NS | * |
| 13 June | * | NS | NS | NS | NS |
| 15 June | *** | NS | NS | NS | * |
| 17 June | ** | NS | NS | NS | NS |
| 22 June | NS | * | ** | NS | *** |
| 25 June | * | NS | ** | NS | ** |
| 30 June | * | ** | ** | NS | *** |
| 2 July | NS | * | ** | NS | *** |
| 7 July | ** | NS | NS | NS | *** |
| 9 July | * | * | NS | NS | *** |
| 12 July | * | NS | NS | NS | ** |
| 16 July | *** | NS | NS | NS | *** |
| PAB AUDPC | ** | * | ** | NS | *** |

[†] Chlorothalonil–alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June, 2004.
[‡] Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June, 2004.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant; respectively.

Figure 1. Dew Measurements



Appendix A. Table 1. Fungicide and herbicide applications made to the irrigation study site between 2002 and 2004.

| Date(s) | Chemical Name | Full IUPAC name | Rate | Target |
|---|---|---|---|---|
| 5 June, 3 July 2002 and 9 and 24 June 2004 | Flutolanil | N-[3-(1-methylethoxy) phenyl ]-2-(trifluoromethyl) benzamid | 8.0 kg $ha^{-1}$ | Brown patch (*Rhizoctonia solani* Kuhn) |
| 20 April 2003 | Chlorothalonil + propiconazole | tetrachloroisophthalonitrile + (1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1*H*-1,2,4-triazole | 10.2 + 1.1 kg a.i. $ha^{-1}$ | Dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) |
| 15 May 2003, 24 October and 10 November 2004 | Chlorothalonil | tetrachloroisophthalonitrile | 10.2 kg a.i. $ha^{-1}$ | Dollar spot and seedling diseases |
| 22 May 2003 9 and 24 June 2004 | Mefenoxam | (R)-20[2, 6-dimethylphenyl)-methoxyacetylamino]-propionic | 1.1 kg a.i. $ha^{-1}$ | Pythium blight (*Pythium* spp.) |
| 24 June 2003 15 May 2004 | 2, 4-D + MCPP + dicamba | dimethylamine salt of 2, 4, dichlorophenoxyacetic acid); MCPP (dimethylamine salt of (+)-(R)-2-(2-methyl-4-chlorophenoxy) propionic acid) and dicamba (dimethylamine salt (3, 6-dichloro-o-anisic acid | 3.18 kg $ha^{-1}$ | Broadleaf weeds |
| 11 July 2003[†] | Fenoxaprop-ethyl | (+)-ethyl2-[4[(6-chloro-2-benzoaczolyl) oxy] propanoate | 1.5 kg a.i. $ha^{-1}$ | Smooth crabgrass (*Digitaria ischaemum* Schreb.) |
| 14 July 2003 | Halosulfuron | 3-chloro-5-(4,6-dimethoxypyrimidin-2-ylcarbamoylsulfamoyl)-1-methylpyrazole-4-carboxylic acid | 2.0 kg a.i. $ha^{-1}$ | Yellow nutsedge (*Cyperus esculentus* L.) |

[†] Only perennial ryegrass plots were treated.

Appendix A. Table 1 (cont'd). Fungicide and herbicide applications made to the irrigation study site between 2002 and 2004.

| Date(s) | Chemical Name | Full IUPAC name | Rate | Target |
|---|---|---|---|---|
| 25 July 2003<br>9 June and 10 August 2004 | Deltamethrin | (s)-alpha-cyano-3-phenoxybenzyl (1R, 3R)-3-(2-2-dibro movinyl)-2, 2-dimethyl-cyclopropanecar. | 0.004 kg a.i. $ha^{-1}$ | Black cutworms (*Agrotis ipsilon* Hufnagel) |
| 6 and 29 August 2003 | Iprodione[†] | (3-(3.5-dichlorophenyl)-H-(1-methylethyl)-2, 4dioxo-1-imidazolidinecarboxamide) | 6.1 kg a.i. $ha^{-1}$ | Dollar spot |
| 21 April, 10 May and 1 June 2002; 27 April, 18 May and 8 June 2004 | Siduron | 1-(2-methylcyclohexyl)-3-phenylurea | 8.9 kg a.i. $ha^{-1}$ | Smooth crabgrass (*Digitaria ischaemum* Schreb) |
| July 14 2004 | Propamocarb | propyl 3-(dimethylamino) propylcarbamate | 3.9 kg a.i. $ha^{-1}$ | Pythium blight (*Pythium* spp.) |

[†] Only perennial ryegrass plots were treated.

Appendix A. Table 2. Fertilizer applications made to the irrigation study site between 2002 and 2004.

| Date(s) of application ¶ | Analysis | Amount (kg N $ha^{-1}$) | Composition and sources |
|---|---|---|---|
| 5, 7 April and 17 May, and 14 June 2002 | 19-4-8 | 24.0, 24.0, 24.0, 24.0 | 14.4% ammonical N, 1.6% urea N, 4 % $P_2O_5$, 8 % $K_2O$, 15% S and small amounts of Fe and Mn |
| 6 June 2002 | 19-0-19 | 24.0 | 2.0% urea N, 17.0 % sulfur coated urea N, 19.0% soluble potash, 16.0 % sulfur and small amounts of Fe and Cl) |
| 15 April 2003<br>(Starter fertilizer) ‡ | 19-25- 5 | 48.8 | 4.3% ammoniacal N, 7.4% urea N, 6.3% other water soluble N, 1.0% water insoluble N and 1.8% combined S |
| 5 May†, 3 June†, 7 July 2003†<br>4 and 11 May 2004 | 20-20-20 | 24.0, 48.8, 12.2, 12.2, 12.2 | 3.95 % ammonical N, 9.8% urea N, 6.25% nitrate N, 20% $P_2O_5$, 20 % $K_2O$ and small amounts of B, Cu, Fe, Mn, Mo and Zn |
| 27 June and 8 September 2003<br>17, 21 and 28 May 2004 | 46-0-0 | 24.4 and 48.8<br>24.4, 24.4, 24.4 | 46% urea N |
| 10 November 2003<br>(Complete fertilizer) | 18-24-12 | 49 | 9% ammonical N, 9 %urea N; 4.5% slowly available N, 24% $P_2O_5$, 12% $K_2O$ |
| 19 April 2004 | 18-18-18 | 24.4 | 7.04% ammonical nitrogen 10.96% urea nitrogen |

† Denotes application dates where perennial ryegrass plots only received fertilizer.

‡ Denoted application dates where creeping bentgrass only received fertilizer.

¶ To prevent any turf burning if needed, all fertilizer applications were watered-in immediately after application.

Appendix A. Table 3. Total estimate evapotranspiration (ET) at the experimental site during the study period (2002-2004).

| Month | Total estimated ET (mm)† |
|---|---|
| 2002 | |
| June | 66 |
| July | 130 |
| August | 106 |
| September | 80 |
| Total | 382 |
| 2003 | |
| June | 53 |
| July | 68 |
| August | 76 |
| September | 38 |
| Total | 235 |
| 2004 | |
| June | 83 |
| July | 92 |
| August | 58 |
| September | 42 |
| Total | 275 |

† Evapotranspiration was estimated using an atmometer (ET Gauge, Spectrum Technologies, Inc. Plainfield, IL.) located next to the rainfall gauge and within 20 meters of the center of the study site.

Appendix A. Table 4. Number *Sclerotinia homoeocarpa* infection centers as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 3 July | 19 July | 29 July | 7 August |
|---|---|---|---|---|---|
| Chemical | | no. *S. homoeocarpa* infection centers $plot^{-1}$ | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 a[‡] | 0.0 a | 0.1 b | 0.1 ab |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.0 a | 0.1 a | 0.8 ab | 0.4 ab |
| Primer Select (WA) | 6.3 L prod. | 0.0 a | 0.0 a | 0.8 ab | 0.4 ab |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 a | 0.0 a | 0.1 b | 0.0 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.4 ab | 0.1 ab |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.0 b | 0.2 ab |
| Untreated | - | 0.0 a | 0.1 a | 1.8 a | 2.3 a |
| | | | | | |
| Irrigation | | | | | |
| Frequent | | 0.0 a | 0.0 a | 0.6 a | 0.5 a |
| Infrequent | | 0.0 a | 0.1 a | 0.4 a | 0.5 a |
| ANOVA | | | | | |
| Irrigation (I) | | NS[§] | NS | NS | NS |
| Chemical (C) | | NS | NS | *** | * |
| I*C | | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 5. Number of *Sclerotinia homoeocarpa* infection centers and percent of plot area blighted by dollar spot as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent in 'Crenshaw' creeping bentgrass, 2003.

| Treatment[†] | Rate $ha^{-1}$ | 12 June | 19 June | 26 June |
|---|---|---|---|---|
| Chemical | | no. of *S. homoeocarpa* IC's | % plot area blighted | |
| Chlorothalonil | 8.0 kg a.i. | 1.6 b[‡] | 0.1 b | 0.1 c |
| Paclobutrazol (PB) | 0.12 kg a.i. | 13.0 a | 3.8 a | 3.9 b |
| Primer Select (WA) | 6.3 L prod. | 23.4 a | 4.9 a | 6.3 ab |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 1.5 b | 0.1 b | 0.0 c |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 1.4 b | 0.1 b | 0.0 c |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 1.6 b | 0.1 b | 0.0 c |
| Untreated | - | 35.4 a | 5.0 a | 12.2 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 13.2 a | 2.5 a | 3.8 a |
| Infrequent | | 8.9 a | 1.4 a | 2.7 a |
| ANOVA | | | | |
| Irrigation (I) | | NS[§] | NS | NS |
| Chemical (C) | | *** | *** | *** |
| I*C | | NS | NS | NS |

[†] Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 6. Percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent in ‘Crenshaw’ creeping bentgrass, 2003.

| Treatment† | Rate ha $^{-1}$ | 21 August | 27 August |
|---|---|---|---|
| Chemical | | % of plot area blighted | |
| Chlorothalonil | 8.0 kg a.i. | 0.2 c‡ | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 5.9 b | 3.4 a |
| Primer Select (WA) | 6.3 L prod. | 9.9 a | 5.9 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.1 c | 0.0 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.1 c | 0.0 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.1 c | 0.0 b |
| Untreated | - | 12.4 a | 7.3 a |
| | | | |
| Irrigation | | 4.3 a | 2.1 a |
| Frequent | | 3.9 a | 2.3 a |
| Infrequent | | | |
| ANOVA | | | |
| Irrigation | | NS§ | NS |
| Chemical | | *** | *** |
| I*C | | NS | NS |

† Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.

‡ Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 7. Number of *Sclerotinia homoeocarpa* infection centers as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent in 'Brightstar' perennial ryegrass, 2003.

| Treatment[†] | Rate ha $^{-1}$ | 31 July Frequent | 31 July Infrequent |
|---|---|---|---|
| Chemical | | No. of *S. homoeocarpa* infection centers plot$^{-1}$ | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 a[‡] | 0.75 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.0 a | 0.0 a |
| Primer Select (WA) | 6.3 L prod. | 0.0 a | 1.8 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 a | 0.0 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 a | 0.0 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 a | 0.0 a |
| Untreated | - | 0.0 a | 0.8 a |
| Irrigation | | | |
| Frequent | | 0.0 a | |
| Infrequent | | 0.6 a | |
| ANOVA | | | |
| Irrigation | | NS[§] | |
| Chemical | | * | |
| I*C | | * | |

[†] Treatments were applied on a 14-day interval beginning 10 July and ending 21 August.
[‡] Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 8. Number of *Sclerotinia homoeocarpa* infection centers as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent in 'Southshore' creeping bentgrass, 2004.

| Treatment† | Rate ha $^{-1}$ | 7 June | 22 June | 29 June | 6 July | 13 July |
|---|---|---|---|---|---|---|
| Chemical | | no. *S. homoeocarpa* infections centers plot$^{-1}$ | | | | |
| Chlorothalonil | 4.5 kg a.i. | 0.0 a‡ | 0.0 a | 0.0 a | 0.1 b | 0.5 ab |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.0 a | 0.0 a | 0.5 a | 1.4 b | 2.9 ab |
| Primer Select (WA) | 6.3 L prod. | 0.0 a | 0.0 a | 0.6 a | 8.8 a | 6.5 ab |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 0.0 a | 0.0 a | 0.0 a | 0.0 b | 0.3 b |
| Chlorothalonil + WA | 4.5 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.0 a | 0.1 b | 1.5 ab |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.0 a | 0.0 b | 1.9 ab |
| Untreated | - | 0.0 a | 0.0 a | 0.9 a | 6.6 a | 6.9 a |
| Irrigation | | | | | | |
| Frequent | | 0.0 a | 0.0 a | 0.5 a | 2.7 a | 3.4 a |
| Infrequent | | 0.0 a | 0.0 a | 0.0 a | 2.1 a | 2.3 a |
| ANOVA | | | | | | |
| Irrigation | | NS§ | NS | NS§ | NS | NS |
| Chemical | | NS | NS | NS | *** | *** |
| I*C | | NS | NS | NS | NS | NS |

†Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

‡ Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 9. Percent of plot area blighted by *Sclerotinia homoeocarpa* as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent in 'Southshore' creeping bentgrass, 2004.

| Treatment[†] | Rate ha $^{-1}$ | 17 August | 9 September | | 22 September | |
|---|---|---|---|---|---|---|
| | | | Frequent | Infrequent | Frequent | Infrequent |
| | | % of plot area blighted | | | | |
| Chemical | | | | | | |
| Chlorothalonil | 4.5 kg a.i. | 1.0 bc[‡] | 3.2 c | 5.5 bc | 15.5 a | 19.8 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 1.9 b | 8.3 b | 9.0 b | 15.5 a | 23.3 b |
| Primer Select (WA) | 6.3 L prod. | 4.1 a | 15.8 a | 39.5 a | 15.0 a | 61.0 a |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 0.5 c | 1.9 c | 2.0 c | 13.0 a | 7.8 c |
| Chlorothalonil + WA | 4.5 kg a.i. + 6.3 L | 1.1 bc | 4.9 bc | 7.2 b | 19.5 a | 17.8 b |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.9 c | 2.0 c | 7.1 c | 13.5 a | 17.0 c |
| Untreated | - | 5.0 a | 17.5 a | 51.0 a | 15.8 a | 41.3 a |
| Irrigation | | | | | | |
| Frequent | | 1.9 a | 7.6 b | | 15.4 b | |
| Infrequent | | 2.2 a | 17.4 a | | 30.5 a | |
| ANOVA | | | | | | |
| Irrigation | | NS[§] | * | | * | |
| Chemical | | *** | *** | | *** | |
| I*C | | NS | *** | | *** | |

[†]Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡]Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, NS and refer to significant at the 0.05, 0.01, 0.001, non-significant, respectively.

