ABSTRACT

Title of Thesis: FACTORS AFFECTING FUNGICIDE PERFORMANCE WHEN TARGETING DOLLAR SPOT DISEASE IN CREEPING BENTGRASS

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Creeping bentgrass (*Agrostis stolonifera)* is commonly grown on golf course fairways and dollar spot (*Sclerotinia homoeocarpa*) is perhaps the most chronically severe disease of bentgrass. Field studies were conducted to: a) determine the influence of simulated rainfall and two mowing timings (AM and PM) on the performance of four fungicides, and b) to assess the effects of two fungicide spray volumes (468 and 935 L water ha^{-1}) and application timings (AM and PM) on dollar spot control in creeping bentgrass. Fungicide effectiveness generally was reduced by simulated rain imposed about 30 minutes after application. Boscalid and chlorothalonil were most and least rain-safe; respectively, and propiconazole and iprodione were intermediate in rain-safeness. Fungicide performance was improved by mowing in the AM prior to fungicide application. A tank-mix of chlorothalonil +

propiconazole was unaffected by spray volume or application timing, but the performance of chlorothalonil and propiconazole applied separately was inconclusive.

FACTORS AFFECTING FUNGICIDE PERFORMANCE WHEN TARGETING DOLLAR SPOT DISEASE IN CREEPING BENTGRASS

By

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List of Abbreviations

Full Meaning[†]	Abbreviation
Acre	A
Active ingredient	a.i.
Analysis of variance	ANOVA
Ante meridian	AM
Carbon Dioxide	CO_2
Centimeter	cm
Feet	ft
Fluid	fl
Gallon	gal
Gallon per acre	GPA
Gram	g
Hectare	ha
Hour	h
Inches	in
Infection centers	IC
Kilogram	kg
Kilopascal	kPa
Least significance difference	LSD
Liter	L
Maryland	MD
Meter	m
Milligram	mg
Millimeter	mm
National Oceanic and Atmosphere Administration	NOAA
Ounce	oz
Pounds per square inch	psi
Product	prod
Post meridian	PM
Total nonstructural carbohydrates	TNC
United States of America	USA
United States Environmental Protection Agency	USEPA
Volume to volume	v/v

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

Chapter I: Simulated Rainfall and Mowing Impact on Fungicide Performance When Targeting Dollar Spot in Creeping Bentgrass

Synopsis

The performance of fungicides as influenced by rainfall and mowing timing has not been studied for any turfgrass disease. In this two year field study, four chemically diverse fungicides (i.e., chlorothalonil, boscalid, iprodione, propiconazole and a tank-mix of chlorothalonil and propiconazole in 2008 only) were evaluated for their ability to control dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) in creeping bentgrass (*Agrostis stolonifera* L.) as influenced by simulated rain and mowing timing. The simulated rain parameter involved applying 2.54 to 3.18 cm rain using an overhead irrigation system about 30 minutes after fungicides were applied and was compared to rain-free plots. One set of plots was mowed in the AM with dew present prior to fungicide application and was compared to plots that only were mowed when the canopy was dry in the PM. Disease was assessed by counting the number of *S. homoeocarpa* infection centers (IC) in each plot. Simulated rain generally reduced the effectiveness of all fungicides. The percent reduction in dollar spot control associated with simulated rain versus rain-free treatments in 2007 and 2008 was as follows: chlorothalonil 68 to 96%; propiconazole 43 to 82%; boscalid 38 to 45%; and iprodione 28 to 87%. Hence, the activity of chlorothalonil was most consistently diminished by simulated rain. Iprodione and propiconazole exhibited an intermediate level of rain-safeness; whereas, boscalid was consistently the most rain-safe fungicide evaluated. The time of day that plots were mowed also impacted fungicide performance significantly. Mowing in the AM reduced dollar spot severity compared

to PM mowing in non- fungicide treated plots by 21 to 26 % in both years, but the difference was not significant. The range in the percent reduction in dollar spot associated with AM mowing for all fungicides over two years was 34 to 84%. The reduction in dollar spot severity in AM mowed plots generally improved the performance of all fungicide.

Introduction

Maintaining dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) injury at levels acceptable to most golfers is a difficult challenge for many golf course superintendents. Although numerous biological agents and cultural practices have shown some success in suppressing dollar spot, fungicides remain necessary to maintain acceptable levels of turf quality at most golf courses. According to label specifications and independent testing, fungicides targeting dollar spot need to be applied on 7 to 28 day intervals to maintain effective threshold levels (Latin, 2006). The timing of fungicide applications can be a complicated process, in which the superintendent has to balance special events, heavy play, or other logistical considerations. Also, the weather is an uncontrollable and unpredictable obstacle that has to be considered when applying fungicides. Applications are sometimes performed when rain is in the forecast or when unpredicted storm activity develops. The combination of these factors creates problems when applying fungicides to fairways. Furthermore, golf course fairways are mowed several times weekly and clippings normally are removed. The impact of mowing just prior to and after the application of fungicides is unknown.

Most research efforts to evaluate the effect of a rainfall following a fungicide application have been conducted in crops other than turf. Armengol and Garcia-Jimenez (2007) evaluated the rain fastness of fungicides for control of Alternaria brown spot [A. *alternaria* (Fr.:Fr.) Keissl.] of citrus This study evaluated eight different fungicides as follows: mancozeb; difenoconazole; iprodione; pyraclostrobin; famoxadone; copper oxychloride; copper oxychloride; copper hydroxide; Bordeaux mixture; and copper oxide. Of the fungicides evaluated, iprodione, mancozeb, and pyraclostrobin are commonly used on turf. Rain was simulated at levels of 0, 30, 60, and 90 mm (0, 1.2, 2.4, and 3.5 in) 24 h after fungicide application to leaf tissue. Results showed that only iprodione and mancozeb provided a negative linear relationship between disease control and the amount of artificial rain applied. Although iprodione and mancozeb were the only two of eight fungicides that provided a negative relationship, the difference in the level of disease control among fungicides was relatively small. The predicted disease control of the two aforementioned fungicides in response to the maximum rainfall level tested, however, was very high (i.e., 79% and 87% for iprodione and mancozeb, respectively).

The effect of rainfall duration and intensity on the persistence of chlorothalonil was evaluated on tomato (*Lycopersicon esculentum* Mill.) foliage by Fife and Nokes (2002). In this laboratory study, chlorothalonil was applied to the tomato canopy until runoff and no pathogen was involved. The foliage then was subjected to simulated rainfall after the fungicide had dried on plant surfaces, which was approximately five hours. During the first evaluation of rainfall intensity levels and duration periods the following treatments were assessed: rainfall intensity levels of 13, 25, 51, and 76 mm h^{-1} (0.5, 1.0, 2.0, and 3.0 in h^{-1}) and rainfall duration periods of 10, 20 and 30 minutes. The second evaluation period had two rainfall intensity levels of 13 and 25 mm $^{-1}$ (0.5 and 1.0 in h^{-1}) and five different rainfall duration periods of 10, 20, 30, 68, and 150 minutes. Chlorothalonil residues then were quantified by a bioassay. The residues remaining after receiving rainfall at an intensity level of 13 mm h^{-1} (0.5 in h^{-1}) were significantly higher than the other three rainfall intensity levels (i.e., 25, 51, and 76 mm h^{-1}; 1.0, 2.0, and 3.0 in h^{-1}). The residue levels associated with the three highest intensity levels were not significantly different from one another. It also was determined that tomato foliage subjected to 10 minutes of rainfall had significantly higher chlorothalonil residues on leaf surfaces than plants receiving rainfall for a duration of 20 minutes or more. Furthermore, data from all periods of rainfall 20 minutes or longer were statistically similar, when measuring residues on plant foliage. Fife and Nokes (2002) concluded that most of the chlorothalonil was displaced with a small amount of rain, but the chlorothalonil that is not initially washed off was very difficult to remove by rain. The authors hypothesized that the chlorothalonil remaining after initial displacement was held within the leaf matrix and thus was not easily removed by rainfall, regardless of intensity or duration.

The efficacy of fungicides when subjected to rainfall on potato (*Solanum tuberosum* L.) to control potato late blight (*Phytophthora infestans* (Mont.) de Bary) was evaluated by Schepers (1996). Potted potato plants were sprayed with fluazinam and maneb + fentinacetate. Both fungicide treatments were subjected to two different rainfall intensities delivering 8 mm h^{-1} (i.e., low intensity) and 38 mm h^{-1} (i.e., high intensity) of water. Rainfall was simulated either four hours or four days after fungicide application. In the first year of this laboratory study, fungicides were applied a total of six times and rainfall was simulated four times. Each plant was treated with fungicides on each application date, but not all plants were subjected to simulated rainfall on each date. Furthermore, each individual simulation of rainfall was treated as an individual experiment. In the second year of the laboratory study, all plants were sprayed only once before rainfall treatments were imposed. Field trials also were conducted with both fungicides and leaf samples were taken prior to the next fungicide application to determine the amount of wash-off that occurred. Fungicide residues were measured by inoculating leaf samples with *P. infestans* and counting the number of infections. In the first year of the laboratory study, when fluazinam was subjected to rainfall four hours after application, approximately the same or fewer infected leaflets were observed versus the control. Furthermore, in one instance when fluazinam was subjected to low intensity rainfall four hours after application, treated leaflets had significantly lower numbers of infections than the control. This presumably was due to the redistribution of the fungicide on the leaflets. Conversely, plants treated with maneb + fentinacetate generally had more infections than untreated plants, especially after a high intensity rainfall. In the second year of the laboratory study, fluazinam was found to be relatively rain-safe. Maneb + fentinacetate, however, was found to have retained significantly less residue when subjected to both low and high intensity rainfall compared to fluazinam. In both years, fungicide wash-off was not detected for either fungicide when subjected to rainfall four days after application. In field trials, wash-off only was observed when rain fell on the same day as fungicide application. When this occurred, maneb + fentinacetate again was found not to be rain-safe and fluazinam was. In general, high intensity rainfall was more likely to result in fungicide wash-off versus low intensity rainfalls.

Elliott and Spurr (1993) evaluated, among other factors, the influence of rainfall on chlorothalonil residues on peanut (*Arachis hypogaea* L.) foliage. Chlorothalonil was applied to peanut foliage in the field. Leaf samples were periodically taken for the duration of each spray trial. It was determined by the relationship between decay rate and rainfall that low levels (i.e., 0 to 7 cm; 0 to 2.8 in) of rainfall had a small effect on chlorothalonil wash-off; whereas, higher levels (i.e., 8 to 17 cm; 3.1 to 6.7 in) of rainfall had a disproportionately high effect on chlorothalonil wash-off.

A laboratory study determined that high intensity rainfall washed off more fungicide when compared to low intensity rainfall on pea (*Pisum sativum* L.) and potato plants (Kudsk et al., 1991). Two formulations of maneb and mancozeb were evaluated to determine their rain-safeness. Simulated rain was applied 24 hours after fungicide application at three rainfall intensities: low (3 mm h^{-1}; 0.1 in h^{-1}), medium (9 mm h^{-1}; 0.4 in h^{-1}), and high (27 mm h^{-1}; 1.1 in h^{-1}). Fungicide rain-safeness was determined by chemical analysis. Data showed that suspension concentrate formulations were more rain safe than wettable powder formulations. Potato cultivar also influenced the amount of fungicide that was washed off. The difference in formulation performance was attributed to particle size; that is, the smaller the particle sizes the more rain safe the fungicide appeared to be.

In a study involving the dynamics of chlorothalonil residues on potato foliage, rainfall affected displacement of chlorothalonil more than any other weather factor (Bruhn and Fay, 1982). In the aforementioned study, 1.0 cm (0.375 in) of simulated rainfall was applied three hours after chlorothalonil (emulsifiable concentrate) application, and 66% of the fungicide was displaced. When rainfall was applied one or seven days after the application, 55 and 36% of the chlorothalonil was displaced, respectively. Hence, Bruhn and Fry (1982) found that the resistance to chlorothalonil displacement from potato leaves increased as time between its application and simulated rainfall was increased.

Ko et al. (1975), determined the retention time of chlorothalonil and captafol in a field study. Leaf brown spot [*Alternaria alternaria* (Fries) Kessler] on passion fruit (*Passiflora edulis* f. *flavicarpa* Degener) were the target and host, respectively. Half-retention times were defined as the period during which half of a fungicide on the leaf was lost as determined by a spore germination test. Spore germination tests were conducted by harvesting leaves from passion fruit vines weekly and then inoculating them with *A. alternaria* spore suspensions. Germinated spores then were counted under a compound microscope. Half-retention times were determined after fruit was subjected to 8 cm (3.1 in) and 16 cm (6.3 in) of total rainfall during a 3-week test period. For captafol and chlorothalonil, the half-retention times were 3.0 and 2.6 days after application, respectively, when subjected to 8 cm (3.1 in.) of total rainfall. When fruit was subjected to 16 cm (6.3 in) of total rainfall the half-retention time decreased to 2.0 days for captafol and 1.2 days for chlorothalonil. Hence, half-retention times decreased when rainfall totals increased. However, the following important factors were not described: how intense was the rainfall; how soon after application did the rainfall occur; how often did the rainfall occur; and whether or not the two test periods were conducted at the same time. The aforementioned factors are important since they have been shown to influence the rain safeness of fungicides.

Neely (1971) found in the laboratory that the persistence of fungicides subjected to rainfall was directly correlated with deposition. The three pathogens that were used in the study were as follows: brown rot [*Monilinia fructicola* (Wint.) Honey]; Dutch elm disease [*Ophiostoma ulmi* (Brisman)Nannf. formerly *Ceratocystis ulmi* (Buism.) C. Moreau]; and Verticillum wilt [*Verticillium albo-atrum* Reinke and Berth.]. Propagules of each pathogens were suspended and seeded (i.e., inoculated) on leaf sections of three hosts: bush bean (*Phaseolus vulgaris* L.); cotton (*Gossypium hirsutum* L.); and soybean [*Glycine max* (L.) Merr.]. In this study, Neely (1971) evaluated 19 different fungicides, one of which was chlorothalonil. Fungicides were applied to two leaves of one plant and then allowed to dry for about 1.5 to 2.0 h. After drying, leaves were subjected to simulated rainfall. Fungicide efficacy was determined by a bioassay. The first trial evaluated simulated rainfall amounts of 0.0, 2.5, 5.0, and 7.5 cm (0.0, 1.0, 2.0, and 3.0 in.). After this trial, all fungicides that persisted after being subjected to 7.5 cm (3.0 in) of rainfall were placed into a second trial where the plants were exposed to rainfall amounts totaling 0.0, 5.0, 10.0, 15.0, 20.0, and 25.0 cm (0.0, 2.0, 3.9, 5.9, 7.9 and 9.8 in). The third trial consisted only of the fungicides that persisted after 25 cm (9.8 in) of simulated rainfall. These fungicides were subjected to rainfall totals of 0.0, 7.5, 15.0, 22.5, 30.0, 37.5, 45.0, 52.5, and 60 cm (0.0, 3.0, 5.9, 8.9, 11.8, 14.8, 17.7, 20.7, and 23.6 in). Among the 19 fungicides tested, six (dodine; ferbam; chlorothalonil; Bordeaux mixture; dithianon; and captafol) remained at levels high enough to suppress disease after the final and highest rainfall total of 60 cm (23.6 in). When the initial fungicide application amount was more than twice that needed for disease suppression a considerable amount of rainfall was required to wash-off the fungicide to levels in which it was unable to suppress disease. Furthermore, if the amount of fungicide applied were less than twice the amount needed for disease suppression, little rainfall was needed to remove fungicides to levels not suitable for disease control. Finally, it was determined that the fungicide deposited on leaf surfaces after a rainfall simulation was inversely correlated with pubescence of leaf surfaces.

Turner et al. (1964) conducted a laboratory study to determine the tenacity of three fungicides applied to tomato foliage. Fungicides were applied to foliage and allowed to dry. After drying, plants were exposed to a rainfall simulator until they received a total of 2.54 cm (1 in) of water. Disease control then was determined by counting early blight (*A. solani*) lesions and comparing them to the control. They found that 50% of chlorothalonil, 70% of maneb, and 90 % of captan were removed from the surface after the simulated rain.

In contrast to previously discussed studies, Lukens and Ou (1976) found that the effect of rain on chlorothalonil, when protecting against early blight [*Alternaria solani* (Ell. and G. Martin) L.R. Jones and Growth.], on field grown tomatoes could not be identified as a factor that contributed to fungicide loss. The amount of chlorothalonil residue remaining on leaf tissue was measured by chemical analysis. Disease protection accorded by chlorothalonil was determined by a bioassay. They made their conclusion based on the linear relationship between loss of residue on leaf tissue and fungicide protection against time. This study did not simulate rainfall and no rainfall data were given. Therefore, the following important factors are unknown: the total amount of rainfall, how long after fungicide application, and how intense rainfall was during this study. Similarly, in a field study reported by Neely (1970), it was found that leaf pubescence, and not rain, was the primary factor in the loss of fungicides on woody plant species. The fungicides evaluated in that study were as follows: captan; dichlone; dodine; ferbam; folpet; maneb; thiram; ziram and mixtures of thiram and maneb. Fungicide-treated leaves were assayed for the presence of the 14 fungicides for the following 12 species: ash (*Fraxinus pennsylvanica* Marsh.); catalpa (*Catalpa speciosa* Warder); dogwood (*Cornus alba* L.); euonymus (*Euonymus fortunei* [Turcz.] Hand.-Maz.); hackberry (*Celtis occidentalis* L.); maple (*Acer saccharum* Marsh.); oak (*Quercus rubra* L.); redbud (*Cercis Canadensis* L.); sycamore (*Platanus occedentalis* L.); tulip tree (*Liriodendron tulipifera* L.); viburnum (*Viburnum carlesii* Hemsl.); and willow (*Salix discolor* Muhl.). Neely (1970) did not simulate rainfall, but instead recorded precipitation amounts and the number of days with precipitation. Little information was reported on the intensity of rainfall and time between fungicide application and a rainfall event.

Carroll et al. (2001) measured the residence time in the field of three formulations of chlorothalonil on creeping bentgrass (*Agrostis stolonifera* L.) foliage after a simulated rainfall event. Flowable and water dispersible granule (both applied at 9.2 kg a.i. ha^{-1}) and granular (10 kg a.i. ha^{-1}) chlorothalonil formulations were evaluated. Flowable and water dispersible granules were applied using a sprayer. The granular formulation was distributed by shaker bottle and immediately watered-in with 3 mm of water. Simulated rainfall events, which delivered 32 mm (1.2 in) of water in 40 minutes, were applied 1, 8, 24, and 72 h after chlorothalonil application. Turf was allowed to dry for one hour before clippings were harvested and residence time was measured. There were no wash-off differences among formulations for any residence time. However, there were differences in the level of chlorothalonil displacement at different simulated rainfall times. They found that 35% of chlorothalonil was displaced from creeping bentgrass foliage when turf was subjected to a rainfall event one hour after the fungicide was applied. Simulated rain imposed 8, 24, and 72 hours resulted in 10 to 15% of the chlorothalonil being displaced. The findings of Carroll et al. (2001) were similar to that reported by Bruhn and Fay (1982), who evaluated the loss of chlorothalonil on potato foliage when subjected to simulated rainfall. Furthermore, Schepers (1996) also reported that the greatest loss of fungicide residue on potato foliage occurred when plants were subjected to the shortest interval between fungicide application and rainfall simulation. Conversely, Lukens and Ou (1976) found that chlorothalonil losses from tomato foliage were not influenced by rainfall

In another field study reported by Carroll et al. (1993), chlorothalonil (flowable formulation) was applied to Kentucky bluegrass (*Poa pratensis* L.) and subjected to simulated rain 18 to 30 hours later. Plots were subjected to six different simulated rainfall durations (5, 10, 15, 30, 60, or 90) minutes and two different rainfall intensities of approximately 18.6 mm h^{-1} (0.7 in h^{-1}) and 39.9 mm h^{-1} (1.6 in h^{-1}). Although not significantly different, there was a trend suggesting that increased rainfall intensities would increase the amount of chlorothalonil that was displaced from plant surfaces. Similarly, Fife and Nokes (2002), Schepers (1996), and Kudsk et al. (1991) concluded that an increase in rainfall intensity would increase the amount of fungicide washed-off leaf tissue.

Mowing, even within the recommended height range, can have a negative effect on turfgrasses. Mowing causes a reduction in the amount of carbohydrates that are produced for growth and development, and reduces the amount of photosynthetic leaf area. For example, Davis and Dernoeden (1991) found that stem tissue collected from Kentucky bluegrass mowed to a height of 3.8 cm contained lower total nonstructural carbohydrates (TNC) levels than plants mowed to a height of 7.6 cm. Howieson and Christians (2008) reported that mowing caused a transient reduction in leaf sugar levels in creeping bentgrass. Conversely, Narra et al. (2004) reported that TNC levels were higher in creeping bentgrass mowed to a height of 0.64 cm compared to 1.27 or 1.90 cm. They explained these unexpected findings by suggesting that more sheath and stem tissues may have been inadvertently collected at the lower mowing height. Low mowing heights that are used on most golf course fairways also can limit root production and decrease root length and depth (Beard and Daniel, 1965; Liu and Huang, 2002). These negative mowing effects can intensify the stress level of turf and indirectly may increase plant susceptibility to disease. To mitigate this problem, fungicides often are applied to golf course turfs to help maintain plant health, while ensuring quality playing conditions.