Appendix A. Table 10. Number of *Sclerotinia homoeocarpa* infection centers as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent in 'Figaro' perennial ryegrass, 2004.

| Treatment[†] | Rate ha $^{-1}$ | 6 July | 13 July | 2 August |
|---|---|---|---|---|
| Chemical | | No. of *S. homoeocarpa* infection centers plot $^{-1}$ | | |
| Chlorothalonil | 4.5 kg a.i. | 0.0 c[‡] | 0.0 b | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.0 c | 0.0 b | 0.5 b |
| Primer Select (WA) | 6.3 L prod. | 2.0 b | 2.1 ab | 2.5 a |
| Chlorothalonil + PB | 4.5 + 0.12 kg a.i. | 0.0 c | 0.0 b | 0.0 b |
| Chlorothalonil + WA | 4.5 kg a.i. + 6.3 L | 0.0 c | 0.5 b | 0.0 b |
| Chlorothalonil + PB + WA | 4.5 + 0.12 kg a.i. + 6.3 L | 0.0 c | 0.0 b | 0.0 b |
| Untreated | - | 4.8 a | 5.1 a | 5.5 a |
| | | | | |
| Irrigation | | | | |
| Frequent | | 0.4 a | 0.7 a | 0.9 a |
| Infrequent | | 1.4 a | 1.5 a | 1.4 a |
| | | | | |
| ANOVA | | | | |
| Irrigation | | NS[§] | NS | NS |
| Chemical | | *** | *** | *** |
| I*C | | NS | NS | NS |

[†] Treatments were applied on a 14-day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, NS and refer to significant at the 0.05, 0.01, 0.001, non-significant, respectively.

Appendix A. Table 11. Percent of plot area blighted by *Pyricularia grisea* as influenced by irrigation, chlorothalonil, paclobutrazol and a wetting agent, 2002.

| Treatment[†] | Rate $ha^{-1}$ | 3 Jul |
|---|---|---|
| | | — % plot area blighted — |
| Chemical | | |
| Chlorothalonil | 8.0 kg a.i. | 0.1 a[‡] |
| Paclobutrazol (PB) | 0.12 kg a.i. | 1.0 a |
| Primer Select (WA) | 6.3 L prod. | 1.4 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.1 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.1 a |
| Untreated | - | 1.4 a |
| | | |
| Irrigation | | |
| Frequent | | 1.1 a |
| Infrequent | | 0.1 a |
| ANOVA | | |
| Irrigation (I) | | NS[§] |
| Chemical (C) | | * |
| I*C | | NS |

[†] Treatments were applied on a 14 day interval beginning on 17 June and ending 26 August, 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 12. Percent of plot area blighted by *Pyricularia grisea* as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$† | 20 July | 22 July | 27 July Frequent | 27 July Infrequent | 2 August | 17 August |
|---|---|---|---|---|---|---|---|
| Chemical | | % plot area blighted | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 0.0 a[‡] | 0.0 a | 0.0 a | 0.0 a | 0.0 b | 0.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.0 a | 0.1a | 0.2 a | 0.0 a | 0.6 ab | 6.2 a |
| Primer Select (WA) | 6.3 L prod. | 0.1 a | 0.1 a | 0.3 a | 0.0 a | 1.6 a | 5.4 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 b | 0.0 b |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.1 a | 0.0 a | 0.0 b | 0.0 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 0.0 a | 0.0 a | 0.0 a | 0.0 a | 0.0 b | 0.0 b |
| Untreated | - | 0.1 a | 0.1 a | 0.2 a | 0.0 a | 0.4 ab | 3.7 a |
| Irrigation | | | | | | | |
| Frequent | | 0.1 a | 0.1 a | 0.2 a | | 0.4 a | 2.4 a |
| Infrequent | | 0.0 a | 0.0 a | 0.0 b | | 0.0 a | 1.9 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | NS | * | | NS | NS |
| Chemical (C) | | * | NS | * | | *** | *** |
| I*C | | NS | NS | * | | NS | NS |

[†] All chlorothalonil treatments were applied at 4.5 kg a.i. $ha^{-1}$ on 1, 15 and 29 June and 15 July 2004. On 20, 28 July and 6 and 16 August 2004, all chlorothalonil treatments were applied at 8.0 kg a.i. $ha^{-1}$. Paclobutrazol and wetting agent-alone were applied on a 14 day interval beginning 1 June and ending 16 August.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but actual means are shown.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix A. Table 13. Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | | Turf quality[¶] | | | | | |
|---|---|---|---|---|---|---|---|
| | Rate ha$^{-1}$ | 26 June | 3 July | 10 July | 19 July | 29 July | 8 August |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 7.6 ab [‡] | 7.4 a | 7.6 ab | 8.2 ab | 8.2 ab | 8.4 ab |
| Paclobutrazol (PB) | 0.12 kg a.i. | 7.6 ab | 7.5 a | 7.4 ab | 7.7 b | 7.7 b | 8.4 ab |
| Primer Select (WA) | 6.3 L prod. | 7.6 ab | 7.5 a | 7.4 ab | 8.2 ab | 8.2 ab | 8.4 ab |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 7.5 ab | 7.5 a | 7.5 ab | 8.2 ab | 8.2 ab | 8.3 ab |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 7.7 ab | 7.6 a | 7.8 a | 8.3 a | 8.3 a | 8.5 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 7.8 a | 7.7 a | 7.6 ab | 8.4 b | 8.4 b | 8.4 ab |
| Untreated | --- | 7.4 b | 7.4 a | 7.3 b | 7.9 ab | 7.9 ab | 8.2 b |
| Irrigation | | | | | | | |
| Frequent | | 7.7 a | 7.6 a | 7.7 a | 8.2 a | 8.2 a | 8.4 a |
| Infrequent | | 7.4 a | 7.4 b | 7.3 b | 8.1 a | 8.1 a | 8.4 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | ** [§] | ** | ** | NS | NS | NS |
| Chemical (C) | | NS | NS | NS | NS | NS | NS |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 13 (Cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment† | | Turf quality¶ | | | | | |
|---|---|---|---|---|---|---|---|
| | | | 22 August | | 29 August | | |
| | Rate ha$^{-1}$ | 16 August | Frequent | Infrequent | Frequent | Infrequent | 13 September |
| | | 0-10 | | | | | |
| Chemical | | | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 8.1 a‡ | 8.5 a | 8.5 a | 8.3 a | 8.3 a | 9.3 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.0 a | 8.5 a | 8.5 a | 7.9 ab | 7.9 ab | 8.0 b |
| Primer Select (WA) | 6.3 L prod. | 8.1 a | 8.3 a | 8.3 a | 7.3 bc | 7.3 bc | 6.5 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.1 a | 8.5 a | 8.5 a | 8.4 a | 8.4 a | 9.8 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.1 a | 8.5 a | 8.5 a | 8.3 a | 8.3 a | 9.4 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 8.0 a | 8.5 a | 8.5 a | 7.9 ab | 7.9 ab | 9.8 a |
| Untreated | --- | 7.8 b | 7.5 b | 7.5 b | 7.0 c | 7.0 c | 5.7 d |
| Irrigation | | | | | | | |
| Frequent | | 8.0 a§ | 8.3 a | | 7.9 a | | 8.3 a |
| Infrequent | | 8.0 a | 7.9 b | | 7.8 a | | 8.4 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS§ | *** | | *** | | NS |
| Chemical (C) | | NS | *** | | *** | | *** |
| I*C | | NS | *** | | *** | | *** |

†Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

‡ Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

¶ Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 13 (Cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | | Turf quality[¶] | | | | |
|---|---|---|---|---|---|---|
| | | 23 September | | 1 October | | |
| | Rate $ha^{-1}$ | Frequent | Infrequent | Frequent | Infrequent | 25 October |
| Chemical | | 0-10 | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.5 a[‡] | 9.5 a | 8.6 a | 8.3 b | 9.9 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 6.0 b | 5.4 b | 5.5 b | 5.7 c | 9.2 b |
| Primer Select (WA) | 6.3 L prod. | 6.0 b | 4.4 c | 5.6 b | 4.6 dc | 8.9 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.9 a | 9.8 a | 9.3 a | 9.8 a | 9.8 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 9.3 a | 9.5 a | 9.0 a | 8.6 b | 9.8 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.8 a | 10.0 a | 8.7 a | 9.9 a | 9.8 a |
| Untreated | --- | 5.0 c | 3.6 d | 4.9 b | 3.6 d | 8.3 c |
| Irrigation | | | | | | |
| Frequent | | 7.4 b | | 7.2 a | | 9.4 a |
| Infrequent | | 7.9 a | | 7.4 a | | 9.4 a |
| ANOVA | | | | | | |
| Irrigation (I) | | **[§] | | NS | | NS |
| Chemical (C) | | *** | | *** | | *** |
| I*C | | ** | | * | | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§]*, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 14. Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2003.

| Treatment[†] | Rate $ha^{-1}$ | Turf quality[¶] 24 July | 31 July | 6 August | 13 August | 21 August | 27 August |
|---|---|---|---|---|---|---|---|
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.1 a[‡] | 8.8 a | 8.6 a | 8.8 a | 8.6 a | 8.7 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.1 b | 7.2 c | 6.8 b | 6.7 b | 6.9 b | 7.1 b |
| Primer Select (WA) | 6.3 L prod. | 7.9 b | 6.5 d | 6.2 c | 6.0 c | 6.1 c | 6.4 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.2 a | 8.6 ab | 8.6 a | 9.0 a | 8.9 a | 9.0 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 9.0 a | 8.6 ab | 8.7 a | 8.8 a | 8.6 a | 8.8 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.1 d | 8.2 b | 8.6 a | 9.0 a | 8.9 a | 9.0 a |
| Untreated | --- | 7.9 b | 6.6 d | 5.8 c | 5.6 c | 5.4 d | 6.0 d |
| Irrigation | | | | | | | |
| Frequent | | 8.6 a | 7.7 a | 7.5 a | 7.7 a | 7.6 a | 7.9 a |
| Infrequent | | 8.6 a | 7.8 a | 7.7 a | 7.7 a | 7.6 a | 7.8 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | NS | NS | NS | NS | NS |
| Chemical (C) | | *** | *** | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.
[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 14 (Cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2003.

| Treatment[†] | | Turf quality[¶] | | |
|---|---|---|---|---|
| | | | 15 September | |
| | Rate $ha^{-1}$ | 5 September | Frequent | Infrequent |
| Chemical | | | 0-10 | |
| Chlorothalonil | 8.0 kg a.i. | 8.8 a[‡] | 7.7 bc | 8.5 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 7.1 b | 7.2 cd | 6.9 b |
| Primer Select (WA) | 6.3 L prod. | 6.6 c | 6.8 d | 6.2 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.9 a | 8.2 ab | 8.8 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.8 a | 8.0 ab | 8.6 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.0 a | 8.6 a | 8.9 a |
| Untreated | --- | 6.6 c | 6.9 d | 6.2 c |
| Irrigation | | | | |
| Frequent | | 7.9 a | 7.6 a | |
| Infrequent | | 8.0 a | 7.7 a | |
| ANOVA | | | | |
| Irrigation (I) | | NS[§] | NS | |
| Chemical (C) | | *** | *** | |
| I*C | | NS | ** | |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 15. Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$ | Turf quality[¶] 7 June | 15 June | 22 June | 29 June | 6 July | 13 July |
|---|---|---|---|---|---|---|---|
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 8.6 a[‡] | 9.1 a | 9.2 ab | 9.4 a | 9.3 a | 9.2 ab |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.6 a | 9.1 a | 9.4 a | 9.5 a | 9.2 a | 9.2 ab |
| Primer Select (WA) | 6.3 L prod. | 8.7 a | 9.0 a | 9.2 ab | 9.4 a | 8.9 b | 8.9 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.6 a | 8.9 a | 9.3 a | 9.4 a | 9.3 a | 9.3 ab |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.6 a | 9.0 a | 9.2 ab | 9.4 a | 9.3 a | 9.2 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 8.6 a | 9.0 a | 9.3 ab | 9.5 a | 9.4 a | 9.4 a |
| Untreated | --- | 8.6 a | 9.0 a | 9.1 b | 9.4 a | 8.9 b | 9.0 c |
| Irrigation | | | | | | | |
| Frequent | | 8.6 b | 8.9 b | 9.2 b | 9.4 a | 9.1 b | 9.1 b |
| Infrequent | | 8.7 a | 9.2 a | 9.3 a | 9.4 a | 9.3 a | 9.3 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | *[§] | *** | * | NS | ** | *** |
| Chemical (C) | | NS | NS | NS | NS | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 15 (cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | | Turf quality[¶] | | | | | |
|---|---|---|---|---|---|---|---|
| | Rate $ha^{-1}$ | 20 July | 27 July | 2 August | 9 August | 17 August | 24 August |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.4 ab[‡] | 9.1 a | 9.3 a [y] | 9.3 a | 9.0 a | 9.2 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 9.4 ab | 9.0 ab | 9.0 a | 8.4 b | 8.3 b | 7.7 b |
| Primer Select (WA) | 6.3 L prod. | 8.9 c | 8.6 b | 7.4 b | 6.7 c | 7.3 c | 6.1 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.5 a | 9.1 a | 9.5 a | 9.4 a | 9.2 a | 9.3 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 9.3 b | 9.2 a | 9.3 a | 9.2 a | 9.1 a | 9.1 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.4 ab | 9.4 a | 9.4 a | 9.4 a | 9.3 a | 9.4 a |
| Untreated | --- | 9.0 c | 8.6 b | 7.7 b | 6.5 c | 7.5 c | 6.1 c |
| | | | | | | | |
| Irrigation | | | | | | | |
| Frequent | | 9.2 a | 8.8 b | 8.7 a | 8.3 b | 8.4 a | 8.1 a |
| Infrequent | | 9.3 a | 9.1 a | 8.9 a | 8.6 a | 8.7 a | 8.2 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | * | NS [z] | * | NS | NS |
| Chemical (C) | | *** | ** | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 15 (cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | | Turf quality[¶] | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 9 September | | 13 September | |
| | Rate ha$^{-1}$ | 30 August | 3 September | Frequent | Infrequent | Frequent | Infrequent |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.3 a[‡] | 9.3 b | 8.4 a | 7.1 b | 7.7 a | 7.0 b |
| Paclobutrazol (PB) | 0.12 kg a.i. | 9.0 b | 8.4 b | 7.0 b | 6.6 a | 7.1 a | 6.1 c |
| Primer Select (WA) | 6.3 L prod. | 7.4 c | 6.7 c | 5.3 c | 4.3 c | 5.5 b | 2.9 d |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.5 a | 9.4 a | 8.4 a | 8.8 b | 8.2 a | 8.6 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 9.3 a | 9.2 b | 7.9 ab | 7.0 b | 7.8 a | 6.9 b |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.4 a | 9.4 a | 8.9 a | 8.7 a | 8.4 a | 8.6 a |
| Untreated | --- | 7.7 c | 6.5 c | 5.2 c | 3.4 d | 5.3 b | 2.5 d |
| Irrigation | | | | | | | |
| Frequent | | 7.6 a | 6.7 b | 6.5 b | | 6.1 b | |
| Infrequent | | 7.7 a | 7.3 a | 7.3 a | | 7.1 a | |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[z] | ** | *** | | *** | |
| Chemical (C) | | *** | *** | *** | | *** | |
| I*C | | NS | NS | * | | *** | |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.
[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 15 (cont'd). Turf quality in 'Crenshaw' creeping bentgrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | | Turf quality[¶] | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | | 17 September | | 22 September | | | |
| | Rate $ha^{-1}$ | Frequent | Infrequent | Frequent | Infrequent | 27 September | 4 October |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 6.0 ab | 5.8 b | 5.8 a [y] | 5.2 b | 5.2 abc | 4.2 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 6.0 ab | 5.8 b | 6.2 a | 4.9 b | 5.6 ab | 5.4 a |
| Primer Select (WA) | 6.3 L prod. | 4.8 bc | 2.9 c | 5.8 a | 1.2 c | 4.6 c | 4.9 a |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 7.3 a | 8.1 a | 6.4 a | 7.3 a | 5.7 ab | 5.1 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 5.5 bc | 5.4 b | 5.7 a | 4.9 b | 4.9 bc | 4.3 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 7.0 a | 8.1 a | 6.2 a | 7.3 a | 6.9 a | 4.9 a |
| Untreated | --- | 4.5 c | 2.3 c | 5.4 a | 1.0 c | 4.5 c | 4.7 a |
| Irrigation | | | | | | | |
| Frequent | | 5.5 a | | 4.5 b | | 4.5 b | 4.5 a |
| Infrequent | | 5.9 a | | 5.9 a | | 5.8 a | 5.1 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS | | *** [z] | | *** | NS |
| Chemical (C) | | *** | | *** | | * | NS |
| I*C | | *** | | *** | | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 16. Turf quality in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | Rate ha$^{-1}$ | Turf quality[¶] 26 June | 3 July | 10 July | 19 July | 29 July | 8 August |
|---|---|---|---|---|---|---|---|
| | | 0-10 | | | | | |
| Chemical | | | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 7.6 a[‡] | 7.4 a | 7.7 ab | 7.4 ab | 7.4 a | 6.9 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 7.6 a | 7.6 a | 7.7 ab | 7.3 ab | 5.7 b | 2.3 b |
| Primer Select (WA) | 6.3 L prod. | 7.6 a | 7.5 a | 7.4 b | 7.1 b | 5.8 b | 2.6 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 7.8 a | 7.6 a | 7.9 a | 7.9 a | 7.7 a | 7.2 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 7.8 a | 7.6 a | 7.8 ab | 7.6 ab | 7.4 a | 7.1 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 7.8 a | 7.7 a | 7.7 ab | 7.3 ab | 7.4 a | 7.0 a |
| Untreated | --- | 7.6 a | 7.6 a | 7.6 ab | 6.9 b | 6.1 b | 3.1 b |
| Irrigation | | | | | | | |
| Frequent | | 7.7 a | 7.7 a | 7.6 a | 6.9 b | 6.6 a | 5.3 a |
| Infrequent | | 7.6 a | 7.5 a | 7.7 a | 7.8 a | 6.9 a | 5.1 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | NS | NS | *** | NS | NS |
| Chemical (C) | | NS | NS | NS | NS | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5= minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 16 (Cont'd). Turf quality in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2002.