The presence of canopy dew is known to increase disease severity in turfgrasses. Disease generally is promoted when leaf wetness duration is prolonged and by the presence of nutrients in guttation fluids. Guttation fluids contain various nutrients, including amino acids, sugars and other carbohydrates, which can enhance pathogen growth and their ability to penetrate tissue (Curtis, 1944; Goatley and Lewis, 1965; Healy and Britton, 1967; Marion, 1974). Dew on the plant surface also assists the pathogen in adhering itself to the plant surface, which further helps the pathogen to resist displacement by flowing water (Agrios, 2005). Furthermore, the presence of dew aids in hyphal growth by providing a source of free water and in maintaining fungal turgidity (Jackson and Howard, 1966). The displacement of dew by mowing or poling in the morning has been shown to decrease the severity of dollar spot (Williams et al., 1996; Ellram et al., 2007). Williams et al. (1996) reported that displacement of dew by mowing or poling at 0800 h on fairway height creeping bentgrass reduced the number of *S. homoeocarpa* infection centers 66 to 81% on selected rating dates, when compared to plots mowed only at 1300 h. Disease pressure at the site was high and *S. homoeocarpa* IC's totals were as high as 115 plot^{-1}. Ellram et al. (2007) studied the effects of the time of day that dew was displaced on the severity of dollar spot, and also evaluated different methods of dew displacement. The disease pressure at the site was low and in the range of 0.6 to 8.7% of plot area blighted. They found that plots that had dew displaced at 0400 h had about 40% less dollar spot, when compared to plots subject to dew removal at 1000 h and about 15% less disease when dew was displaced at 2200 h. They also found that plots in which dew was displaced at 2200 h had about 20% less dollar spot compared to plots subject to dew removal at 1000 h. Finally, mowing to displace dew was shown to be more effective than squeeging for dollar spot suppression.

We are unaware of any studies that have evaluated the impact of simulated or natural rainfall and/or mowing timing on the performance of fungicides used to target a turfgrass disease. Therefore, the objectives of this study were: (1) to determine the level of dollar spot control provided by chemically diverse fungicides applied approximately 30 minutes prior to a simulated rain event; and (2) to determine if AM mowing to displace dew prior to fungicide application would impact fungicide performance compared to mowing a dry canopy in the PM.

Materials and Methods

This field 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 g of organic matter kg^{-1} soil. A 50:50 v/v blend of 'Crenshaw' and 'Backspin' creeping bentgrass was established in September 2006 in eight, 3.1 m x 12.2 m (10 ft x 40 ft) independently irrigated blocks. Each block was outfitted with pop-up, matched precipitation spray irrigation heads (Weathermatic Model 5520; Weathermatic Irrigation Company; Dallas, TX). Since it has been shown that a turfgrass irrigation system can be employed to effectively simulate rainfall (Bell and Koh, 2008), the term simulated rain will be used to describe these treatments. In 2007 and 2008, the irrigation system was calibrated by placing 18 cans in each block and adjusting the irrigation heads as needed to ensure uniform water delivery. The range in the amount of water delivered to each block was determined to be 2.54 to 3.18 cm (1.0 to 1.25 in) after 8 minutes. Four plots received the equivalent of approximately 2.54 to 3.18 cm (1 to 1.25 in) of water in an 8 minute period within 30 to 35 minutes of fungicide application, which simulated a natural rainfall event. In a 2006 pilot study, few differences in dollar spot control were detected among fungicides using 0.64 cm of simulated rain 60 minutes after fungicide application. Hence, the amount of simulated rain was increased to 2.54 cm and duration between fungicide application and simulated rainfall was reduced to 30 minutes in the current study. The other four plots were not irrigated for several days or until there were visual signs of wilt. In 2007, the following fungicides and rates were assessed: chlorothalonil (tetrachloroisophthalonitrile; Daconil Ultrex 87.5 DG; Syngenta Crop Protection, Inc., Greensboro, NC.) applied at 8.1 kg a.i. ha^{-1} (3.2 oz prod 1000 ft^2); propiconazole [(1-(2-(2',4'-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl-methyl)-1H-1,2,4-triazole; Banner MAXX 1.3 ME; Syngenta Crop Protection, Inc., Greensboro, NC] applied at 0.5 kg a.i. ha^{-1} (1.0 fl oz prod 1000 ft^2); iprodione [3-(3,5-dichlorophenyl)-N-(1-methylethyl)-2, 4-dioxo-1-imidazolidinecarboxamide; Chipco 26GT 2SC; Bayer Environmental Sciences, Research Triangle Park, NC] applied at 3.1 kg a.i. ha^{-1} (4.0 fl oz prod 1000 ft^2); boscalid [3-pyridinecarboxamide, 2-chloro-N-(4'-chloro(1,1'-biphenyl)-2-yl]; Emerald; BASF Corporation, Research Triangle Park, NC] applied at 0.28 kg a.i. ha^{-1} (0.13 oz prod 1000 ft^2); and thiophanate methyl [dimethyl 4,4'-o-phenylenebis(3-thioallophanate); 3336 Plus 4F; Cleary Chemical Corporation, Dayton, NJ] applied at 2.47 kg a.i. ha^{-1} (4.0 fl oz prod 1000 ft^2). In 2008, thiophanate-methyl was eliminated as a treatment since it was found that isolates of *S. homoeocarpa* obtained from the study site were resistant to this fungicide in 2007. To take its place, a tank-mix combination of chlorothalonil (8.1 kg a.i. ha^{-1}; 3.2 oz prod 1000 ft^2) and propiconazole (0.5 kg a.i. ha^{-1}; 1.0 fl oz prod 1000 ft^2) was assessed in 2008. In 2008, the simulated rainfall plots and mowing treatments were reversed in all blocks. Furthermore, the fungicide treatments were re-randomized to minimize the potential influence of fungicide effects and inoculum levels from the previous year. In both years, sub-plots were 1.5 m x 3.1 m (5 ft x 10 ft) and consisted of the five fungicide treatments and one untreated control. Sub-plots were split into two sub-sub plots (wet AM vs. dry PM mowing), which were 1.5 m x 1.5 m (5 ft x 5 ft). One set of sub-sub plots was mowed and clippings removed prior to each fungicide application at about 0700 h when the canopy was wet. These AM plots always were mowed in the morning throughout the remainder of the study (i.e., wet mowing; AM). The other sub-sub plots were mowed the day following each fungicide application after the canopy was dry (i.e., dry mowing; PM). Thereafter, the PM-mowed sub-sub plots always were mowed after the canopy had dried (typically after 1200 h). Plots were mowed three times a week to a height of 12.0 mm (0.5 in) and clippings were removed. All fungicides were applied in 468 liters of water ha^{-1} (50 gal A^{-1}) using a CO_2 pressurized backpack sprayer (262 kPa; 35 psi) equipped with one 8004E Tee Jet flat fan nozzle; (Tee Jet Technologies, Wheaton, IL). Prior to fungicide application the amount of canopy dew present was measured using the blotting technique described by Williams et al. (1998). Briefly, two Kim Wipe tissues (Kimberly-Clark, Rosewell, GA) were placed into a bag and weighed. After weighing, tissues were taken out of the bag and blotted over a 100 cm^2 area of the turfgrass canopy. Blotting was performed to ensure that only dew in the canopy, and not in thatch, was absorbed. The tissues then were placed back into the bag and reweighed. The gain in weight was used to calculate the amount of dew present on the canopy. Data were converted to millimeters moisture (i.e., dew) from grams 100 cm^{-2} and then were converted into L ha^{-1} (Figure 1).

In 2007 and 2008, the application of treatments was performed between 0730 and 0800 h by two people and completed in about nine to ten minutes. In 2007, all fungicides initially were applied on 3 July, when dollar spot was active but disease pressure was low (< 5 IC's). In 2008, all fungicides initially were applied on 7 August when dollar spot was active, but disease pressure overall was not as high as experienced in 2007. In both years, four simulated rain plots received approximately 2.54 cm (1.0 in) of water, 30 minutes following the last fungicide application. Hence, the first treatments applied would have had about 40 minutes drying time and the last treatment about 30 minutes drying time. Since the canopy remained moist in AM mowed plots by the time the last treatment was applied it is not likely that any chemical had fully dried on foliage for any one treatment prior to being subjected to simulated rain.

Dollar spot was assessed by counting the number of *S. homoeocarpa* infection centers $plot^{-1}$ (IC's). A reapplication threshold of 20 IC's was chosen to ensure that creeping bentgrass did not sustain severe damage and that more rapid recovery would occur after reapplication. A fungicide was reapplied when the average number of IC's exceeded 20 in two of four replicates of each fungicide within a rain (i.e., simulated and rain-free) treatment in 2007. When the threshold was reached, which occurred first in simulated rain plots, all simulated and rain-free plots within each fungicide treatment were retreated. In 2008, a chemical was not reapplied until all four replicates of each fungicide within a rain treatment had exceeded the 20 IC threshold.

The threshold was changed in 2008 in an attempt to obtain better differences among rainfall and mowing timing treatments. The reapplication dates in 2007 for each fungicide were as follows: thiophanate-methyl on 24 July and 7 August; chlorothalonil on 26 July and 10 August; and boscalid, iprodione, and propiconazole on 31 July. In 2008, chlorothalonil was reapplied on 5 and 11 September; iprodione was reapplied on 13 September; propiconazole and the tank-mix of chlorothalonil + propiconazole were reapplied on 16 September. Boscalid was applied only once in 2008.