| Treatment[†] | Rate $ha^{-1}$ | Turf quality[¶] 16 August | 22 August | 29 August | 13 Sept | 23 Sept | 1 Oct |
|---|---|---|---|---|---|---|---|
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 6.4 ab[‡] | 6.0 a | 5.4 a | 5.1 a | 4.4 a | 4.4 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 0.7 c | 0.1 b | 0.3 c | 0.4 c | 0.3 b | 0.3 b |
| Primer Select (WA) | 6.3 L prod. | 0.5 c | 0.2 b | 0.3 c | 0.2 c | 0.3 b | 0.3 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 6.9 a | 6.0 a | 5.4 a | 5.0 a | 4.5 a | 4.5 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 6.1 b | 6.0 a | 5.2 a | 4.6 ab | 4.1 a | 4.1 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 6.6 ab | 5.4 a | 4.5 b | 4.3 b | 3.9 a | 3.9 a |
| Untreated | --- | 1.0 c | 0.2 b | 0.5 c | 0.6 c | 0.5 b | 0.5 b |
| Irrigation | | | | | | | |
| Frequent | | 4.2 a | 3.8 a | 3.1 a | 2.8 a | 2.8 a | 2.8 a |
| Infrequent | | 3.9 a | 3.0 b | 3.1 a | 3.0 a | 2.3 b | 2.3 b |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | ** | NS | NS | ** | ** |
| Chemical (C) | | *** | *** | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 17. Turf quality in 'Brightstar' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2003.

| Treatment[†] | Rate ha$^{-1}$ | 24 July | 31 July | 6 August | 13 August | 21 August |
|---|---|---|---|---|---|---|
| | | Turf quality[¶] | | | | |
| Chemical | | 0-10 | | | | |
| Chlorothalonil | 8.0 kg a.i. | 8.3 a[‡] | 8.3 a | 8.4 a | 8.4 ab | 8.6 ab |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.3 a | 8.2 a | 8.4 a | 8.4 ab | 8.5 b |
| Primer Select (WA) | 6.3 L prod. | 8.3 a | 8.1 a | 7.9 b | 8.1 bc | 8.0 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.3 a | 8.2 a | 8.4 a | 8.5 a | 8.6 ab |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.3 a | 8.0 a | 8.3 a | 8.4 ab | 8.6 ab |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 8.3 a | 7.9 a | 8.5 a | 8.6 a | 8.8 a |
| Untreated | --- | 8.3 a | 7.8 a | 7.9 b | 8.0 c | 7.9 c |
| Irrigation | | | | | | |
| Frequent | | 8.2 a | 8.0 a | 8.3 a | 8.2 b | 8.4 a |
| Infrequent | | 8.4 a | 8.1 a | 8.2 a | 8.5 a | 8.5 a |
| ANOVA | | | | | | |
| Irrigation (I) | | NS[§] | NS | NS | * | NS |
| Chemical (C) | | NS | NS | ** | ** | *** |
| I*C | | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.
[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.
[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5= minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 17 (Cont'd). Turf quality in 'Brightstar' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2003.

| Treatment[†] | | Turf quality[¶] | | | |
|---|---|---|---|---|---|
| | | 27 August | | | |
| | Rate ha$^{-1}$ | Frequent | Infrequent | 5 Sep | 15 Sep |
| Chemical | | 0-10 | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.0 a[‡] | 8.6 a | 8.8 a | 8.9 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.2 b | 8.2 a | 8.4 b | 8.0 bc |
| Primer Select (WA) | 6.3 L prod. | 7.3 b | 8.1 b | 8.2 c | 7.9 c |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.0 a | 8.7 a | 8.9 a | 8.9 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.9 a | 8.6 a | 8.9 a | 8.7 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.0 a | 8.7 a | 8.9 a | 8.6 ab |
| Untreated | --- | 7.2 b | 8.0 b | 8.1 c | 7.7 c |
| Irrigation | | | | | |
| Frequent | | 8.4 a | | 8.5 b | 8.3 a |
| Infrequent | | 8.4 a | | 8.8 a | 8.4 a |
| ANOVA | | | | | |
| Irrigation (I) | | NS[§] | | ** | NS |
| Chemical (C) | | *** | | *** | *** |
| I*C | | NS | | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5= minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 18. Turf quality in ‘Figaro’ perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$ | Turf quality[¶] 7 June | 15 June | 22 June | 29 June | 6 July | 13 July |
|---|---|---|---|---|---|---|---|
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 8.48 a[‡] | 8.9 a | 9.0 a | 9.3 a | 9.1 ab | 9.3 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 8.43 ab | 8.9 a | 9.0 a | 9.3 a | 9.2 a | 9.2 a |
| Primer Select (WA) | 6.3 L prod. | 8.45 ab | 8.9 a | 9.0 a | 9.2 ab | 9.0 bc | 9.0 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.45 ab | 8.9 a | 9.0 a | 9.3 a | 9.1 ab | 9.3 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.45 ab | 8.9 a | 9.0 a | 9.3 a | 9.1 ab | 9.3 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 8.45 ab | 8.9 a | 9.0 a | 9.3 a | 9.2 a | 9.3 a |
| Untreated | --- | 8.39 b | 8.9 a | 9.0 a | 9.1 b | 8.9 c | 9.0 b |
| Irrigation | | | | | | | |
| Frequent | | 8.4 a | 8.8 b | 8.9 b | 9.2 b | 9.0 b | 9.2 a |
| Infrequent | | 8.4 a | 9.0 a | 9.1 a | 9.3 a | 9.2 a | 9.2 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS [z] | ** | *** | ** | ** | NS |
| Chemical (C) | | NS | NS | NS | NS | NS | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer’s protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 18 (cont'd). Turf quality in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | | Turf quality[¶] | | | | | |
|---|---|---|---|---|---|---|---|
| | Rate $ha^{-1}$ | 20 July | 27 July | 2 August | 9 August | 17 August | 24 August |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.3 ab[‡] | 9.2 ab | 9.4 a [y] | 9.4 a | 9.4 a | 9.4 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 9.4 a | 9.3 a | 8.9 b | 8.4 b | 8.2 b | 6.6 b |
| Primer Select (WA) | 6.3 L prod. | 9.2 c | 9.2 ab | 8.9 b | 8.3 b | 8.2 b | 7.0 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.3 ab | 9.3 a | 9.4 a | 9.4 a | 9.4 a | 9.4 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 9.2 bc | 9.3 ab | 9.4 a | 9.4 a | 9.4 a | 9.4 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.3 ab | 9.3 ab | 9.4 a | 9.4 a | 9.4 a | 9.4 a |
| Untreated | --- | 9.2 c | 9.1 b | 8.8 b | 8.5 b | 8.3 b | 7.0 b |
| | | | | | | | |
| Irrigation | | | | | | | |
| Frequent | | 9.3 a | 9.2 b | 9.1 a | 8.8 a | 8.8 a | 8.0 b |
| Infrequent | | 9.3 a | 9.3 a | 9.3 a | 9.1 a | 9.0 a | 8.6 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | NS[§] | ** | NS | NS | NS | ** |
| Chemical (C) | | * | NS | ** | *** | *** | *** |
| I*C | | NS | NS | NS | NS | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 18 (cont'd). Turf quality in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | | Turf quality[¶] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30 August | | 3 Sept | | | |
| | Rate ha$^{-1}$ | Frequent | Infrequent | Frequent | Infrequent | 9 Sept | 13 Sept |
| Chemical | | 0-10 | | | | | |
| Chlorothalonil | 8.0 kg a.i. | 9.3 a [‡] | 9.4 a | 9.4 a | 9.4 a | 9.1 a | 9.2 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 2.9 c | 7.0 b | 3.0 b | 5.6 b | 4.2 b | 3.4 b |
| Primer Select (WA) | 6.3 L prod. | 3.5 bc | 7.4 b | 3.1 b | 5.5 b | 4.6 b | 3.9 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 9.3 a | 9.4 a | 9.4 a | 9.4 a | 9.1 a | 9.0 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.8 a | 9.4 a | 9.4 a | 9.4 a | 9.1 a | 9.1 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 9.1 a | 9.4 a | 8.7 a | 9.4 a | 9.2 a | 9.1 a |
| Untreated | --- | 4.1 b | 6.8 b | 3.6 b | 5.8 b | 4.5 b | 3.5 b |
| Irrigation | | | | | | | |
| Frequent | | 6.8 b | | 6.8 b | | 6.4 b | 6.1 b |
| Infrequent | | 8.4 a | | 7.8 a | | 7.8 a | 7.4 a |
| ANOVA | | | | | | | |
| Irrigation (I) | | ***[§] | | *** | | *** [z] | *** |
| Chemical (C) | | *** | | *** | | *** | *** |
| I*C | | *** | | ** | | NS | NS |

[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at $P$ =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

Appendix A. Table 18 (cont'd). Turf quality in 'Figaro' perennial ryegrass as influenced by irrigation, chlorothalonil, paclobutrazol and wetting agent, 2004.

| Treatment[†] | Rate $ha^{-1}$ | Turf quality[¶] 17 Sept | 22 Sept | 27 Sep | 4 Oct | 16 Oct |
|---|---|---|---|---|---|---|
| Chemical | | 0-10 | | | | |
| Chlorothalonil | 8.0 kg a.i. | 8.2 a[‡] | 8.2 a | 8.0 a | 7.5 a | 7.2 a |
| Paclobutrazol (PB) | 0.12 kg a.i. | 2.2 b | 0.9 b | 1.4 b | 1.4 b | 2.4 b |
| Primer Select (WA) | 6.3 L prod. | 2.4 b | 0.9 b | 1.3 b | 1.3 b | 2.5 b |
| Chlorothalonil + PB | 8.0 + 0.12 kg a.i. | 8.1 a | 8.3 a | 8.0 a | 7.0 a | 7.2 a |
| Chlorothalonil + WA | 8.0 kg a.i. + 6.3 L | 8.0 a | 8.1 a | 7.7 a | 6.9 a | 6.7 a |
| Chlorothalonil + PB + WA | 8.0 + 0.12 kg a.i. + 6.3 L | 8.0 a | 8.2 a | 7.9 a | 7.3 a | 7.3 a |
| Untreated | --- | 2.4 b | 1.1 b | 1.8 b | 1.5 b | 3.1 b |
| Irrigation | | | | | | |
| Frequent | | 4.5 b | 4.1 b | 4.3 b | 3.6 b | 4.5 b |
| Infrequent | | 6.7 a | 6.0 a | 6.0 a | 5.8 a | 5.8 a |
| ANOVA | | | | | | |
| Irrigation (I) | | ***[§] | *** | *** | *** | *** |
| Chemical (C) | | *** | *** | *** | *** | *** |
| I*C | | NS | NS | NS | NS | NS |

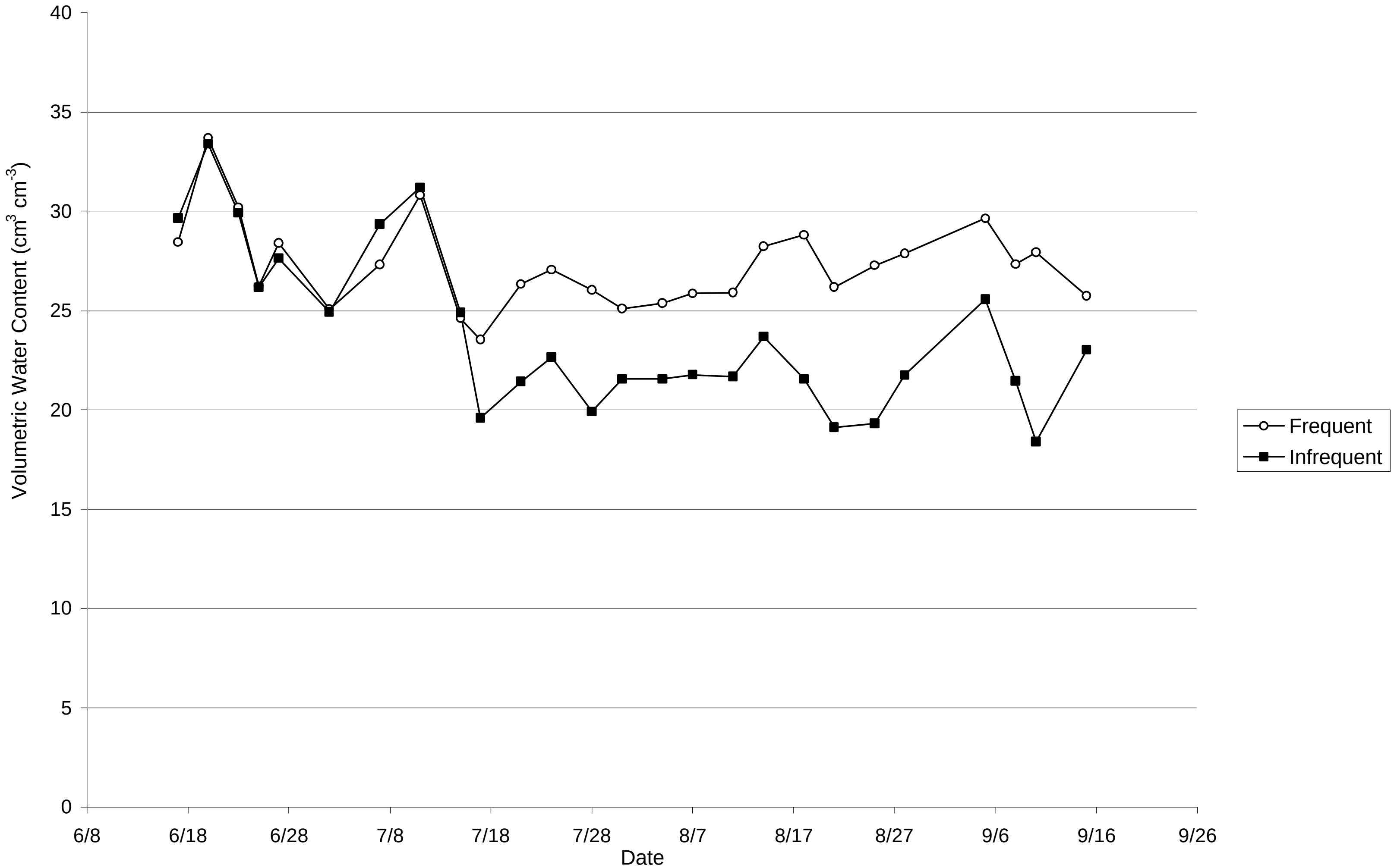
[†]Treatments were applied on a 14-day interval beginning 17 June and ending 26 August 2002.