There generally are two dollar spot epidemics in a season in the northern USA; one in early summer and one in late summer (Powell and Vargas, 2001). It is not unusual for dollar spot symptoms to subside following the early summer epidemics in May and June and turf often recovers prior to the second, late summer epidemic. Sustained and severe dollar spot epidemics, however, are common in mid-to-late summer in Maryland (Dernoeden and Kaminski, 2000; Bigelow et al., 2002; McDonald et al. 2006). To avoid fluctuations in dollar spot activity, the study area was kept dollar spot- free during early summer epidemics in both years. Hence, treatments were not imposed until 3 July 2007 and 7 August 2008, when sustained and severe dollar spot pressure was most likely. To maintain healthy turf during the early summer epidemic period, the study site was treated on 1 June 2007 with chlorothalonil applied at 7.6 kg a.i. ha^{-1} (3.0 oz prod 1000 ft^2)]. Following data collection in August 2007, the study areas again were treated with fungicides to enhance turf recovery as follows: 30 August [chlorothalonil at 8.1 kg a.i. ha^{-1} (3.2 oz prod 1000 ft^2) tank-mixed with propiconazole at 0.5 kg a.i. ha^{-1} (1.0 fl oz prod 1000 ft^2), plus boscalid at 0.39 kg a.i. ha^{-1} (0.18 oz prod 1000 ft^2)]; 30 September {chlorothalonil at 8.9 kg a.i. ha^{-1} [3.5 oz prod 1000 ft^2] plus propiconazole at 0.25 kg a.i. ha^{-1} [0.5 fl oz prod 1000 ft^{-2}], and 17 October [chlorothalonil at 8.9 kg a.i. ha^{-1} (3.5 oz prod 1000 ft^2) plus propiconazole at 0.5 kg a.i. ha^{-1} (1.0 fl oz prod 1000 ft^2)] In 2008 the following fungicide rates and dates of application were: 23 May {chlorothalonil at 8.1 kg a.i. ha^{-1} [3.2 oz prod 1000 ft^2] plus boscalid at 0.39 kg a.i. ha^{-1} [0.18 oz prod 1000 ft^2] plus vinclozolin ([3-(3, 5-dichlorophenyl)-5-ethenyl-5-methyl-2, 4-oxazolidinedione]; Curalan (BASF Corporation, Research Triangle Park, NC)) at 3.2 kg a.i. ha^{-1} [2.0 fl oz prod 1000 ft^2]}; and 20 June [chlorothalonil at 5.1 kg a.i. ha^{-1} (2.0 oz prod 1000 ft^2) plus propiconazole at 0.5 kg a.i. ha^{-1} (1.0 fl oz prod 1000 ft^2)].

As previously described, treatments were arranged in a randomized complete block split-split plot design with four replications. Disease data were tested for normality using the SAS Plot procedure (SAS version 9.1, SAS Institute; Cary, NC). Disease data were square-root transformed to correct for normality, but actual means are shown in data tables and figures. In 2008, one replicate of selected treatments was eliminated from the analysis because of disproportionately high or low disease levels compared to the other three replicates. The deletion of a single replicate in 2008 was performed for the following treatments: chlorothalonil simulated rain plus AM mowing the deleted replicate had on average 31.4 IC’s compared to 8.2 IC’s on average in the other three replicates; chlorothalonil rain-free PM-mowing the deleted replicate had on average 29.8 IC’s compared to 0.7 IC’s on average in the other three replicates; propiconazole simulated rain and AM mowing the deleted replicate had on average 18.4 IC's compared to 3.9 IC's; propiconazole rain-free and AM mowing the deleted replicate had on average 7.8 IC's compared to 0.7 IC's; iprodione simulated rainfall and AM mowing the deleted replicate had on average 11.2 IC's compared to 1.7 IC's for the other three replicates; iprodione simulated rainfall and PM mowing the deleted replicate had on average 0.8 IC's compared to 16.6 IC's; iprodione rain-free and PM mowing the deleted replicate had on average 14.9 IC's compared to 1.3 IC's for the other three replicates; boscalid simulated rain and AM mowing the deleted replicate had on average 8.3 IC's compared to 0.4 IC's on average in the other three replicates; boscalid simulated rain PM mowing replicate had on average 30.1 IC's compared to 6.8 IC's; tank-mix simulated rainfall AM mowing the deleted replicate had on average 13.9 IC's compared to 1.7 IC's for the other three replicates; and tank-mix rain-free PM mowing the deleted replicate had on average 0.2 IC's compared to 10.6 IC's for the other three treatments Disease data were examined for normality using the SAS Plot procedure (SAS version 9.1, SAS Institute; Cary, NC). Disease data were square-root transformed to satisfy the assumption that the data were normally distributed prior to conducting a three-way analysis of variance (ANOVA). Significantly different means were separated by Fisher's protected least significant difference test at $P \leq 0.05$ using the SAS Mixed procedure. Pre-planned orthogonal contrasts were used to examine the effects of simulated rain versus rain-free and AM versus PM mowing treatments on fungicide performance.

Results

Simulated Rain versus Rain-Free 2007

Orthogonal contrasts were used to compare the simple effects between simulated rain and mowing treatments for each fungicide. Little or no dollar spot control was provided by thiophanate-methyl. It was determined *in-vitro* by a fungicide-amended potato dextrose agar study that isolates from the site obtained in September 2007 were resistant to thiophanate-methyl (G. Olaya, personal communication; Syngenta Crop Protection Laboratory, Vero Beach, FL). Hence, thiophanate-methyl data as well as data from the untreated control (hereafter control or untreated plots) were eliminated from the analyses and will not be discussed. Data from the untreated control were eliminated from the analyses because no fungicide was applied and thus no differences between rain and rain-free plots would occur. It also was determined that isolates exhibited some loss in sensitivity to propiconazole, which may have impacted results.

All treatments initially were applied on 3 July, and were reapplied when dollar spot reached the threshold level (i.e., > 20 IC's in two of four replicates for each fungicide treatment). Dollar spot was evaluated initially on 9 July and data collection ceased on 25 August. Data in Appendix I Table 1 show analysis of variance (ANOVA) for main effects and interactions. Data in Appendix I Table 2 show pre-planned orthogonal contrasts for the four fungicide treatments contrasted against the two rain treatments. There were no rain x mowing or rain x mowing x chemical interactions in 2007 (Appendix I Table 1). There was one rating date (20 July) when there was a significant rain x chemical interaction. Most interactions occurred after 3 August for mowing x chemical and rain x chemical interactions, but only pre-planned contrasts will be discussed.

There were significantly more IC's in chlorothalonil-treated plots subjected to simulated rain compared to rain-free plots on 12 of 19 rating dates. Chlorothalonil-treated plots subject to simulated rain exceeded the threshold 20 days after the initial application and plots had an average of 20.9, 24.6, and 31.3 IC's on 23, 25, and 27 July, respectively (Figure 2; Appendix I Table 3). Chlorothalonil-treated plots subjected to simulated rain appeared to lose effectiveness following the initial application about three days earlier than rain-free plots. There were more IC's in simulated rain versus rain-free plots between 18 and 26 July. Chlorothalonil was reapplied on 26 July, but blighting increased for 24 h and then the number of IC's dropped below the threshold in plots subjected to simulated rain by 1 August. Plots subjected to simulated rain only exhibited suppressed dollar spot for about six days following the second application, and exceeded the threshold again on 3 August. Chlorothalonil-treated plots subjected to simulated rain had more IC's (21.1, 26.4, and 33.3) than rain-free (3.6, 6.5, and 7.1) plots on 3, 8, and 9 August, respectively. Dollar spot levels fell dramatically in simulated rain plots following the third chlorothalonil application (i.e., 10 August) to very low levels by 15 August. Five days later on 20 August, plots subjected to simulated rain again exhibited reduced effectiveness. Dollar spot levels above the threshold were apparent in chlorothalonil-treated plots subjected to simulated rain 13 days following the third application (i.e., 23 August; 28.0 IC's) and remained above the threshold until the final rating date. Dollar spot levels were greater in simulated versus rain-free plots on 20 and 23

August. Rain-free plots treated with chlorothalonil showed their greatest loss of effectiveness a day after the second application on 27 July, but dollar spot levels were always below the threshold. Chlorothalonil-treated plots subjected to simulated rain had dollar spot levels that exceeded the threshold on six dates between 18 July and 12 August; whereas, rain-free plots had dollar spot levels below the threshold on all dates.

There were three rating dates on which simulated rain had reduced the effectiveness of propiconazole (15, 23, and 25 August). Propiconazole-treated plots, regardless of rain treatment, began to clearly show a reduced level of effectiveness nine days (i.e., 18 July) following the initial application (i.e., 3 July; Figure 3; Appendix I Table 4). Following the first application of propiconazole, however, neither simulated rain nor rain-free plots had reached the threshold. There were no significant differences between simulated and rain- free plots for between 3 and 31 July. Following the second propiconazole application on 31 July, blight ratings continued to increase for three days before declining below the threshold on 6 August. Reduced effectiveness was observed 15 days (i.e., 15 August) later in propiconazole-treated plots subjected to simulated rain as well as rain-free plots. Data in Figure 3 show that dollar spot levels in simulated rain plots treated with propiconazole exceeded the threshold on 1, 3, 23, and 25 August; whereas, in rain-free plots the threshold was reached on 3 and 25 August. Dollar spot levels were significantly lower in rain-free vs. simulated rain plots treated with propiconazole on 15, 23, and 25 August.

There were four rating dates in which rain had reduced the effectiveness of boscalid (9, 13, 16, and 18 July). Boscalid-treated plots subjected to simulated rain exhibited a reduction in effectiveness ten days (i.e., 13 July) after initial application (i.e., 3 July); whereas; rain-free plots began to lose effectiveness about ten days (i.e., 23 July) later. There were more IC's in simulated rain versus rain-free plots on 13, 16, and 18 July, but the differences were small. Boscalid was reapplied on 31 July and blighting increased for about three days before subsiding on 6 August in plots subjected to simulated rain. The time lag between the second application and a decline in blighting, however, was only about one day in rain-free plots. Boscalid-treated plots subjected to simulated rain had 19.6 IC's on 1 August and exceeded the threshold by 3 August (Figure 4; Appendix I Table 5). Following the second boscalid application (i.e., 31 July), plots subjected to simulated rain did not begin to show an increase in dollar spot until 20 August, or 20 days following the application. Data in Figure 4 show that dollar spot levels were numerically higher in simulated rain versus rain-free plots between 18 and 25 July, and on 23 and 25 August. Boscalid-treated plots subjected to simulated rain reached threshold levels on 3 August, but the difference between rain treatments was not significant on any date following the second application. There were four dates in July (i.e., 9, 13, 16, and 18 July), when dollar spot levels were significantly higher in simulated rain versus rain-free plots, but there were no significant differences thereafter. Dollar spot resurgence (i.e., a rapid increase in blighting) occurred in boscalid-treated plots by late August.

There were only two rating dates in which rain had reduced the effectiveness of iprodione (20 and 23 August). Iprodione-treated plots, regardless of rain treatment, began to show a loss of effectiveness 20 days after the initial application (i.e., 23 July). The threshold, however, was not exceeded in either rain treatment before the fungicide was reapplied (Figure 5; Appendix I Table 6). Like chlorothalonil, blighting only increased for about one day following the second iprodione application. There were no significant rain treatment differences between 3 and 30 July. Twenty days following the second iprodione application, simulated rain and rain-free plots exhibited a loss in effectiveness (i.e., 20 August). Only plots subjected to simulated rain, however, had dollar spot levels at the threshold (20.9 IC's) on 20 August. On 23 and 25 August, plots subjected to simulated rain had greater number of IC's (44.8 and 54.8) compared to rain-free plots (28.1 and 43.0 IC's). Hence, 23 and 25 August were the only dates when significant differences between rain treatments were observed.