[‡] Means in the same column followed by the same letter are not significantly different at *P* =0.05 according to Fischer's protected least significant difference test.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[¶] Turf quality was rated on a 0 to scale where 0= entire plot area brown or dead, 7.5=minimal acceptable level for golf course fairway and 10= optimum greenness and density.

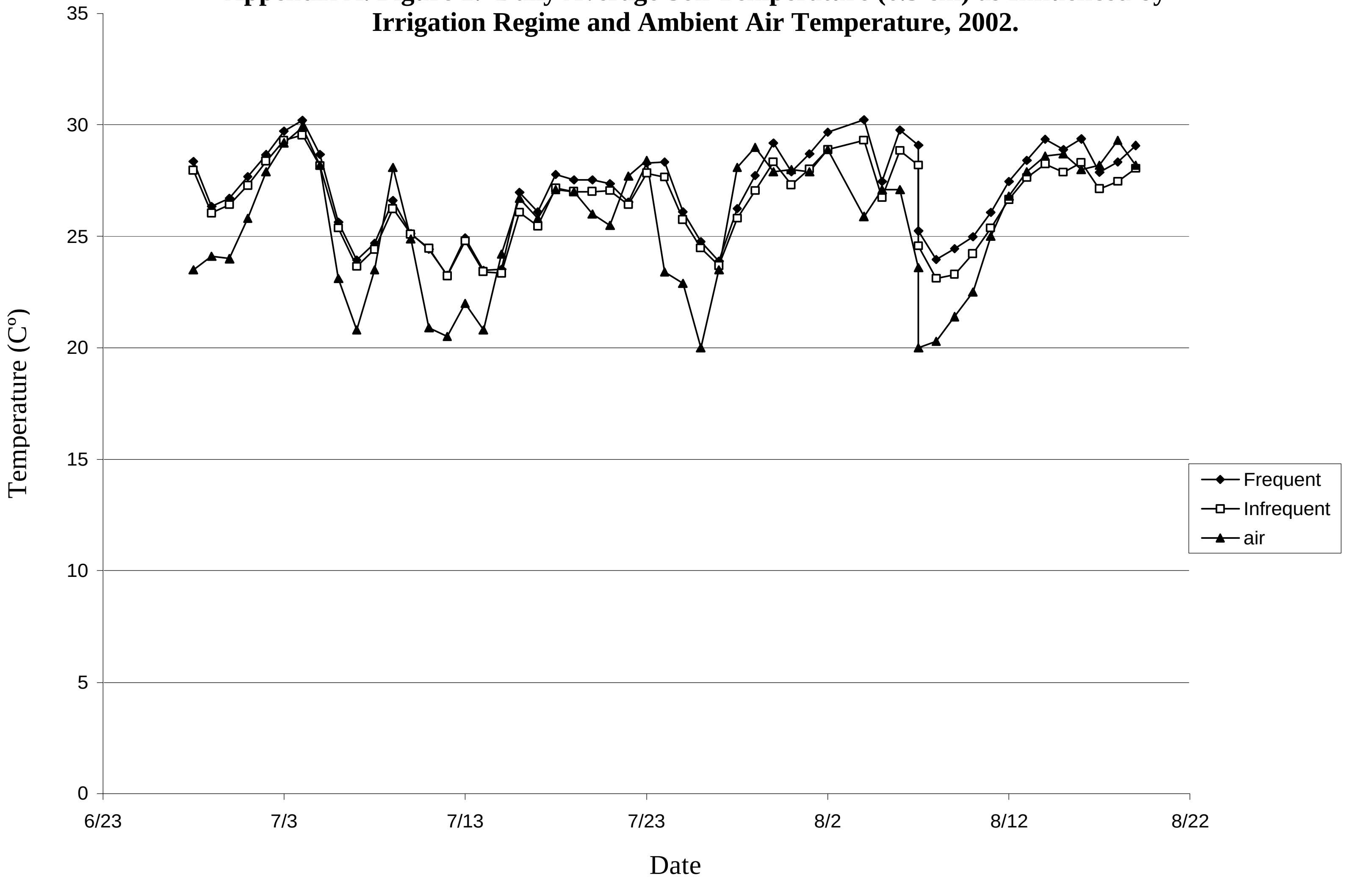
**Appendix A. Figure 1. Soil Moisture Measurements, 2003.†**



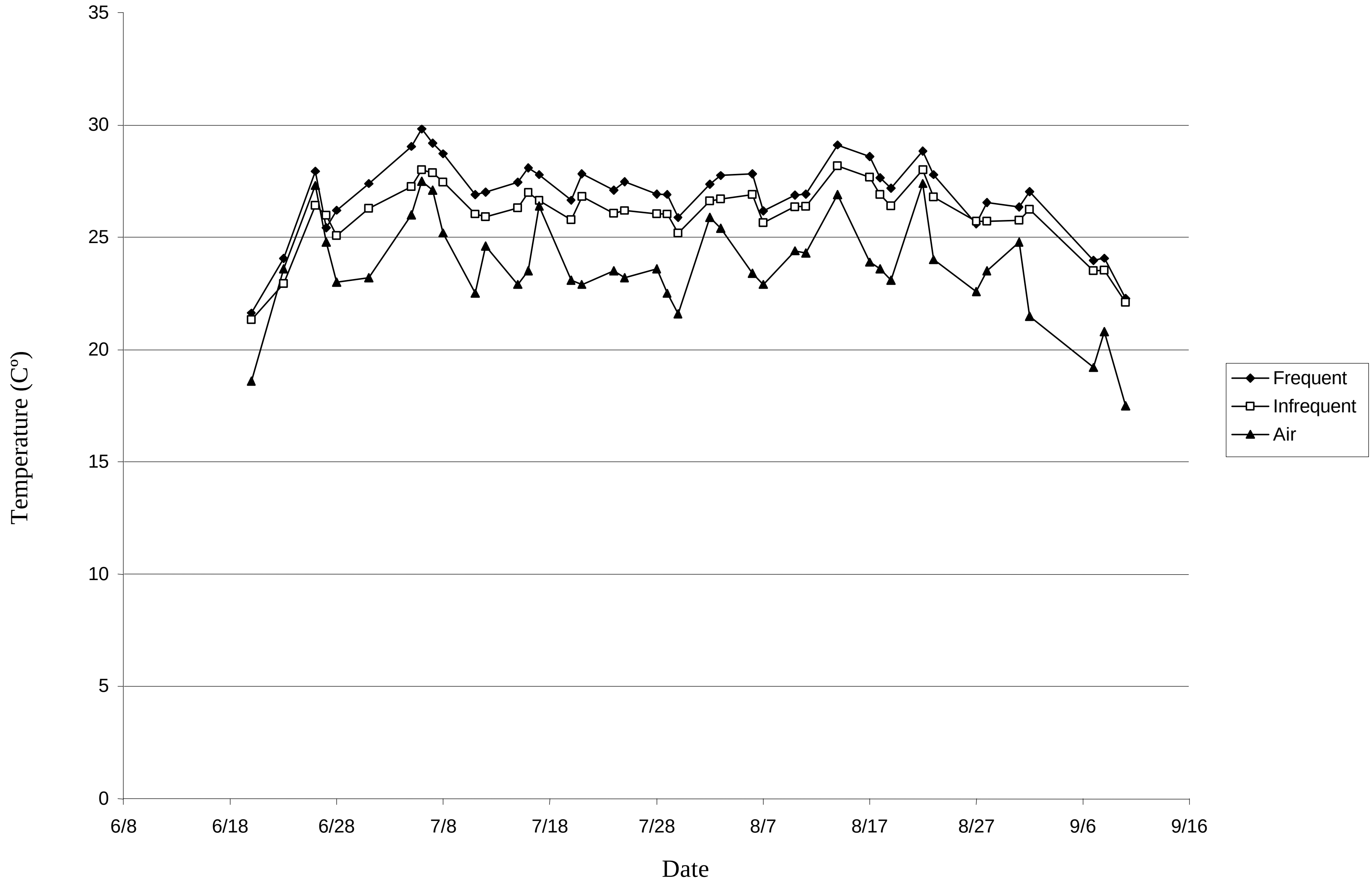

Vertical bars represent +- 1standard error of the mean (SE) where the bars exceed the size of the symbol.

† There were no rating dates throughout 2003 where there was a significant irrigation effect on dollar spot or gray leaf spot.

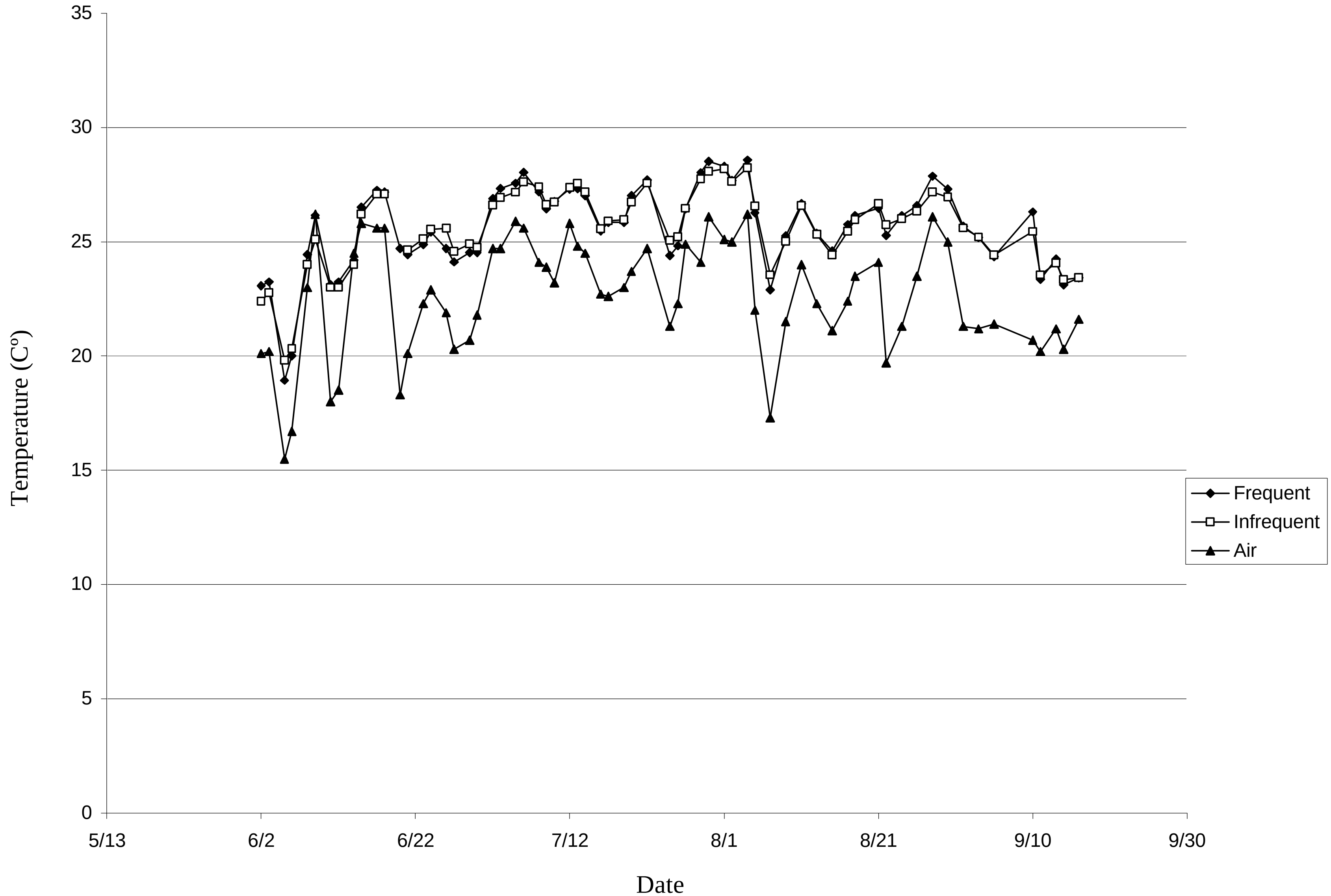
**Appendix A. Figure 2. Daily Average Soil Temperature (6.5 cm) as Influenced by Irrigation Regime and Ambient Air Temperature, 2002.**