Simulated Rain versus Rain-Free 2008

Thiophanate-methyl was replaced with a tank-mix of chlorothalonil + propiconazole in 2008. Otherwise, all treatments were the same as in 2007. All treatments were applied initially on 7 August 2008 and reapplied when dollar spot exceeded threshold levels in all four plots for each individual fungicide within a rain treatment. An exception was boscalid, which was applied only one time in 2008. As previously noted, dollar spot was slower to develop and was less severe than was observed in 2007. Dollar spot was evaluated initially on 8 August and data collection ceased on 22 September. Data in Appendix I Table 7 show ANOVA's for main effects and interactions. Data in Appendix I Table 8 show pre-planned orthogonal contrasts for the four fungicide treatments contrasted against the two rain treatments. There were no significant differences among the following interactions in 2008: rain x mowing (except 27 August); mowing x chemical; or rain x mowing x chemical (except 27 August).There were significant rain x chemical interactions on 11 of 18 rating dates, but only pre-planned contrasts will be discussed. Initially, data collection was made a little confusing due to the presence of some dollar spot at the time treatments were applied.

Chlorothalonil effectiveness was less in simulated rain versus rain-free plots on nearly all rating dates. Chlorothalonil-treated plots subjected to simulated rain began to lose effectiveness on 18 August and exceeded the threshold on 2 September, (i.e., 26 days after initial treatment; Figure 2). Dollar spot levels in chlorothalonil-treated plots subjected to simulated rain (30.6 IC's) exceeded threshold levels on 4 September (Figure 2; Appendix I Table 9). In contrast, chlorothalonil-treated rain-free plots did not lose effectiveness until 2 September and disease levels in rain-free plots did not exceed the threshold prior to its second application. Chlorothalonil was reapplied on 5 September, and there was little change in disease levels by 8 September. Following the second application of chlorothalonil, dollar spot levels fell slightly, but remained above the threshold in simulated rain plots between 5 and 11 September. Dollar spot levels were below the threshold in rain-free plots on all rating dates before the third application of chlorothalonil. Chlorothalonil was applied for a third time when dollar spot levels began to increase in simulated rainfall plots on 11 September (Figure 2; Appendix I Table 9). The number of IC's remained above the threshold in simulated rain plots until data collection ceased on 22 September. Hence, the two curative applications of chlorothalonil had little effect on reducing dollar spot in simulated rain plots. Rain-free plots treated with chlorothalonil, however, did not exceed the threshold and had less than 2 IC’s between 15 and 22 September. Unlike 2007, dollar spot was almost completely controlled by chlorothalonil in rain-free plots.

Following the initial application of propiconazole, residual effectiveness began to decline about 25 (i.e., 30 August) and 35 days (i.e., 12 September) in simulated rain versus rain-free plots, respectively (Figure 3). Propiconazole-treated plots subjected to simulated rain initially exceeded the threshold on 15 September (31.0 IC’s; Figure 3; Appendix I Table 10). During this period, rain-free plots treated with propiconazole did not exceed the threshold. Prior to the second propiconazole application, there was less dollar spot in rain-free versus simulated rain plots on 12 and 15 September. There were fewer IC’s in rain-free compared to simulated rain plots on all dates after the second propiconazole application. Following the second propiconazole application (i.e., 16 September), plots subjected to simulated rain remained above the threshold (23 to 36 IC’s) on 17, 19, and 22 September. The number of IC’s in simulated rain plots peaked on 17 September and declined thereafter. In contrast, rain-free, propiconazole-treated plots did not exceed the threshold up to the time data collection ceased. On the last four rating dates, dollar spot levels were higher in simulated versus rain-free plots.

There were no significant differences between rain treatments on any date in boscalid-treated plots. Following the initial application of boscalid, simulated rain and rain-free plots exhibited a reduction in effectiveness about 8 (i.e., 15 August) and 23 days (i.e., 30 August) later, respectively (Figure 4). The threshold was not exceeded in either rain-free or simulated rain plots at any time and the fungicide was not reapplied (Figure 4; Appendix I Table 11).

There was only one significant rating date difference between rain treatments in iprodione-treated plots in 2008. Iprodione-treated plots subjected to simulated rain versus rain-free exhibited a reduction in effectiveness about 23 (i.e., 30 August) and 34 days (i.e., 10 September) after the initial application, respectively (Figure 5). Only plots subjected to simulated rain, however, had dollar spot levels above the threshold (about 31.0 IC's) on 10 and 12 September (Figure 5 Appendix I Table 12). September 12 was the only date on which there were significantly more IC's in simulated rain compared to rain-free plots. Following the second iprodione application (i.e., 13 September), all plots exhibited a gradual decline in IC's until the last rating date (i.e., 22 September). During this decline, the number of IC's in iprodione-treated plots subjected to simulated rain was above the threshold on 15 September (i.e., 22.2 IC's). Between the second application of iprodione and the cessation of data collection, rain-free plots had an average of only 4.0 IC's on 15 September.

The chlorothalonil + propiconazole tank-mix applied to rain-free plots began to lose effectiveness on 8 September (Figure 6; Appendix I Table 13). Conversely, the tank-mix applied to simulated rain plots lost effectiveness 9 days earlier (i.e., 30 August). Except on the first two rating dates, there were no dates when significant differences in IC number were observed between the two rain treatments in 2008. Unlike at any other time in either year, the number of IC's exceeded the threshold in rain-free plots treated with the tank-mix on 15 September (26.2 IC's); whereas; plots subjected to simulated rainfall did not. Following the second application of the tank-mix (i.e., 16 September), plots subjected to simulated rainfall continued to have fewer IC's than rain-free plots, but the difference was not significant. Plots treated with chlorothalonil + propiconazole and subjected to simulated rainfall exceeded the threshold once on 17 September (21.9 IC's). Rain-free plots exceeded the threshold between 15 and 22 September, however, there were no dates when IC differences were statistically significant between rain treatments.

AM versus PM Mowing 2007

Data in Appendix I Table 14 show pre-planned orthogonal contrasts for the four fungicide treatments contrasted against the two mowing timings. Appendix I Tables 15 to 18 and Figures 7, 8, 9, and 10 show actual disease data for all rating dates. Data in Figure 13 show the dollar spot levels in non fungicide-treated plots subjected to AM versus PM mowing.

There were 53% fewer IC's in plots subjected to AM versus PM mowing when data were averaged over all 19 rating dates and treatments in 2007. The percent of dollar spot reduction in AM versus PM mowed plots for each fungicide and the control was as follows: chlorothalonil = 64%; propiconazole = 49%; boscalid = 61%; iprodione = 34%; and control = 26% (Figures 7, 8, 9, 10, and 12). Hence, AM mowing had a very significant impact on decreasing disease pressure.

There were significant contrast statement differences for the AM vs. PM mowing timings for all four fungicides. Except for boscalid on 9 and 11 July, more IC's were observed in plots subjected to PM (i.e., dry canopy) vs. AM mowing (i.e., wet canopy; (Figure 7, 8, 9, and 10). The AM mowed plots had significantly fewer IC's versus PM mowed plots on the following dates for each fungicide as follows:

chlorothalonil on 12 rating dates (18, 20, 23, 25, and 27 July; 3, 6, 8, 9, 13, 23, and 25 August); propiconazole on eight rating dates (20 July; 3, 6, 9, 13, 15, 23, and 25 August); and boscalid on eight rating dates (9, 11, 18, 20, and 23 July; 3, 6, 9, and 25 August). There were no significant timing differences for iprodione in 2007. On 9 and 11 July, boscalid -treated plots mowed in the PM had an average of 2.8 and1.0 IC vs. 1.0 and 0.0 IC's in AM mowed plots, respectively, which was a significant yet unimportant difference (Appendix I Table 17).

Plots treated with chlorothalonil and subjected to AM and PM mowing began to lose effectiveness 13 days following the initial application (i.e., 16 July; Figure 7; Appendix I Table 15). The PM-mowed plots had on average 22.0, 24.6, and 31.3 IC's on 23, 25, and 27 July, respectively. Hence, chlorothalonil-treated plots subjected to PM mowing were above the threshold as early as 23 July. Significant differences between mowing timings were first observed on 18 July and differences remained evident on most rating dates thereafter. Blighting increased for one day and subsided about five days following the second chlorothalonil application (i.e., 26 July). Dollar spot levels in plots subjected to PM mowing fell below the threshold on 1 August, increased slightly above the threshold on 3 August, and again exceeded the threshold on 8 August. Plots subjected to AM mowing, however, did not show reduced effectiveness until 13 days following the second chlorothalonil application on 8 August. Chlorothalonil-treated plots subjected to PM mowing exceeded the threshold on 3, 8, and 9 July with an average of 20.6, 25.3, and 30.0 IC's, respectively. Following the third chlorothalonil application on 10 August, dollar spot levels in PM-mowed plots fell below the threshold by 13 August. Dollar spot levels continued to decline in PM-mowed plots as late as 15 August, and then increased dramatically on 23 August (i.e., 13 days following the third application). Plots subjected to PM mowing had 25.9 and 36.0 IC's on 23 and 25 August, respectively. Conversely, AM mowed plots treated with chlorothalonil did not lose effectiveness at the time data collection ceased on 25 August. Data in Figure 7 show that the chlorothalonil applications made to plots on 26 July and 10 August provided better post plant infection (i.e., curative) control in AM versus PM-mowed plots. Data also show that dollar spot levels in AM-mowed plots were below the threshold on all dates. The PM-mowed chlorothalonil- treated plots had higher dollar spot levels versus AM-mowed plots on most dates between 18 July and 25 August.

Following the initial application (i.e., July 3) of propiconazole, PM-mowed plots began to show a loss of effectiveness by 18 July and in AM-mowed plots by 23 July (Figure 8; Appendix I Table 16). Except for a slight drop in IC's on 25 July, dollar spot levels increased gradually in all plots from 18 July until propiconazole was reapplied on 31 July. July 20, however, was the only date prior to the second application when significantly fewer IC's were observed in AM versus PM mowed plots. Following propiconazole reapplication, however, there were fewer IC's in AM versus PM mowed plots on most rating dates. On 1 and 3 August, PM-mowed plots had dollar spot levels above the threshold (31.0 to 32.9 IC's).Thereafter, dollar spot declined in AM and PM mowed plots. The PM-mowed plots did not begin to lose effectiveness following the second propiconazole application until 15 August. The AM mowed plots appeared to lose effectiveness five days later on 20 August. The AM-mowed plots treated with propiconazole had 15.3 and 24.9 IC's and PM-mowed plots had 31.8 and 41.9 IC's on 23 and 25 August, respectively. Except for the last rating date, data in Figure 8 show that dollar spot levels were below threshold levels in AM mowed plots on all dates. Dollar spot resurgence appeared in both AM and PM mowed plots treated with propiconazole at the time data collection ceased.