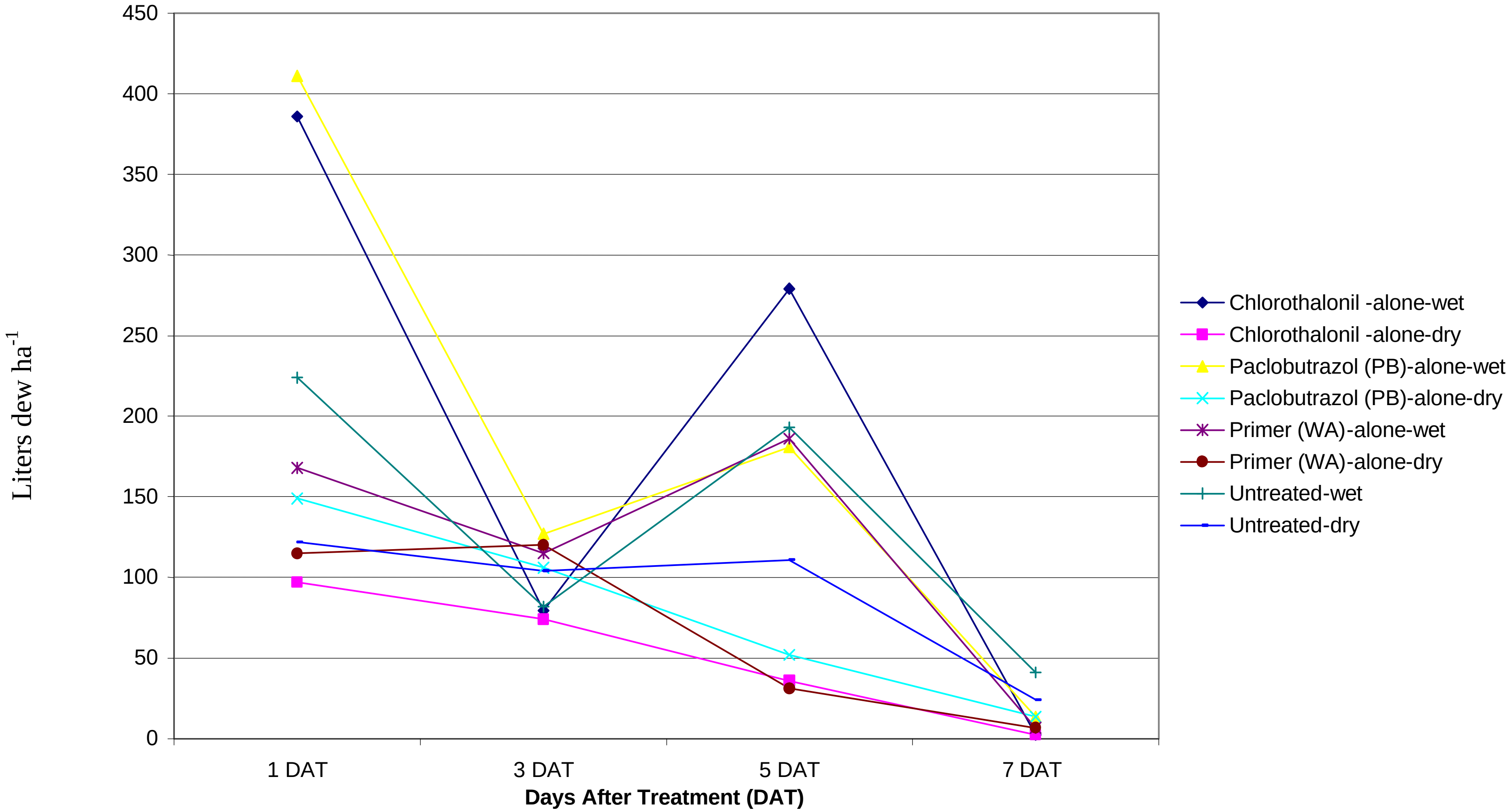
**Appendix A. Figure 3. Daily Average Soil Temperature (6.5 cm) as Influenced by Irrigation Regime and Ambient Air Temperature, 2003.**



**Appendix A. Figure 4. Daily Average Soil Temperature (6.5 cm) as Influenced by Irrigation Regime and Ambient Air Temperature, 2004.**

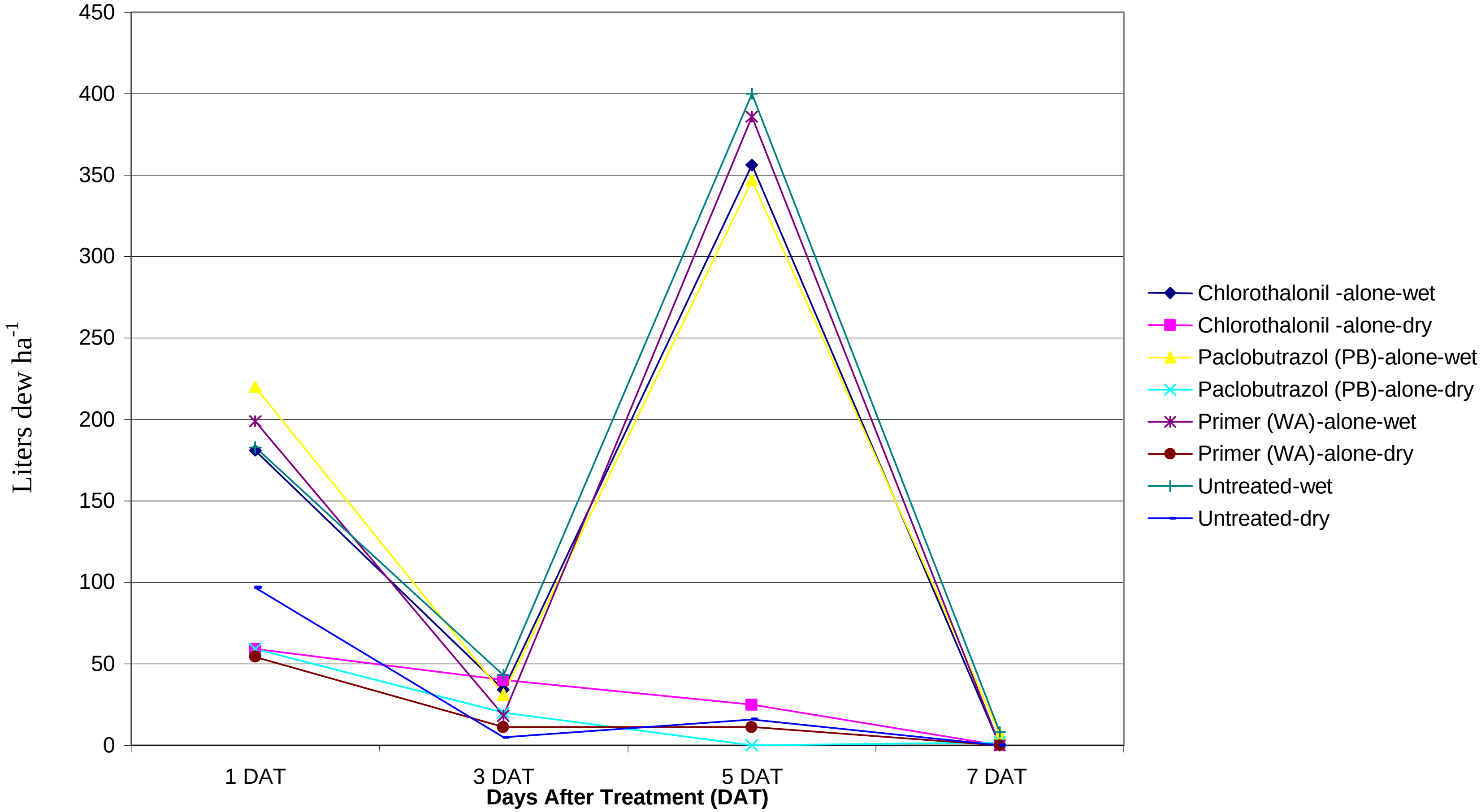


**Appendix A. Figure 5. Creeping bentgrass dew measurements as influenced by chemical and irrigation treatments following the fifth application*, 2004**




*Fifth application was the only application that dew measurements were taken at 1, 3, 5 and 7 days after treatment (DAT).

**Appendix A. Figure 6. Perennial ryegrass dew measurements as influenced by chemical and irrigation treatments following the fifth application*, 2004**




*Fifth application was the only application that dew measurements were taken at 1, 3, 5 and 7 days after treatment (DAT).

Appendix B. Table 1. Restrictions placed on use of chlorothalonil (Daconil Ultrex 82.5 WDG) by United States E.P.A. in 2000.

| Site | Maximum individual application of active ingredient (minimum re-treatment timing)* | Maximum season total per ha.* |
|---|---|---|
| Golf course green | 2.07 kg/ha (11.3 lb/A) (14 days)<br>1.34 kg/ha (7.3 lb/A) (7 days) | 81 kg/ha<br>(73 lb/A) |
| Golf course tee | 2.07 kg/ha (11.3 lb/A) (14 days)<br>1.34 kg/ha (7.3 lb/A) (7 days) | 58.38 kg/ha<br>(52 lb/A) |
| Golf course fairway | 2.07 kg/ha (11.3 lb/A) (one application)<br>1.34 kg/ha (7.3 lb/A) (7 days) | 29.2 kg/ha<br>(26 lb/A) |
| Sod farm | 2.07 kg/ha (11.3 lb/A) (one application)<br>1.34 kg/ha (7.3 lb/A) (7 days) | 29.2kg/ha<br>(26 lb/A) |
| General turf | 2.07 kg/ha (11.3 lb/A) (one application)<br>1.34 kg/ha (7.3 lb/A) (7 days) | 29.2kg/ha<br>(26 lb/A) |

Appendix B. Table 2. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil in 'L-93' creeping bentgrass, 2002.

| Source of variation | 17 July | 19 July |
|---|---|---|
| Time | NS[‡§] | NS |
| Spray volume[†] | * | NS |
| Spray volume* time | NS | NS |

[†] Chlorothalonil (8.0 kg. a.i. $ha^{-1}$) was applied 20 June and 21 July 2002.
[‡] On certain dates when significant differences between spray volumes had occurred the ANOVA may not indicate a significant spray volume effect because of the inclusion of the untreated control data.
[§] *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B. Table 3. Number of *Sclerotinia homoeocarpa* infection centers as influenced by chlorothalonil, application timing and spray volume in 'L-93' creeping bentgrass, 2002.

| Timing | Spray volume[†] | *S. homoeocarpa* infection centers plot$^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | (L ha$^{-1}$) | 3 July | 17 July | 19 July | 22 July | AUDPC |
| | | (no.) | | | | |
| AM[§] | 468 | 6.5 a[‡] | 19.8 a | 28.3 a | 43.0 a | 528 b |
| AM | 1020 | 7.3 a | 26.0 a | 36.5 a | 44.5 a | 811 b |
| PM[¶] | 468 | 2.3 a | 10.5 a | 22.0 a | 36.5 a | 391 b |
| PM | 1020 | 9.3 a | 24.8 a | 40.5 a | 37.5 a | 710 b |
| - | Untreated control | 13.3 a | 15.3 a | 30.3 a | 36.0 a | 2211 a |
| - | P>F | 0.0970 | 0.0863 | 0.2358 | 0.8899 | 0.0001 |

[†] Chlorothalonil (8.0 kg a.i ha-1) spray volume and application timing treatments were applied 20 June and 21 July 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[§] AM treatments were applied in early morning with dew present on the canopy.
[¶] PM treatments were applied in the afternoon to a dry canopy.

Appendix B.. Table 4. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil in 'Crenshaw' creeping bentgrass, 2002.

| Source of variation | 20 June | 28 June | 3 July | 17 July | 19 July | 22 July | 29 July | 1 August |
|---|---|---|---|---|---|---|---|---|
| Time | NS‡ | NS | NS | NS | NS | NS | NS | NS |
| Spray volume† | NS | NS | NS | NS | NS | NS | NS | *** |
| Spray volume* time | NS | NS | NS | NS | NS | NS | NS | NS |

† Treatments were applied 20 June, 21 July and 23 August 2002.
‡ *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B.. Table 4 (cont'd). Influence of spray volume and application timing on the level of dollar spot control in ' Crenshaw' creeping bentgrass provided by chlorothalonil, 2002.

| Source of variation | 7 August | 14 August | 16 August | 20 August | 22 August | 30 August | 5 Sept | AUDPC |
|---|---|---|---|---|---|---|---|---|
| Time | NS[‡] | NS | NS | NS | NS | NS | NS | NS |
| Spray volume[†] | NS | NS | NS | NS | NS | * | NS | NS |
| Spray volume* time | NS | NS | NS | NS | NS | NS | NS | NS |

[†] Treatments were applied 20 June, 21 July and 23 August 2002.
[‡] *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B. Table 5. Number of *Sclerotinia homoeocarpa* infection centers as in ‘ Crenshaw’ creeping bentgrass influenced by chlorothalonil, application timing and spray volume, 2002.

| Timing | Spray volume† | *S. homoeocarpa* infection centers plot$^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | 28 June | 3 July | 17 July | 19 July | 7 August |
| | (L ha$^{-1}$) | (no.) | | | | |
| AM[§] | 468 | 1.2 b[‡] | 0.4 b | 0.6 a | 2.0 a | 2.4 b |
| AM | 1020 | 1.4 b | 1.6 b | 1.4 a | 3.0 a | 7.4 b |
| PM[¶] | 468 | 0.6 b | 0.4 b | 1.4 a | 2.6 a | 5.6 b |
| PM | 1020 | 0.8 b | 0.6 b | 1.0 a | 2.4 a | 8.0 b |
| - | Untreated control | 6.8 a | 4.8 a | 2.8 a | 3.0 a | 23.8 a |
| - | P>F | 0.0011 | 0.0011 | 0.1844 | 0.7795 | 0.0012 |

† Chlorothalonil (8.0 kg a.i ha$^{-1}$) spray volume and application timing treatments were applied 20 June, 21 July and 23 August 2002.

‡ Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means

§ AM treatments were applied in early morning with dew present on the canopy.

¶ PM treatments were applied in the afternoon to a dry canopy.

Appendix B. Table 5 (cont'd). Number of *Sclerotinia homoeocarpa* infection centers in 'Crenshaw' creeping bentgrass as influenced by chlorothalonil, application timing and spray volume.

| Timing | Spray volume[†] | *S. homoeocarpa* infection centers plot$^{-1}$ | | | |
|---|---|---|---|---|---|
| | | 14 August | 16 August | 20 August | 22 August |
| | L ha$^{-1}$ | (no.) | | | |
| AM[§] | 468 | 8.2 b[‡] | 15.0 a | 38.4 b* | 57.4 a |
| AM | 1020 | 14.6 b | 22.8 a | 40.8 b | 55.8 a |
| PM[¶] | 468 | 11.6 b | 23.8 a | 39.2 b | 54.4 a |
| PM | 1020 | 10.6 b | 20.4 a | 44.0 b | 55.4 a |
| - | Untreated control | 27.2 a | 37.0 a | 59.4 a | 67.2 a |
| - | P>F | 0.0431 | 0.0702 | 0.0342 | 0.5953 |

[†] Chlorothalonil (8.0 kg a.i ha$^{-1}$) spray volume and application timing treatments were applied 20 June, 21 July and 23 August 2002.
[‡] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means
[§] AM treatments were applied in early morning with dew present on the canopy.
[¶] PM treatments were applied in the afternoon to a dry canopy.

Appendix B. Table 6. Pre-planned orthogonal contrasts for chlorothalonil applied in two spray volume and their effects on dollar spot control in ‘Crenshaw’ creeping bentgrass with chlorothalonil, 2002.

| Contrast | 20 June | 28 June | 3 July | 17 July | 19 July | 22 July | 29 July | 1 August |
|---|---|---|---|---|---|---|---|---|
| Chlorothalonil 468 vs. 1020† | NS‡ | NS | NS | NS | NS | NS | ** | *** |
| Chlorothalonil AM vs. PM† | NS | NS | NS | NS | NS | NS | NS | NS |

† Chlorothalonil was applied 20 June and 21 July 2002 at the rate of 8.0 kg a.i. $ha^{-1}$.

‡ *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B. Table 6 (cont'd). Pre-planned orthogonal contrasts for chlorothalonil applied in two spray volume and their effect on dollar spot control in Crenshaw' creeping bentgrass with chlorothalonil. 2002

| Contrast | 7 August | 14 August | 16 August | 20 August | 22 August | 30 August | 5 Sept | AUDPC |
|---|---|---|---|---|---|---|---|---|
| Chlorothalonil 468 vs. 1020† | NS‡ | NS | NS | NS | NS | * | NS | NS |
| Chlorothalonil AM vs. PM † | NS | NS | NS | NS | NS | NS | NS | NS |

† Chlorothalonil was applied 20 June and 21 July 2002 at the rate of 8.0 kg a.i. $ha^{-1}$.
‡ *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B. Table 7. Influence of spray volume and application timing on the level of dollar spot control in ‘ Crenshaw’ creeping bentgrass provided by chlorothalonil, propiconazole and propiconazole + chlorothalonil tank-mix, 2003

| Source of variation | 30 Jul | 4 Aug | 6 Aug | 8 Aug | 11 Aug | 13 Aug | 21 Aug | 27 Aug | 18 Sept | 26 Sept |
|---|---|---|---|---|---|---|---|---|---|---|
| Fungicide[†] | NS[‡] | ** | ** | ** | *** | * | ** | *** | *** | *** |
| Spray volume (SV) | NS | NS | NS | NS | * | * | *** | NS | *** | *** |
| Dew | NS | NS | NS | NS | NS | NS | NS | NS | ** | ** |
| Fungicide*SV | NS | NS | NS | NS | NS | NS | NS | NS | * | * |
| Fungicide*dew | NS | NS | NS | NS | NS | NS | * | NS | NS | NS |
| SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003. Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

[‡] *, **, ***, and NS refer to significance level at the 0.05, 0.01, 0.001 levels and non-significant; respectively.

Appendix B. Table 8. Percent of plot area blighted by Sclerotinia *homoeocarpa* in ' Crenshaw' creeping bentgrass as influenced by fungicides, spray volumes, and application timing where dew was either present or displaced, 2003.

| Fungicide | Dew/displaced/ none | Timing | L ha$^{-1}$ | Plot area blighted by *S. homoeocarpa*[¶] 30 Jul | 4 Aug | 6 Aug | 8 Aug | 11 Aug |
|---|---|---|---|---|---|---|---|---|
| | | | | % | | | | |
| Chlorothalonil [†] | Dew | AM | 468 | 0.0 a[§] | 0.1 b | 0.1 b | 0.5 ab | 0.1 bc |
| Chlorothalonil | Displaced | AM | 468 | 0.0 a | 0.1 b | 0.2 b | 0.4 ab | 0.1 bc |
| Chlorothalonil | None | PM | 468 | 0.0 a | 0.0 b | 0.1 b | 0.1 b | 0.0 bc |
| Propiconazole [‡] | Dew | AM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 bc |
| Propiconazole | Displaced | AM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole | None | PM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.2 b | 0.0 c |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.0 a | 0.0 b | 0.0 b | 0.1 b | 0.0 c |
| Chlorothalonil | Dew | AM | 1020 | 0.0 a | 0.2 b | 0.2 b | 0.8 ab | 0.3 b |
| Chlorothalonil | Displaced | AM | 1020 | 0.0 a | 0.2 b | 0.2 b | 1.2 ab | 0.2 bc |
| Chlorothalonil | None | PM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.1 b | 0.0 bc |
| Propiconazole | Dew | AM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.2 b | 0.0 bc |
| Propiconazole | Displaced | AM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.2 b | 0.0 bc |
| Propiconazole | None | PM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.0 b | 0.0 c |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.0 a | 0.0 b | 0.0 b | 0.6 ab | 0.0 c |
| Untreated control | - | - | - | 0.3 a | 1.1 a | 1.2 a | 1.9 a | 3.9 a |
| P>F | | | | .108 | .0001 | .0001 | .0007 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

[‡]Propiconazole (3.3 kg a.i. ha$^{-1}$) and propiconazole (3.3 kg a.i. ha$^{-1}$) + chlorothalonil (4.5 kg a.i. ha$^{-1}$) were applied on 23 July and 19 August 2003.

[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.

[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Appendix B. Table 8 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in ' Crenshaw' creeping bentgrass as influenced by fungicides, spray volumes, and application timings where dew was either present or displaced, 2003.

| | | | | Plot area blighted by *S. homoeocarpa*¶ | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Dew/displaced/ none | Timing | L $ha^{-1}$ | 13 Aug | 27 Aug | 29 Aug | 7 Sept |
| | | | | % | | | |
| Chlorothalonil † | Dew | AM | 468 | 0.0 b§ | 0.3 b | 0.1 bc | 0.6 bcd |
| Chlorothalonil | Displaced | AM | 468 | 0.2 b | 0.2 b | 0.0 bc | 0.5 cde |
| Chlorothalonil | None | PM | 468 | 0.0 b | 0.0 b | 0.0 c | 0.2 def |
| Propiconazole ‡ | Dew | AM | 468 | 0.1 b | 0.0 b | 0.0 c | 0.0 f |
| Propiconazole | Displaced | AM | 468 | 0.3 b | 0.1 b | 0.0 bc | 0.0 f |
| Propiconazole | None | PM | 468 | 0.1 b | 0.0 b | 0.0 c | 0.0 f |
| Propiconazole + Chlorothalonil‡ | Dew | AM | 468 | 0.0 b | 0.0 b | 0.0 c | 0.0 f |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 b | 0.0 b | 0.0 c | 0.0 f |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.1 b | 0.0 b | 0.0 c | 0.0 f |
| Chlorothalonil | Dew | AM | 1020 | 0.2 b | 0.4 b | 0.2 b | 1.2 bc |
| Chlorothalonil | Displaced | AM | 1020 | 0.1 b | 0.3 b | 0.1 bc | 1.3 b |
| Chlorothalonil | None | PM | 1020 | 0.0 b | 0.0 b | 0.0 bc | 0.6 bcd |
| Propiconazole | Dew | AM | 1020 | 0.1 b | 0.0 b | 0.0 c | 0.1 ef |
| Propiconazole | Displaced | AM | 1020 | 0.2 b | 0.0 b | 0.0 c | 0.1 ef |
| Propiconazole | None | PM | 1020 | 0.2 b | 0.0 b | 0.0 c | 0.1 def |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.1 b | 0.0 b | 0.0 c | 0.0 f |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.1 b | 0.2 b | 0.0 c | 0.0 f |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.1 b | 0.0 b | 0.0 c | 0.0 f |
| Untreated control | - | - | - | 3.6 a | 2.2 a | 3.0 a | 3.6 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

† Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

‡Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

§ Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.

¶ Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Appendix B. Table 8 (cont'd). Percent of plot area blighted by Sclerotinia *homoeocarpa* in ' Crenshaw' creeping bentgrass as influenced by fungicides, spray volumes, and application timings where dew was either present or displaced, 2003.

| Fungicide | Dew/displaced/ none | Timing | L $ha^{-1}$ | 10 Sept | 18 Sept | 26 Sept | 29 Sept |
|---|---|---|---|---|---|---|---|
| | | | | Plot area blighted by *S. homoeocarpa*[¶] | | | |
| | | | | % | | | |
| Chlorothalonil [†] | Dew | AM | 468 | 0.5 bcd[§] | 1.7 ab | 2.2 ab | 3.7 ab |
| Chlorothalonil | Displaced | AM | 468 | 0.4 cde | 1.5 ab | 2.1 abc | 3.3 abc |
| Chlorothalonil | None | PM | 468 | 0.2 cde | 0.8 bc | 0.9 bcd | 1.9 bcd |
| Propiconazole [‡] | Dew | AM | 468 | 0.1 de | 0.3 cde | 0.3 de | 0.8 d |
| Propiconazole | Displaced | AM | 468 | 0.0 de | 0.3 cde | 0.4 de | 0.8 d |
| Propiconazole | None | PM | 468 | 0.0 e | 0.2 cde | 0.2 de | 0.8 d |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.0 e | 0.2 cde | 0.2 de | 0.6 d |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 e | 0.1 de | 0.1 de | 0.7 d |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.0 e | 0.0 e | 0.0 e | 0.6 d |
| Chlorothalonil | Dew | AM | 1020 | 1.3 b | 2.7 a | 4.2 a | 5.3 a |
| Chlorothalonil | Displaced | AM | 1020 | 1.2 b | 2.6 a | 3.4 a | 4.7 a |
| Chlorothalonil | None | PM | 1020 | 0.6 bc | 1.5 ab | 2.2 ab | 3.3 abc |
| Propiconazole | Dew | AM | 1020 | 0.1 cde | 0.7 bcd | 0.7 bcde | 1.5 bcd |
| Propiconazole | Displaced | AM | 1020 | 0.0 de | 0.6 bcd | 0.6 bcde | 1.2 d |
| Propiconazole | None | PM | 1020 | 0.1 cde | 0.5 bcd | 0.4 cde | 0.9 d |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.0 e | 0.3 cde | 0.2 de | 1.0 d |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.0 e | 0.2 cde | 0.2 de | 0.8 d |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.0 e | 0.1 cde | 0.1 de | 0.8 d |
| Untreated control | - | - | - | 2.9 a | 3.1 a | 0.7 bcde | 1.5 cd |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.
[‡]Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.
[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Appendix B. Table 9. Pre-planned orthogonal contrasts for spray volume level and application timing among fungicide treatments on dollar spot control in ‘Crenshaw’ creeping bentgrass, 2003.

| | Contrast | | | | |
|---|---|---|---|---|---|
| Date | Chlorothalonil 468 vs. 1020 L $ha^{-1}$ † | Chlorothalonil AM dew present vs. AM dew displaced † | Chlorothalonil AM dew present vs. PM† | Chlorothalonil AM dew displaced vs. PM † | Propiconazole vs. propiconazole + chlorothalonil ‡ |
| 30 July | NS | NS | NS | NS | NS |
| 4 August | NS | NS | NS | * | NS |
| 6 August | NS | NS | ** | ** | NS |
| 8 August | NS | NS | ** | * | NS |
| 18 August | NS | NS | NS | NS | * |
| 21 August | NS | NS | NS | NS | NS |
| 25 August | *** | NS | ** | * | NS |
| 27 August | NS | NS | ** | NS | NS |
| 29 August | ** | NS | ** | * | NS |
| 4 September | *** | NS | ** | ** | NS |
| 18 September | ** | NS | ** | ** | * |
| 26 September | *** | NS | ** | ** | ** |

† Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July and 7 and 23 August 2003.

‡ Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix B. Table 10. Influence of spray volume and application timing on the level of dollar spot control provided by chlorothalonil, propiconazole and the propiconazole + chlorothalonil tank-mix in 'Southshore' creeping bentgrass, 2004.

| Source of variation | 19 May | 24 May | 28 May | 2 June | IC AUDPC | 3 June | 8 June | 11 June | 30 June | 7 July |
|---|---|---|---|---|---|---|---|---|---|---|
| Fungicide[†] | NS[§] | * | NS | *** | *** | *** | *** | *** | *** | *** |
| Spray volume (SV) | NS | NS | NS | NS | NS | NS | NS | NS | ** | *** |
| Dew[¶] | NS | NS | NS | * | NS | NS | * | NS | *** | NS |
| Fungicide*SV | NS | NS | NS | NS | NS | NS | NS | NS | NS | ** |
| Fungicide*dew | NS | NS | NS | ** | NS | NS | NS | NS | * | * |
| SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | * | NS |

[†]Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004. Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.

[¶] The dew source of variation included three variables: AM dew present, AM dew displaced and PM dry.

[§] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix B. Table 11. Number of *Sclerotinia homoeocarpa* infection centers in ‘Southshore’ creeping bentgrass as influenced by chlorothalonil, spray volumes, and application timings where dew was either present or absents, 2004.

| | | | | *S. homoeocarpa* infection centers plot$^{-1}$ [¶] | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Dew/displaced/ none | Timing | L ha$^{-1}$ | 19 May | 24 May | 28 May | IC AUDPC |
| | | | | | no. | | disease x time |
| Chlorothalonil [†] | Dew | AM | 468 | 0.1 ab[§] | 0.1 b | 0.2 b | 28.8 b |
| Chlorothalonil | Displaced | AM | 468 | 0.1 ab | 0.4 b | 0.1 b | 21.4 b |
| Chlorothalonil | None | PM | 468 | 0.3 ab | 0.1 b | 0.0 b | 6.1 b |
| Propiconazole [‡] | Dew | AM | 468 | 0.1 ab | 0.0 b | 0.0 b | 1.8 b |
| Propiconazole | Displaced | AM | 468 | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Propiconazole | None | PM | 468 | 0.0 b | 0.1 b | 0.0 b | 1.1 b |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Propiconazole + Chlorothalonil | None | P M | 468 | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Chlorothalonil | Dew | AM | 1020 | 0.0 b | 0.1 b | 0.1 b | 31.6 b |
| Chlorothalonil | Displaced | AM | 1020 | 0.0 b | 0.3 b | 0.6 b | 18.8 b |
| Chlorothalonil | None | PM | 1020 | 0.1 ab | 0.0 b | 0.3 b | 14.8 b |
| Propiconazole | Dew | AM | 1020 | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Propiconazole | Displaced | AM | 1020 | 0.1 ab | 0.0 b | 0.3 b | 3.5 b |
| Propiconazole | None | PM | 1020 | 0.0 b | 0.1 b | 0.0 b | 2.2 b |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.0 b | 0.1 b | 0.0 b | 0.0 b |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.1 ab | 0.0 b | 0.0 b | 1.3 b |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 0.1 ab | 0.0 b | 0.3 b | 13.0 b |
| Untreated control | - | - | - | 1.9 a | 11.0 a | 20.0 a | 254.5 a |
| P>F | | | | 0.0120 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.
[‡] Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.
[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey’s protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[¶] Dollar spot was rated visually by counting the number of *S. homoeocarpa* infection centers plot$^{-1}$.