Data in Figure 9 show that the number of IC's were significantly higher in boscalid-treated plots subjected to PM versus AM mowing on 7 or 19 rating dates. Boscalid -treated plots subjected to PM mowing began to exhibit a loss in effectiveness 13 days (i.e., 16 July) following the initial application (i.e., 3 July); whereas, plots subjected to AM mowing did not begin to lose effectiveness for another seven days (i.e., 23 July; Figure 9; Appendix I Table 17). Significantly less dollar spot was observed in AM versus PM mowed plots on 9, 12, 18, 20 and 23 July. Following the second boscalid application on 31 July, dollar spot blighting increased until 3 August in plots subjected to PM mowing. Conversely, blighting in AM-mowed plots remained static and then declined after 3 August. The PM-mowed plots treated with boscalid were above the threshold on 1 (22.1 IC's) and 3 August (28.4 IC's). After the reapplication of boscalid, there were significantly fewer IC's in AM versus PM mowed plots on 3 and 6 August. A loss of effectiveness was observed in PM-mowed plots 20 days following the second boscalid application on 20 August. Boscalid-treated plots mowed in the AM appeared to lose effectiveness 3 days later (i.e., 23 August). The threshold was exceeded only in PM mowed boscalid-treated plots on 1, 3, and 25 August. Resurgence was evident in boscalid-treated plots on 25 August.

There were no significant mowing timing differences in iprodione- treated plots in 2007. Both AM and PM mowed plots treated with iprodione began to show a loss in effectiveness on 23 July, which was 20 days following the initial application (i.e., 3 July; Figure 10; Appendix I Table 18). Following the second application of iprodione, dollar spot levels in both AM and PM mowed plots remained static for three days and then declined sharply between 3 and 6 August. Reduced effectiveness was observed about 20 days following the second iprodione application on 20 August in both AM and PM mowed plots. Dollar spot in PM mowed plots reached or exceeded the threshold on 1, 23, and 25 August, but disease levels were only above the threshold on only two dates (i.e., 23 and 25 August) in AM mowed plots. Dollar spot levels in AM mowed plots were lower than PM mowed plots between 23 July and 9 August, but the difference was not significant on any date in 2007. Dollar spot resurgence was evident by 20 August in both AM and PM mowed plots treated with iprodione.

AM versus PM Mowing 2008

Pre-planned orthogonal contrasts for the five fungicide treatments contrasted against the two mowing treatments are shown in Appendix I Table 19. Appendix I Tables 20 to 24 and Figures 7, 8, 9, 10, and 11 show the actual disease data for all 2008 rating dates. Data in Figure 12 show the dollar spot levels in non- fungicide-treated plots subjected to AM versus PM mowing.

Plots subjected to PM mowing generally had more IC's than AM mowed plots in 2008. In non-fungicide-treated plots, there were on average over the data collection period 21% more IC's in PM versus AM mowed plots (Figure 12). There were 78%

fewer IC’s in plots subjected to AM versus PM mowing when data were averaged over all 18 rating dates and fungicide treatments. The average percent of dollar spot reduction in AM versus PM mowing treatments for each fungicide and the control in 2008 was as follows: chlorothalonil = 76%; propiconazole = 78%; boscalid = 84%; iprodione = 84%; and chlorothalonil + propiconazole = 74%. As was observed in 2007, AM mowing had a very significant impact on reducing dollar spot severity in 2008.

Chlorothalonil-treated plots subjected to PM versus AM mowing began to lose effectiveness 11 (i.e., 18 August) and 23 days (i.e., 30 August) following the initial application, respectively (Figure 7). There were significantly greater numbers of IC’s in PM versus AM mowed plots on all dates between 20 August and 22 September. Following the initial application of chlorothalonil, PM mowed plots exceeded the threshold on 4 September (i.e., 26.9 IC’s; Figure 7; Appendix Table 20). Plots subjected to AM mowing did not exceed the threshold following the initial application. Following the second chlorothalonil application (i.e., 5 September), blighting in PM- mowed plots decreased slightly on 8 September. By 10 September, blighting increased to an average of 34.4 IC’s in PM-mowed plots. Plots subjected to AM mowing did not exceed the threshold following the second chlorothalonil application , and IC differences between mowing timings was significant on all dates thereafter. On the final rating before the third chlorothalonil application (i.e., 10 September), AM mowed plots had an average of 8.6 IC’s. The PM-mowed plots exhibited a slight decrease in IC’s following the third application (i.e., 11 September). This was followed by a sharp increase in IC’s on 15 September, but thereafter dollar spot levels generally declined. On average there were 30.3, 45.8, 41.1, 41.4 and 33.7 IC's in PM mowed plots on 12, 15, 17, 19 and 22 September, respectively. Thus, dollar spot levels were above the threshold on all dates after 2 September in PM mowed plots. Conversely, the threshold was not exceeded at any time in AM mowed plots and the number of IC's gradually decreased by the final rating date.

Following the initial application (i.e., 7 August) of propiconazole to PM mowed plots, a loss in effectiveness became evident on 30 August, whereas, AM mowed plots did not begin to lose effectiveness until 10 September (Figure 8). Beginning on 12 September and continuing until data collection ceased there were significantly more IC's in PM than AM mowed plots (Figure 8; Appendix I Table 21). Propiconazole- treated plots mowed in the PM were above the threshold (28.5 IC's) on 15 September. Prior to the second propiconazole application the threshold was not exceeded in AM-mowed plots. *Sclerotinia homoeocarpa* IC's increased in plots subjected to PM mowing one day following the second propiconazole application (i.e.,16 September). On subsequent rating dates, IC's in PM-mowed plots decreased, but did not fall below the threshold before data collection ceased on 22 September. The number of IC's in AM mowed plots decreased following the second propiconazole application, and the threshold was not exceeded on any date.

As previously noted, boscalid was applied only once in 2008. Boscalid-treated plots subjected to PM mowing began to show a minor loss of effectiveness eight days after application (i.e., 15 August; Figure 9). Except on 15 August, there were no dates when IC differences between AM and PM mowed plots were observed. On 15 August there were slightly more IC's in PM (1.9 IC's) versus AM (0.1 IC's) mowed plots. The relatively small number of IC's in PM-mowed plots generally increased until the threshold was exceeded on 17 September (20.3 IC's; Figure 9; Appendix I Table 22). This was the only date during the study in which IC's reached the threshold in boscalid –treated plots. Plots treated with boscalid and subjected to AM mowing did not come close to the threshold on any date and the number of IC's remained relatively low throughout the duration of the study.

Plots treated with iprodione and subjected to PM mowing began to lose effectiveness about 23 days (i.e., 30 August) following initial application on 7 August (Figure 10B). The AM mowed plots lost effectiveness 11 days later on 10 September. Dollar spot levels were greater in PM versus AM-mowed plots on only 8, 10 and 12 September. Following the initial loss in effectiveness, the number of IC's gradually increased in PM mowed plots before the second iprodione application. The PM-mowed plots exceeded the threshold on 10 and 12 September with an average of about 28 IC's (Figure 10; Appendix I Table 23). Following the second iprodione application (i.e., 13 September), the number of IC's declined somewhat to an average of 23.3 IC's in PM mowed plots on 15 September. After the second iprodione application, blighting decreased and did not exceed the threshold after 16 September. Plots subjected to AM mowing did not exceed the threshold on any rating date in 2008, and the highest number of IC's in AM mowed plots was 8.8 IC's on 12 September. The number of IC's gradually decreased in iprodione-treated plots after the second application, regardless of mowing timing.

Plots treated with chlorothalonil + propiconazole and subjected to AM versus PM mowing began to lose effectiveness 23 (i.e., 30 August) and 34 days (i.e., 10

September) after the initial treatment, respectively. September 15 was the only date before the tank-mix was reapplied in which the number of IC's was statistically greater in PM versus AM mowed plots. The number of IC's (33.8) in PM mowed plots exceeded the threshold on 15 September (Figure 11; Appendix I Table 24). Following the second application (i.e., 16 September) of the tank-mix, the number of IC's in PM-mowed plots remained above the threshold (i.e., 28.1 to 40.1 IC's) on all three rating dates (i.e., 17, 19, and 22 September). On all three of the aforementioned dates there were significantly more IC's in PM versus AM mowed plots. Conversely, the number of IC's in AM mowed plots treated with the tank-mix did not exceed the threshold on any rating date.

Dew Measurements 2007 and 2008

Dew measurements obtained from the study site on dates of each fungicide application in 2007 were as follows: 3 July = 637.3 L ha^{-1}; 26 July = 2266.7 L ha^{-1}; 31 July = 2967.5 L ha^{-1}; and 10 August = 660.0 L ha^{-1} (Figure 1). Dew measurements obtained on days that fungicides were applied in 2008 were as follows: 7 August = 995.0 L ha^{-1}; 5 September = 1583.3 L ha^{-1}; 11 September = 1580.0 L ha^{-1}; 13 September = 1780.0 L ha^{-1}; 15 September = 1952.4 L ha^{-1} (Figure 1).

Discussion

The objective of the study was not to compare the level of dollar spot control among fungicides, but to compare their individual performance as influenced by simulated rain and mowing timing. It is difficult to conclude whether simulated rain or mowing timing impacted results most. Obviously, both played a major role in affecting fungicide performance.

Plots subjected to simulated rain and PM mowing sustained far more dollar spot injury than rain-free and AM mowed plots in both 2007 and 2008. Chlorothalonil is a contact protectant (i.e., active ingredient remains on plant surfaces); whereas, the other fungicides are penetrants (i.e., some active ingredient is translocated into the plant). Boscalid and propiconazole are acropetal penetrants and iprodione is a localized penetrant (Smiley et al., 2005). Penetrants are protected by virtue of some active ingredient being taken up into tissue; whereas, the active ingredient of a contact fungicide is more likely to be diminished on plant surfaces by environmental factors. As expected, the contact protectant (i.e., chlorothalonil) required more frequent application since its residual effectiveness was shorter lived than the penetrants evaluated.