Appendix B. Table 11(Cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Southshore' creeping bentgrass as influenced by chlorothalonil, spray volumes and application timings where dew was either present or absent, 2004.

| | | | | Plot area blighted by *S. homoeocarpa*[¶] | | | |
|---|---|---|---|---|---|---|---|
| Fungicide | Dew/displaced/ none | Timing | L $ha^{-1}$ | 3 June | 8 June | 11 June | 13 June |
| | | | | % | | | |
| Chlorothalonil [†] | Dew | AM | 468 | 0.5 b[§] | 0.3 bc | 0.3 b | 0.0 b |
| Chlorothalonil | Displaced | AM | 468 | 0.4 b | 0.2 bcd | 0.1 b | 0.0 b |
| Chlorothalonil | None | PM | 468 | 0.2 bcd | 0.1 bcd | 0.0 b | 0.0 b |
| Propiconazole [‡] | Dew | AM | 468 | 0.0 d | 0.1 bcd | 0.0 b | 0.0 b |
| Propiconazole | Displaced | AM | 468 | 0.0 cd | 0.0 bcd | 0.2 b | 0.1 b |
| Propiconazole | None | PM | 468 | 0.0 cd | 0.0 bcd | 0.2 b | 0.1 b |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.0 d | 0.0 bcd | 0.0 b | 0.0 b |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.0 d | 0.0 bcd | 0.0 b | 0.1 b |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.0 d | 0.0 bcd | 0.0 b | 0.0 b |
| Chlorothalonil | Dew | AM | 1020 | 0.7 b | 0.5 b | 0.2 b | 0.2 b |
| Chlorothalonil | Displaced | AM | 1020 | 0.4 b | 0.2 bcd | 0.1 b | 0.1 b |
| Chlorothalonil | None | PM | 1020 | 0.3 bc | 0.1 bcd | 0.1 b | 0.0 b |
| Propiconazole | Dew | AM | 1020 | 0.0 cd | 0.0 bcd | 0.2 b | 0.1 b |
| Propiconazole | Displaced | AM | 1020 | 0.0 d | 0.1 bcd | 0.2 b | 0.1 b |
| Propiconazole | None | PM | 1020 | 0.0 d | 0.1 bcd | 0.2 b | 0.2 b |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.0 cd | 0.0 bcd | 0.1 b | 0.0 b |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.0 d | 0.0 bcd | 0.0 b | 0.1 b |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.0 d | 0.0 d | 0.1 b | 0.0 b |
| Untreated control | - | - | - | 1.9 a | 2.5 a | 2.4 a | 2.5 a |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.
[‡] Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.
[§] Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test. Data were analyzed using a square root transformation, but data in columns are actual means.
[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Appendix  B. Table 11 (cont'd). Percent of plot area blighted by *Sclerotinia homoeocarpa* in 'Southshore' creeping bentgrass as influenced by fungicide, spray volume and application timing where dew was either present or absent, 2004.

| | | | | Plot area blighted by *S. homoeocarpa*[¶] | | |
|---|---|---|---|---|---|---|
| Fungicide | Dew/displaced/ none | Timing | L $ha^{-1}$ | 15 June | 30 June | 7 July |
| | | | | | % | |
| Chlorothalonil[†] | Dew | AM | 468 | 0.0 b[§] | 0.9 b | 1.9 bcd |
| Chlorothalonil | Displaced | AM | 468 | 0.0 b | 0.4 b-e | 1.5 b-e |
| Chlorothalonil | None | PM | 468 | 0.0 b | 0.3 b-f | 1.2 b-f |
| Propiconazole[‡] | Dew | AM | 468 | 0.2 b | 0.1 efg | 1.2 b-f |
| Propiconazole | Displaced | AM | 468 | 0.3 b | 0.0 fg | 1.0 c-f |
| Propiconazole | None | PM | 468 | 0.4 b | 0.2 c-g | 1.3 b-e |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 0.3 b | 0.1 efg | 0.4 ef |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 0.1 b | 0.0 g | 0.2 f |
| Propiconazole + Chlorothalonil | None | PM | 468 | 0.2 b | 0.0 g | 0.6 def |
| Chlorothalonil | Dew | AM | 1020 | 0.2 b | 0.9 b | 2.8 b |
| Chlorothalonil | Displaced | AM | 1020 | 0.1 b | 0.7 bcd | 2.0 bcd |
| Chlorothalonil | None | PM | 1020 | 0.1 b | 0.8 bc | 2.4 bc |
| Propiconazole | Dew | AM | 1020 | 0.3 b | 0.3 b-f | 1.2 b-f |
| Propiconazole | Displaced | AM | 1020 | 0.4 b | 0.1 efg | 1.4 b-e |
| Propiconazole | None | PM | 1020 | 0.2 b | 0.2 d-g | 1.3 b-e |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 0.2 b | 0.1 efg | 0.4 ef |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 0.2 b | 0.1 efg | 0.4 ef |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 0.2 b | 0.1 efg | 0.8 c-f |
| Untreated control | - | - | - | 3.0 a | 4.0 a | 13.3 a |
| P>F | | | | .0001 | .0001 | .0001 |

[†] Chlorothalonil–alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.

[‡] Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.

[§] Means in the same column followed by the same letter are not significantly different at $P$ <0.05 according to Tukey's protected least significant difference test.  Data were analyzed using a square root transformation, but data in columns are actual means.

[¶] Dollar spot was rated visually on a 0 to100 scale with 0= no blighting, 0.5= dollar spot threshold in fairway turf and 100= 100% of plot area blighted by *S. homoeocarpa*.

Appendix B. Table 12. Pre-planned orthogonal contrasts among spray volume levels, application timings and fungicide treatments and their effect on dollar spot control in 'Southshore' creeping bentgrass, 2004.

| | Contrast | | | | |
|---|---|---|---|---|---|
| Date | Chlorothalonil 468 vs. 1020 L ha$^{-1}$† | Chlorothalonil AM dew present vs. AM dew displaced† | Chlorothalonil AM dew present vs. PM † | Chlorothalonil AM dew displaced vs. PM† | Propiconazole vs. propiconazole + chlorothalonil‡ |
| 19 May | NS§ | NS | NS | NS | NS |
| 28 May | NS | NS | NS | NS | NS |
| IC AUDPC | NS | NS | NS | NS | NS |

† Chlorothalonil –alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June, 2004.

‡ Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June, 2004.

§ *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant; respectively.

Appendix B. Table 13. Influence of spray volume and application timing on turf quality provided by chlorothalonil, propiconazole and the propiconazole + chlorothalonil tank-mix on 'Crenshaw' creeping bentgrass, 2003.

| Source of variation | 4 Aug | 6 Aug | 16 Aug | 21 Aug | 29 Aug | 4 Sept | 12 Sept | 18 Sept | 26 Sept | 1 Oct |
|---|---|---|---|---|---|---|---|---|---|---|
| Fungicide[†] | NS[‡] | NS | *** | NS | NS | ** | *** | *** | *** | *** |
| Spray Volume (SV) | NS | NS | NS | NS | NS | NS | * | * | ** | ** |
| Dew[§] | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*dew | NS | NS | NS | NS | NS | * | ** | NS | NS | * |
| SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Fungicide*SV*dew | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

[†]Chlorothalonil-alone (4.5 kg a.i. $ha^{-1}$) treatments were re-applied on 23 July and 7 and 23 August, 2003. Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

[‡] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

[§] The dew source of variation included three variables: AM dew present, AM dew displaced and PM dry.

Appendix B. Table 14. Turf quality as influenced by fungicides, spray volume, and application timing where dew was either present or absent in 'Crenshaw' creeping bentgrass, 2003.

| Fungicide | Dew/ Displaced/ None | Timing | L ha$^{-1}$ | Quality | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 4 Aug | 6 Aug | 16 Aug | 21 Aug | 29 Aug |
| | | | | (0-10) | | | | |
| Chlorothalonil [†] | Dew | AM | 468 | 8.3 a[§] | 8.2 a | 8.5 a | 8.4 a | 9.0 a |
| Chlorothalonil | Displaced | AM | 468 | 8.1 a | 8.1 a | 8.6 a | 8.2 a | 9.1 a |
| Chlorothalonil | None | PM | 468 | 8.2 a | 8.5 a | 8.9 a | 8.4 a | 9.2 a |
| Propiconazole [‡] | Dew | AM | 468 | 8.2 a | 8.5 a | 7.8 a | 8.4 a | 9.3 a |
| Propiconazole | Displaced | AM | 468 | 8.1 a | 8.3 a | 7.9 a | 8.3 a | 9.2 a |
| Propiconazole | None | PM | 468 | 8.1 a | 8.5 a | 7.8 a | 8.2 a | 9.3 a |
| Propiconazole + Chlorothalonil [‡] | Dew | AM | 468 | 8.2 a | 8.5 a | 8.4 a | 8.7 a | 9.3 a |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 8.2 a | 8.1 a | 8.9 a | 8.6 a | 9.4 a |
| Propiconazole + Chlorothalonil | None | P M | 468 | 8.0 a | 8.3 a | 8.4 a | 8.2 a | 8.9 a |
| Chlorothalonil | Dew | AM | 1020 | 8.0 a | 8.4 a | 8.6 a | 8.3 a | 8.9 a |
| Chlorothalonil | Displaced | AM | 1020 | 8.1 a | 8.5 a | 8.5 a | 8.2 a | 9.0 a |
| Chlorothalonil | None | PM | 1020 | 8.3 a | 8.6 a | 8.7 a | 8.4 a | 9.2 a |
| Propiconazole | Dew | AM | 1020 | 8.2 a | 8.5 a | 7.7 a | 8.2 a | 9.3 a |
| Propiconazole | Displaced | AM | 1020 | 8.1 a | 8.4 a | 8.1 a | 8.1 a | 9.3 a |
| Propiconazole | None | PM | 1020 | 8.2 a | 8.5 a | 7.6 a | 8.2 a | 9.2 a |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 8.2 a | 8.5 a | 8.0 a | 8.4 a | 9.4 a |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 8.2 a | 8.5 a | 7.9 a | 8.5 a | 9.3 a |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 8.1 a | 8.0 a | 7.6 a | 7.9 a | 8.9 a |
| Untreated control | - | - | - | 7.9 a | 7.9 a | 5.6 b | 6.2 b | 7.3 b |
| P>F | | | | .4919 | .1744 | .0001 | .0001 | .0001 |

[†] Chlorothalonil –alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

[‡] Propiconazole (3.3 kg a.i. ha$^{-1}$) and propiconazole (3.3 kg a.i. ha$^{-1}$) + chlorothalonil (4.5 kg a.i. ha$^{-1}$) were applied on 23 July and 19 August 2003.

[§] Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test.

Appendix B. Table 14. (cont'd). Turf quality as influenced by fungicides, spray volume, and application timing where dew was either present or absent in 'Crenshaw' creeping bentgrass, 2003.

| Fungicide | Dew/ Displaced/ None | Timing | L $ha^{-1}$ | Quality | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 4 Sept | 12 Sept | 18 Sept | 26 Sept | 1 Oct |
| | | | | (0-10) | | | | |
| Chlorothalonil † | Dew | AM | 468 | 8.8 a§ | 8.1 b-e | 7.4 cd | 7.7 b-e | 6.9 efg |
| Chlorothalonil | Displaced | AM | 468 | 8.8 a | 8.1 b-e | 7.5 bcd | 7.4 de | 7.0 defg |
| Chlorothalonil | None | PM | 468 | 8.9 a | 8.7 a-d | 8.0 a-d | 7.9 a-e | 7.1 b-g |
| Propiconazole ‡ | Dew | AM | 468 | 9.1 a | 9.0 ab | 8.5 abc | 8.7 abc | 8.2 a-e |
| Propiconazole | Displaced | AM | 468 | 9.2 a | 9.0 ab | 8.5 abc | 8.7 abc | 8.2 a-e |
| Propiconazole | None | PM | 468 | 9.1 a | 9.3 ab | 8.8 a | 8.9 ab | 8.4 abc |
| Propiconazole + Chlorothalonil ‡ | Dew | AM | 468 | 9.2 a | 9.4 a | 8.7 ab | 8.9 ab | 8.5 ab |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 9.3 a | 9.4 a | 9.1 a | 9.0 a | 8.6 a |
| Propiconazole + Chlorothalonil | None | PM | 468 | 8.7 a | 8.8 abc | 8.5 abc | 8.5 a-d | 7.9 a-f |
| Chlorothalonil | Dew | AM | 1020 | 8.5 a | 7.6 de | 7.1 d | 6.8 e | 5.9 g |
| Chlorothalonil | Displaced | AM | 1020 | 8.6 a | 7.8 cde | 7.1 d | 6.9 e | 6.6 fg |
| Chlorothalonil | None | PM | 1020 | 8.9 a | 8.4 a-d | 7.8 a-d | 7.6 cde | 7.0 c-g |
| Propiconazole | Dew | AM | 1020 | 9.0 a | 8.8 abc | 8.1 a-d | 8.2 a-d | 7.4 a-f |
| Propiconazole | Displaced | AM | 1020 | 9.0 a | 8.8 abc | 8.1 a-d | 8.2 a-d | 7.6 a-f |
| Propiconazole | None | PM | 1020 | 9.2 a | 8.9 abc | 8.4 abc | 8.5 a-d | 8.2 a-e |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 9.1 a | 9.1 ab | 8.6 abc | 8.6 a-d | 8.1 a-e |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 9.2 a | 9.2 ab | 8.7 ab | 8.8 abc | 8.4 abc |
| Propiconazole + Chlorothalonil | None | PM | 1020 | 8.7 a | 8.9a bc | 8.6 abc | 8.6 a-d | 8.3 abcd |
| Untreated control | - | - | - | 7.2 b | 7.2 e | 7.0 d | 8.2 a-d | 7.1 b-g |
| P>F | | | | .0001 | .0001 | .0001 | .0001 | .0001 |

† Chlorothalonil –alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

‡ Propiconazole (3.3 kg a.i. $ha^{-1}$) and propiconazole (3.3 kg a.i. $ha^{-1}$) + chlorothalonil (4.5 kg a.i. $ha^{-1}$) were applied on 23 July and 19 August 2003.

§ Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test.

Appendix B. Table 15.Turf quality as influenced by fungicides, spray volume and application timing where dew was either present or absent in ‘Southshore’ creeping bentgrass, 2004.

| Source of variation | 24 May | 2 June | 8 June | 15 June | 30 June | 9 July | 16 July |
|---|---|---|---|---|---|---|---|
| Fungicide[†] | NS[‡] | *** | *** | *** | *** | *** | *** |
| Spray volume (SV) | NS | NS | NS | NS | ** | NS | *** |
| Dew [§] | NS | ** | NS | NS | NS | * | NS |
| Fungicide* SV | NS | * | NS | NS | NS | NS | NS |
| Fungicide*dew | NS | NS | NS | NS | NS | * | NS |
| SV *dew | NS | NS | NS | NS | NS | NS | * |
| Fungicide* SV *dew | NS | NS | NS | NS | NS | NS | NS |

[†] Chlorothalonil –alone (4.5 kg a.i. $ha^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004. Propiconazole (1.65 kg a.i. $ha^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.
[‡] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.
[§] The dew source of variation included three variables: AM dew present, AM dew displaced and PM dry.

Appendix B. Table 16. Turf quality as influenced by spray volume and application timing on 'Southshore' creeping bentgrass, 2004.

| Fungicide | Dew/ Displaced/ None | Timing | L ha$^{-1}$ | Turf Quality 24 May | 2 June | 8 June | 15 June |
|---|---|---|---|---|---|---|---|
| | | | | (0-10) | | | |
| Chlorothalonil † | Dew | AM | 468 | 8.8 a§ | 8.0 b | 8.8 a | 8.3 bc |
| Chlorothalonil | Displaced | AM | 468 | 8.8 a | 8.2 b | 8.8 a | 8.6 abc |
| Chlorothalonil | None | PM | 468 | 8.8 a | 8.2 b | 8.8 a | 8.8 abc |
| Propiconazole ‡ | Dew | AM | 468 | 8.8 a | 8.7 a | 8.8 a | 8.8 abc |
| Propiconazole | Displaced | AM | 468 | 8.8 a | 8.7 a | 8.8 a | 8.8 ab |
| Propiconazole | None | PM | 468 | 8.8 a | 8.7 a | 8.8 a | 8.8 ab |
| Propiconazole + Chlorothalonil ‡ | Dew | AM | 468 | 8.8 a | 8.9 a | 8.9 a | 9.0 a |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 8.8 a | 8.9 a | 8.9 a | 9.0 a |
| Propiconazole + Chlorothalonil | None | P M | 468 | 8.8 a | 9.0 a | 9.0 a | 9.0 a |
| Chlorothalonil | Dew | AM | 1020 | 8.8 a | 8.0 b | 8.6 a | 8.2 c |
| Chlorothalonil | Displaced | AM | 1020 | 8.8 a | 8.3 b | 8.8 a | 8.6 abc |
| Chlorothalonil | None | PM | 1020 | 8.8 a | 8.3 b | 8.7 a | 8.2 c |
| Propiconazole | Dew | AM | 1020 | 8.8 a | 8.7 a | 8.8 a | 8.8 abc |
| Propiconazole | Displaced | AM | 1020 | 8.8 a | 8.8 a | 8.8 a | 8.8 abc |
| Propiconazole | None | PM | 1020 | 8.8 a | 8.8 a | 8.8 a | 8.8 abc |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 8.8 a | 8.8 a | 8.8 a | 9.2 a |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 8.8 a | 8.8 a | 8.8 a | 9.0 a |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 8.8 a | 8.9 a | 8.9 a | 9.0 a |
| Untreated control | - | - | - | 7.7 a | 6.9 c | 6.4 b | 6.2 d |
| P>F | | | | .0001 | .0001 | .0001 | .0001 |

† Chlorothalonil –alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.