There were differences in disease levels and fungicide performance between years. There was less effective dollar spot control in rain-free plots in 2007 than in 2008. Dollar spot increased in intensity more rapidly after the first application in 2007 than occurred in 2008. Furthermore, dollar spot resurgence was associated with all fungicides in 2007 but none in 2008. Resurgence is defined as a rapid and severe recurrence of a disease in turfs previously treated with fungicides compared to sites that had not been treated (Smiley et al., 2005). Resurgence is common with dollar spot, but the mechanism for the phenomenon is unknown. The best measure of the influence of simulated rain may be to compare the percentage of days each fungicide provided a level of dollar spot control that was below the threshold. The ranges in the percentage of days when *S. homoeocarpa* IC's were below the threshold for each fungicide subjected to simulated rainfall versus rain-free were as follows: chlorothalonil 55 to 66% versus 100% of days; propiconazole 80 to 83% versus 98 to 100% of days; boscalid 89 to 100% versus 100% of days; and iprodione 82 to 94% versus 96 to 100% of days in 2007 and 2008 (Table 1). Plots treated with the tank-mix of chlorothalonil + propiconazole, which was assessed only in 2008, had 93 and 82% of days below the threshold in simulated rain versus rain-free plots, respectively. The tank-mix performed better than chlorothalonil and propiconazole applied separately. Simulated rain plots treated with propiconazole alone lost effectiveness on 8 September, however, in plots treated with the tank-mix effectiveness was lost about five days later on 13 September. Hence, the tank-mix combination improved the level of dollar spot control compared to either fungicide applied alone in simulated rain plots.

The differences in the number of days in which each fungicide treatment was above the threshold in simulated rain plots may provide more clues on which fungicide was most rain safe. In plots treated with chlorothalonil, dollar spot levels were above the threshold eight rating dates in both years in simulated rain plots. Conversely, there were no dates in either year when chlorothalonil-treated plots were above the threshold in rain- free plots. There were four days in both 2007 and 2008 when propiconazole –treated plots were above the threshold in simulated rain plots. In the two study years, there was only one day when boscalid- treated plots were above the threshold in simulated rain plots and there were no significant differences between rain treatments in either year. In boscalid-treated plots, there were no more than three IC differences between rain treatments in 2008. For iprodione, there were only two to three days when the number of IC's was above the threshold in each year. For the tank-mix, which was evaluated in 2008 only, there were four rating days when IC numbers were above the threshold in simulated rain plots. Clearly, chlorothalonil was most negatively impacted by simulated rain. Iprodione, propiconazole and the tank-mix provided similar and intermediate levels of rain-safeness, but boscalid was the most rain-safe fungicide evaluated. It should be noted, however, that *S. homoeocarpa* isolates from the study site were shown to be less sensitive to propiconazole than base-line isolates in Petri dish tests conducted in 2007 and 2008 (Olaya, personal communication.). Hence, the reduced sensitivity of the pathogen population to propiconazole in the study site may have influenced the results.

Another measure of the influence of simulated rain may be to examine the percent difference in IC's between simulated rain and rain-free treatments. The greater the percentage, the less rain safe a fungicide would be. The ranges in the percentage of dollar spot reduction in simulated rain versus rain-free plots for each fungicide treatment averaged over all rating dates in both years were as follows: chlorothalonil = 68 to 96% (two year average = 82%); propiconazole = 43 to 82% (average = 63%); boscalid = 38 to 45% (average = 42%); and iprodione = 28 to 87% (average = 58%). The tank-mix, which was only applied in 2008, had a -7%.percent reduction in IC's in rain-free versus simulated rain plots. The tank-mix was the only treatment in either year in which there were numerically more IC in rain-free versus simulated rain plots, but the difference between rain treatments was not significant.

Hence, these data also support the conclusion that boscalid was most rain-safe and that chlorothalonil was least rain-safe.

There were 48 (2007) to 52% (2008) more IC's in plots subjected to simulated rainfall versus rain-free plots among all fungicides averaged over all rating dates in both years. These percentages are remarkably similar. However, if data from the 2008 chlorothalonil + propiconazole treatment were removed, the percent difference in dollar spot reduction in simulated rain versus rain-free plots increased from 52% to 86% in 2008. The apparent greater influence of simulated rainfall in 2008 may be attributed in part to natural rainfall events that occurred within 24 h following fungicide application (Appendix Figure 4). Natural rainfall totals occurring on the day in which fungicides were applied in 2008 were 6.4 mm on 7 August (initial application); 2.3 mm on 5 September (second application of chlorothalonil); and 0.3 mm on 13 September (second application of iprodione). This additional natural rain may have impacted results. No natural rainfall events occurred within 24 h of any fungicide application in 2007.

Most previous studies involved chlorothalonil and other contact fungicides and data generally demonstrated that a high intensity rainfall removed more fungicide from plant surfaces than a low intensity rainfall (Kudsk et al., 1991; Carroll et al., 1993; Fife and Nokes, 2002; Armengol and Garcia-Jimenez, 2007). Results from the current study have shown that a simulated rainfall event reduced the ability all fungicides evaluated to control dollar spot. In this study, plots were subjected to an intense simulated rain event, which delivered water at a rate of approximately 19.0 to 23.9 cm h^{-1}. According to National Oceanic and Atmospheric Administration's

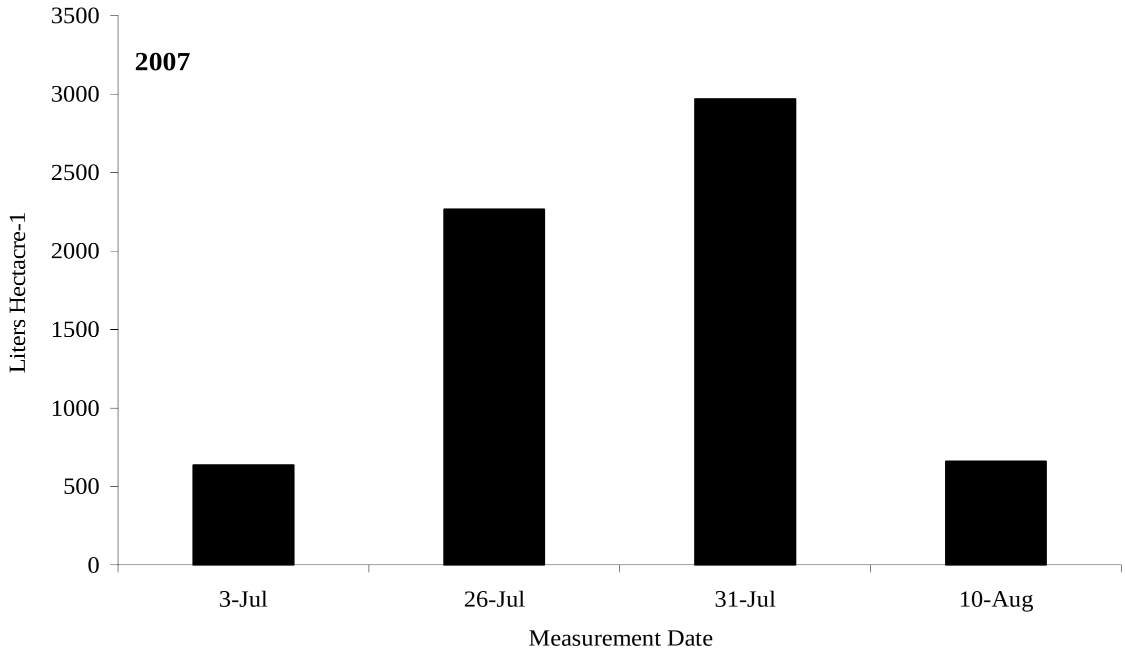
(NOAA) point precipitation frequency estimates (http://hdsc.nws.noaa.gov/cgi-bin/hdsc/buildout.perl?type=idf&units=us&series=pd&statename=NORTH+CAROLINA&stateabv=sc&study=orb&season=All&intype=5&plat=39.069&plon=-76.733&liststation=0&slat=lat&slon=lon&mlat=39.069&mlon=-76.733#) for nearby Silver Spring MD, the return frequency was 50 to 100 years. However, it is not unusual in Maryland for a rain event lasting several hours or days to deliver 2.54 cm or more water. Previous research with chlorothalonil has shown that timing and intensity of rainfall, natural or simulated, is highly correlated to the amount of fungicide washed off the plant. Bruhn and Fry (1982) reported 66% of chlorothalonil was washed off potato foliage when rainfall was simulated three hours after the fungicide was applied. Only 55 and 36% of chlorothalonil was displaced from potato foliage when simulated rainfall treatments were applied one day and seven days after fungicide application, respectively (Bruhn and Fry, 1982). Carroll et al. (2001) found that 35% of chlorothalonil was displaced from creeping bentgrass foliage when subjected to simulated rain of 48 mm hr^{-1} one hour after application. Since chlorothalonil was subjected to an intense level of simulated rain within 30 minutes of application in the current study it would be safe to conclude that its poor performance, compared to rain –free plots, was due to the displacement of chlorothalonil. Since there are no wash off data for the other fungicides evaluated in this study, it is speculated that significant amounts of boscalid, iprodione and propiconazole entered plant foliage within 30 minutes of application.

Except for iprodione between 20 and 25 August 2007, there were no dates in either year when plots subjected to AM mowing were above the threshold for any fungicide. The time plots were mowed impacted chlorothalonil and propiconazole performance more than boscalid or iprodione. For example, there were 25 and 13 rating dates over both years when there were significantly fewer IC's in chlorothalonil and propiconazole –treated plots mowed in the AM versus PM, respectively. There were only three and seven dates in both years when there were significantly more IC's in PM than AM mowed plots treated with iprodione and boscalid, respectively. For the tank-mix in 2008, there were five dates when there were fewer IC's in AM versus PM mowed plots.

Simulated rain generally impacted fungicide performance more than mowing timing. However, mowing timing also was a very important factor in governing fungicide performance in this study. The average percent reduction in IC's in fungicide-treated plots ranged from 35 to 64% in 2007 and from 53 to 80% in 2008 in AM versus PM mowed plots. In non-fungicide-treated plots there was a 21 to 26% reduction in the number of IC's in AM versus PM mowed plots in 2007 and 2008, but the difference was not significant. The lower levels of dollar spot attributed to AM mowing generally improved the performance of all fungicides. Williams et al. (1996) previously reported that mowing in the morning could reduce dollar spot severity by 66 to 81% on fairway height creeping bentgrass. The reduction in dollar spot associated with AM mowing was attributed to the reduction in the duration of leaf wetness episodes (Williams et al., 1996). Ellram et al. (2007) further noted that disrupting dew by mowing at 0400 h, or about half way through the leaf wetness duration period, had the greatest impact on reducing dollar spot. The dollar spot levels in the study reported by Ellram et al. (2007), however, were low and ranged for

0.6 to 8.7% of plot area blighted. Our observations indicate that another important factor was the physical disruption of foliar *S. homoeocarpa* mycelium by mowing. Mowing in the morning not only would reduce leaf wetness duration, but it probably would physically disrupt and/or remove or otherwise displace foliar mycelium. Furthermore, mycelium in infected tissue would also have been removed by collecting clippings. This would explain why Ellram et al. (2007) found that mowing was more effective than the squeegee in reducing dollar spot severity. There is one other factor that may have contributed to improved dollar spot control associated with AM mowing. The PM mowed plots would have been mowed about 26 hours after fungicides were applied. The AM mowed plots would have been mowed about 50 hours after the fungicides were applied. The shorter period between the time fungicides were applied and PM plots were mowed versus AM plots may have impacted results.