‡ Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.

§ Means followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test.

Appendix B. Table 16 (Cont'd). Turf quality as influenced by spray volume and application timing on 'Southshore' creeping bentgrass, 2004.

| Fungicide | Dew/ Displaced/ None | Timing | L ha$^{-1}$ | Turf Quality | | |
|---|---|---|---|---|---|---|
| | | | | 30 June | 9 July | 16 July |
| | | | | (0-10) | | |
| Chlorothalonil † | Dew | AM | 468 | 8.2 de[§] | 7.5 ef | 7.2 de |
| Chlorothalonil | Displaced | AM | 468 | 8.6 a-e | 7.8 c-f | 7.6 cde |
| Chlorothalonil | None | PM | 468 | 8.8 a-e | 7.7 d-f | 7.0 ef |
| Propiconazole ‡ | Dew | AM | 468 | 8.9 abc | 8.6 a-e | 8.7 ab |
| Propiconazole | Displaced | AM | 468 | 9.0 ab | 8.7 a-d | 8.8 ab |
| Propiconazole | None | PM | 468 | 9.0 ab | 8.3 a-e | 8.4 abc |
| Propiconazole + Chlorothalonil ‡ | Dew | AM | 468 | 9.0 ab | 9.0 ab | 9.0 ab |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 9.0 ab | 9.1 a | 9.0 ab |
| Propiconazole + Chlorothalonil | None | P M | 468 | 9.1 a | 8.9 abc | 9.1 a |
| Chlorothalonil | Dew | AM | 1020 | 8.3 cde | 6.9 f | 6.1 f |
| Chlorothalonil | Displaced | AM | 1020 | 8.4 b-e | 8.2 a-e | 6.7 ef |
| Chlorothalonil | None | PM | 1020 | 8.2 e | 7.9 b-f | 7.2 de |
| Propiconazole | Dew | AM | 1020 | 8.8 a-e | 8.6 a-e | 8.1 bcd |
| Propiconazole | Displaced | AM | 1020 | 8.8 a-e | 8.5 a-e | 8.3 abc |
| Propiconazole | None | PM | 1020 | 8.9 abc | 8.6 a-e | 8.4 abc |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 8.9 abc | 8.7 a-d | 8.7 ab |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 8.8 a-d | 8.8 abc | 8.8 ab |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 9.0 ab | 8.8 abc | 8.8 ab |
| Untreated control | - | - | - | 5.4 f | 3.9 f | 4.0 g |
| P>F | | | | .0001 | .0001 | .0001 |

† Chlorothalonil –alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 12 May, 4 and 23 June 2004.

‡ Propiconazole (1.65 kg a.i. ha$^{-1}$) and the tank-mix were applied on 12 May and 18 June 2004.

§ Means followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test.

Appendix B. Table 17. Turf color as influenced by spray volume and application timing on 'Southshore' creeping bentgrass, 2003.

| Fungicide | Dew/ Displaced/ None | Timing | L ha$^{-1}$ | Color ¶ 1 October |
|---|---|---|---|---|
| | | | | (0-10) |
| Chlorothalonil † | Dew | AM | 468 | 7.1 de § |
| Chlorothalonil | Displaced | AM | 468 | 7.2 cde |
| Chlorothalonil | None | PM | 468 | 7.2 cde |
| Propiconazole ‡ | Dew | AM | 468 | 8.5 ab |
| Propiconazole | Displaced | AM | 468 | 8.7 ab |
| Propiconazole | None | PM | 468 | 8.7 ab |
| Propiconazole + Chlorothalonil ‡ | Dew | AM | 468 | 8.6 ab |
| Propiconazole + Chlorothalonil | Displaced | AM | 468 | 8.9 a |
| Propiconazole + Chlorothalonil | None | P M | 468 | 8.2 abc |
| Chlorothalonil | Dew | AM | 1020 | 6.6 de |
| Chlorothalonil | Displaced | AM | 1020 | 6.5 de |
| Chlorothalonil | None | PM | 1020 | 7.6 bcd |
| Propiconazole | Dew | AM | 1020 | 8.4 ab |
| Propiconazole | Displaced | AM | 1020 | 8.4 ab |
| Propiconazole | None | PM | 1020 | 8.7 ab |
| Propiconazole + Chlorothalonil | Dew | AM | 1020 | 8.4 ab |
| Propiconazole + Chlorothalonil | Displaced | AM | 1020 | 8.8 a |
| Propiconazole + Chlorothalonil | None | P M | 1020 | 8.2 abc |
| Untreated control | - | - | - | 6.3 e |
| P>F | | | | 0.0001 |

† Chlorothalonil –alone (4.5 kg a.i. ha$^{-1}$) treatments were applied on 23 July, and 7 and 23 August 2003.

‡ Propiconazole (3.3 kg a.i. ha$^{-1}$) and propiconazole (3.3 kg a.i. ha$^{-1}$) + chlorothalonil (4.5 kg a.i. ha$^{-1}$) were applied on 23 July and 19 August 2003.

§ Means in the same column followed by the same letter are not significantly different at *P* <0.05 according to Tukey's protected least significant difference test.

¶ Color was rated on a linear scale from 0-10; 0 being brown dead turf, 7 being acceptable fairway color, and 10 being optimal density and greenness.

Appendix B. Table 18. Mean amounts of canopy dew measured in 2003 and 2004.

| | Treatments applied | Amount of dew (L $ha^{-1}$) |
|---|---|---|
| 23 July 2003 | All | 1529† |
| 7 August 2003 | Chlorothalonil-alone | 2548 |
| 19 August 2003 | Propiconazole and tank-mix | 2548 |
| 22 August 2003 | Chlorothalonil-alone | 2039 |
| 12 May 2004 | All | 1777 |
| 4 June 2004 | Chlorothalonil-alone | 982 |
| 18 June 2004 | Propiconazole and tank-mix | 2291 |
| 23 June 2004 | Chlorothalonil-alone | 1019 |

† Dew was measured by blotting Kimwipe tissues over 120 $cm^2$ area of creeping bentgrass turf using a wooden frame as a template.

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# Curriculum Vitae

**Name:** Steven James McDonald

**Address:** 206 Highland Rd.
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**Education:**

University of Maryland, M.S., December 2005
Advisor: Peter H. Dernoeden, Ph. D.
Delaware Valley College, B.S., Turfgrass Science, May 2003
Advisor: Douglas T. Linde, Ph. D.

**Employment:**

Graduate Research Assistant, University of Maryland, College Park, MD. June 2003-December 2005
Assistant Superintendent-in-Training, Philadelphia Country Club, Gladwyne, PA., May 2002-June 2003
Intern, Philadelphia Country Club, Gladwyne, PA., June 2000-May 2002
Student Research Technician, Delaware Valley College, Doylestown, PA, September 2002-May 2003
Student Intern, Hickory Valley Golf Club, Gilbertsville, PA, May 1999-June 2000
Caddie, Philadelphia Country Club, Gladwyne, PA, September 1997-May 2002

**Current Responsibilities:**

Research:

Thesis title: Dollar Spot and Gray Leaf Spot Severity as Influenced by Irrigation Practice and Disease Management With Plant Protection Materials

Thesis research:

- Irrigation frequency effects on dollar spot and gray leaf spot incidence and severity
- Chlorothalonil, plant growth regulator and wetting agents effects on dollar spot and gray leaf spot in fairway height turf
- Influence of dilution rate/ spray volume and application timing for fungicide (contact vs. penetrant vs. tank-mix) applications targeting dollar spot in fairway height creeping bentgrass
- Quantify canopy dew and its effect of fungicide performance in fairway height creeping bentgrass

Other research projects:

- *Poa annua* and *Poa trivialis* control in fairway height turf with bispyribac-sodium (Velocity)

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- Cool-season turfgrass seedling tolerance to bispyribac
- Masking discoloration elicited by bispyribac in creeping bentgrass
- Yellow tuft control in creeping bentgrass with Subdue MAXX
- Monitering *Pyricularia grisea* conidia release using a spore trap
- Fertilizer and bio-stimulant uses for increased dollar spot suppression
- Curative control of dollar spot with various fungicides
- Dollar spot control using early season fungicide application
- Evaluated new herbicides for broadleaf weed control in lawn turf
- Kentucky bluegrass mitigation and soil residual effects of non-selective herbicides on overseeded Kentucky bluegrass
- Selective control of creeping bentgrass in tall fescue turf with mesotrione, fenoxaprop-ethyl and triclopyr
- Yellow nutsedge control with sulfosulfuron and halosulfuron

Extension:

- Perform turfgrass disease diagnostics at the University of Maryland Turfgrass Disease Diagnostic Laboratory
- Assist on extension visits to golf courses and athletic fields within the state of Maryland
- Author or co-author of turfgrass disease and insect extension publications (University of Maryland Turfgrass Technical Updates)
- Assist with the field evaluation of fungicides, herbicides and fertilizers and performed statistical analyses of data
- Developed of a database of digital images of turfgrass disease symptoms, signs and maladies
- Gave presentations at annual University of Maryland field days and conferences

Teaching:

Assistant Lab Instructor: NRSC410 Principles of Plant Pathology, Fall 2005

- Prepare turfgrass samples for an undergraduate laboratory exercise on Koch's Postulate

Guest Lecturer: PLSC402 Sports Turf Management, Spring 2005

- Turfgrass disease research and how golf course superintendents benefit from information obtained through university research

Co-Lab Instructor: NRSC410 Principles of Plant Pathology, Fall 2004

- Prepare disease samples and isolates for class laboratory

Guest Lecturer: NRSC410 Principles of Plant Pathology, Fall 2004

- Biology and control of dollar spot disease in turfgrass

Guest Lecturer: NRSC423 Soil-Water Pollution, Fall 2004

- Audubon International Certification for Golf Course Environmental Stewardship

**Course Preparation Volunteer for PGA Tour Tournaments and USGA Championships:**

2005 USGA Amateur, Merion Golf Club, Ardmore, PA, August 2005.
2005 Booz-Allen Classic, Congressional Country Club, Bethesda, MD, June 2005.
2003 USGA Women's Amateur, Philadelphia Country Club, Gladwyne, PA, August 2003.
2002 SEI Pennsylvania Classic, Waynesborough Country Club, Paoli, PA September 2002.

**Honors and Awards:**

Dale Carnegie Training Program, 2002
Delaware Valley College Agricultural Ambassador, 2000-2002
Delaware Valley College Agronomy and Environmental Science Distinguished Student, 2003
Delaware Valley College Deans List (2000-2003)
Delaware Valley College NCAA Golf Team, 2000-2003 (Captain 2002)
Middle Atlantic Conference (MAC) All-Academic Golf Team, 2002-2003
Delaware Valley College Turf Club, President, 2002
Delaware Valley College Turfgrass Scholarship, 2002
Golf Course Superintendents Association of America Scholars Scholarship, 2003
GCSAA Student Essay Contest (Third Place), 'Dollar Spot, a Historic Disease of Golf Course Turf'', 2005
Philadelphia Association of Golf Course Superintendents Scholarship, 2002
United States Golf Association Mid-Atlantic Green Section Internship, 2002
Golf Association of Philadelphia J. Wood Platt Caddie Scholar, 2000-2003

**Certifications:**
Pennsylvania State Pesticide Certification, Category 7 and core, 2000-Present

**Professional Societies and Other Memberships:**

American Phytopathological Society
Golf Course Superintendents Association of America
Maryland Turfgrass Council
Mid-Atlantic Association of Golf Course Superintendents
Philadelphia Association of Golf Course Superintendents
United States Golf Association

**Abstracts Published:**

Dernoeden, P.H, J. E. Kaminski, and S. J. McDonald. 2004. Preemergence smooth crabgrass and postemergence annual bluegrass control in turfgrass. Proceedings Northeastern Weed Science Society 58: 119.

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McDonald, S. J. and P. H. Dernoeden. 2005. Postemergence control of annual and roughstalk bluegrass in creeping bentgrass with bispyrabac sodium. Proceedings Northeastern Weed Science Society 59:92

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Dernoeden, P.H, J.E. Kaminski, and S.J. McDonald. 2005. Maryland 2004 smooth crabgrass control studies in turf. Proceedings Northeastern Weed Science Society 59:97-98.

J.E. Kaminski, P.H. Dernoeden, and S.J. McDonald. 2006. Colonial, creeping and velvet bentgrass safety and tolerance to bispyribac sodium. Proceedings Northeastern Weed Science Society 60: (submitted)

**Invited Professional Presentations:**

Pennsylvania Turfgrass Council, Southeastern Pennsylvania Conference, January 12, 2006. (In preparation)

- Dollar spot management as influence by irrigation and fungicide spray volume

**Extension Presentations:**

Maryland Turfgrass Conference, January 2004.

- Dollar spot control as influenced by fungicide application timing and dew removal

Maryland Turfgrass Conference, January 2005.

- Dollar spot severity as influenced by irrigation in creeping bentgrass

Maryland Turfgrass Conference, January 2006. (In preparation)

- The use of Velocity to control *Poa annua* in cool-season turf

**Extension Publications:**

McDonald, S. J., and P. H. Dernoeden. 2004. Biology and management of the annual bluegrass weevil (*Listronotus maculicolis*) in turfgrass. www.mdturfcouncil.org.

**Reports Published in Fungicide and Nematicide Tests:**

Dernoeden, P.H., S.J. McDonald, and J.E. Kaminski. 2005. Brown patch and dollar spot control in bentgrass with fungicides, 2003. Fungicide and Nematicide Tests 60: 38.

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Dernoeden, P.H., S.J. McDonald, J.M. Krouse and J.E. Kaminski. 2005. Brown patch control in colonial bentgrass with various fungicides, 2003. Fungicide and Nematicide Tests 60:36.

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Dernoeden, P.H., S.J. McDonald, J.M. Krouse and J.E. Kaminski. 2005. Dollar spot and brown patch control in creeping bentgrass with fungicides, 2004. Fungicide and Nematicide Tests 60:39.

Dernoeden, P.H., S.J. McDonald, and J.E. Kaminski. 2005. Gray leaf spot control with Syngenta and Cleary's fungicides, 2003. Fungicide and Nematicide Tests 60: 40.

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