Figure 1. Dew measurements (L ha^{-1}) taken prior to each fungicide application in 2007 and 2008.



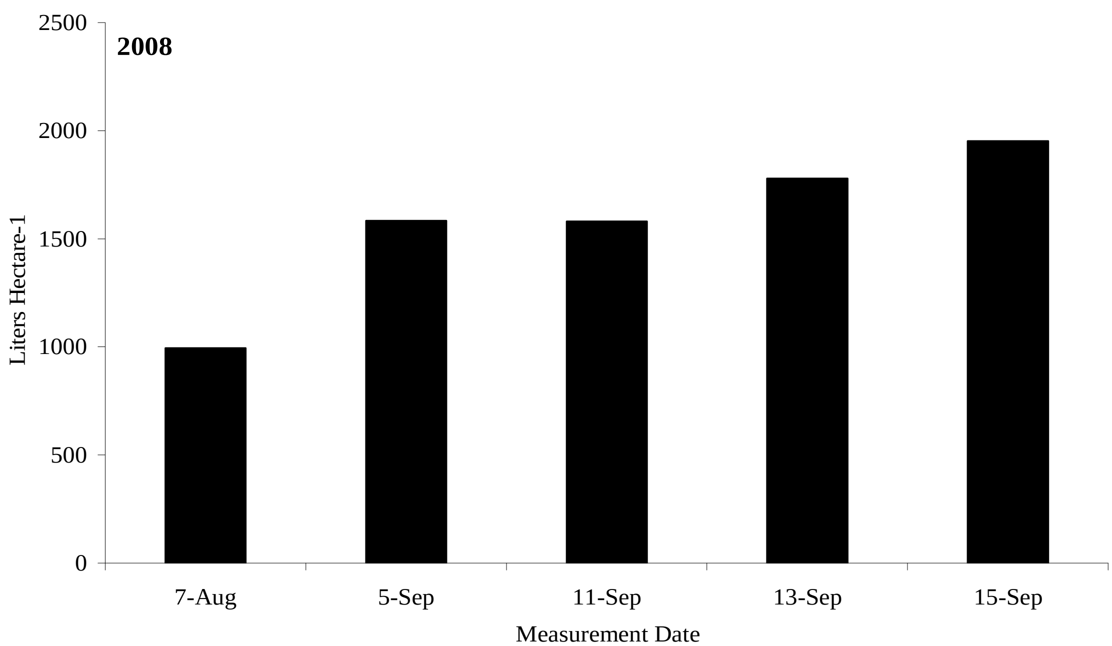
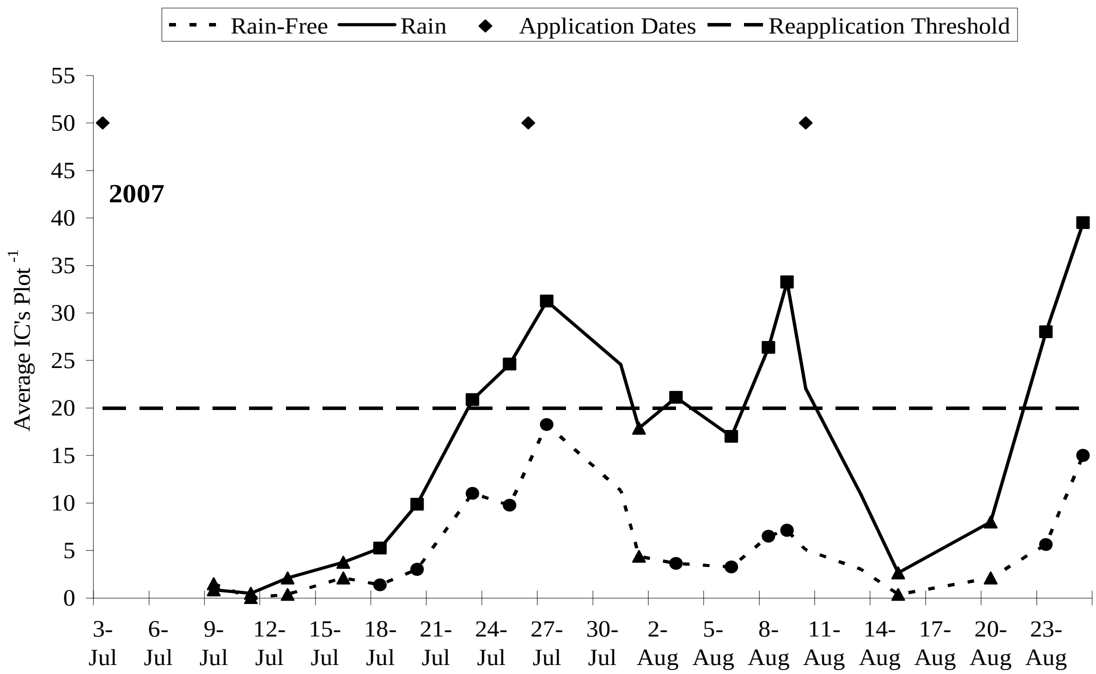


Figure 2. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with chlorothalonil (Daconil Ultrex) and subjected to simulated rain versus rain-free plots in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



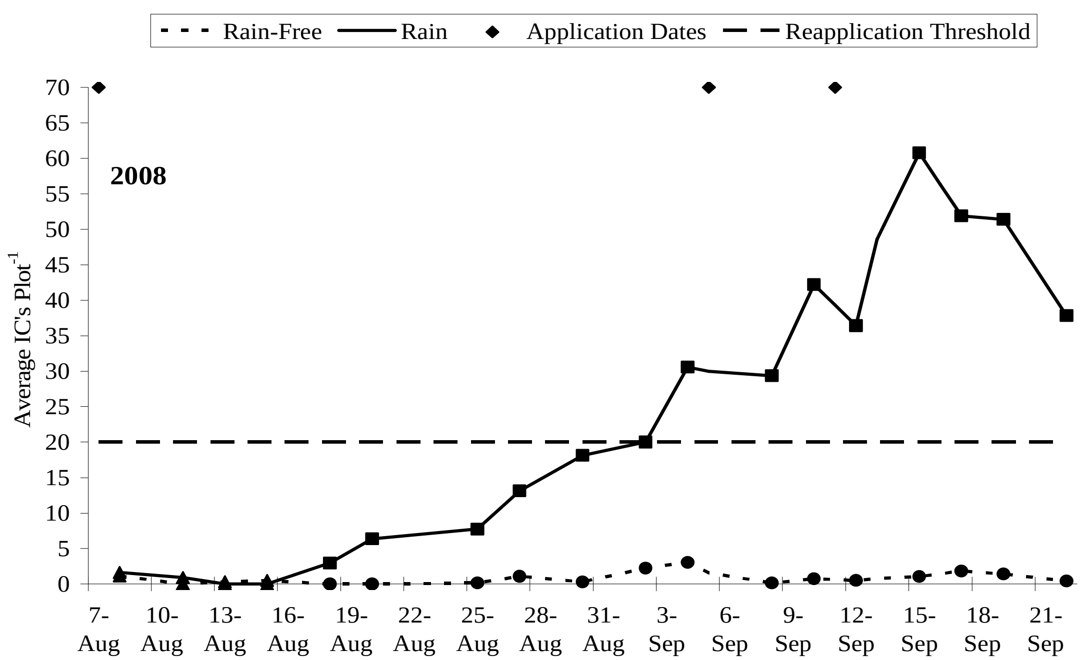
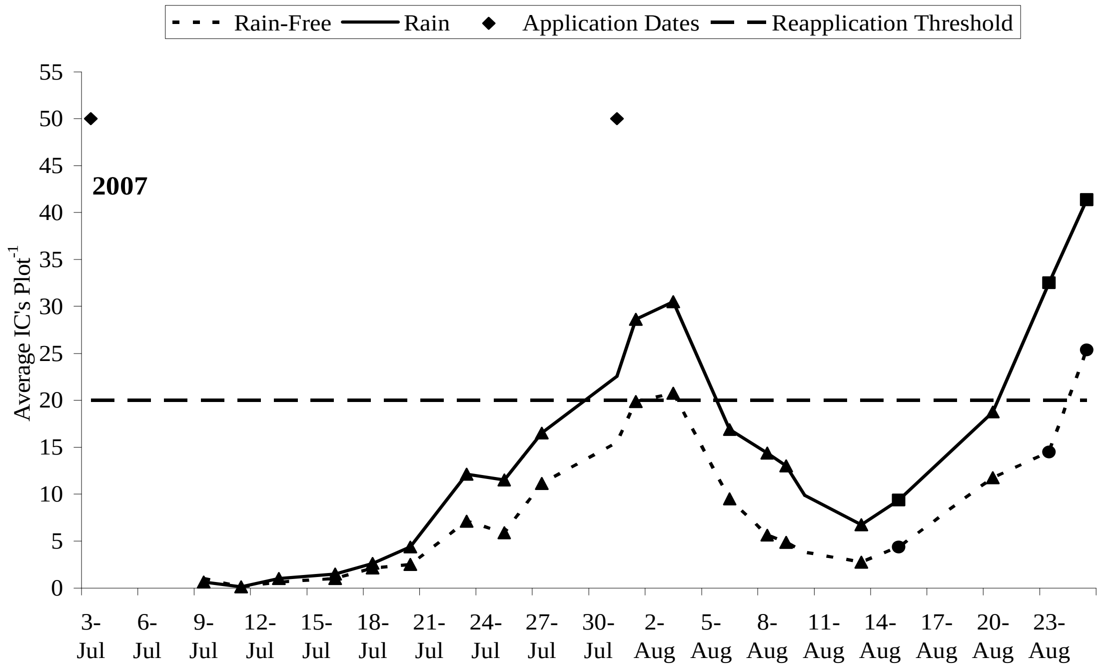


Figure 3. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with propiconazole (Banner MAXX) and subjected to simulated rain versus rain-free plots in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



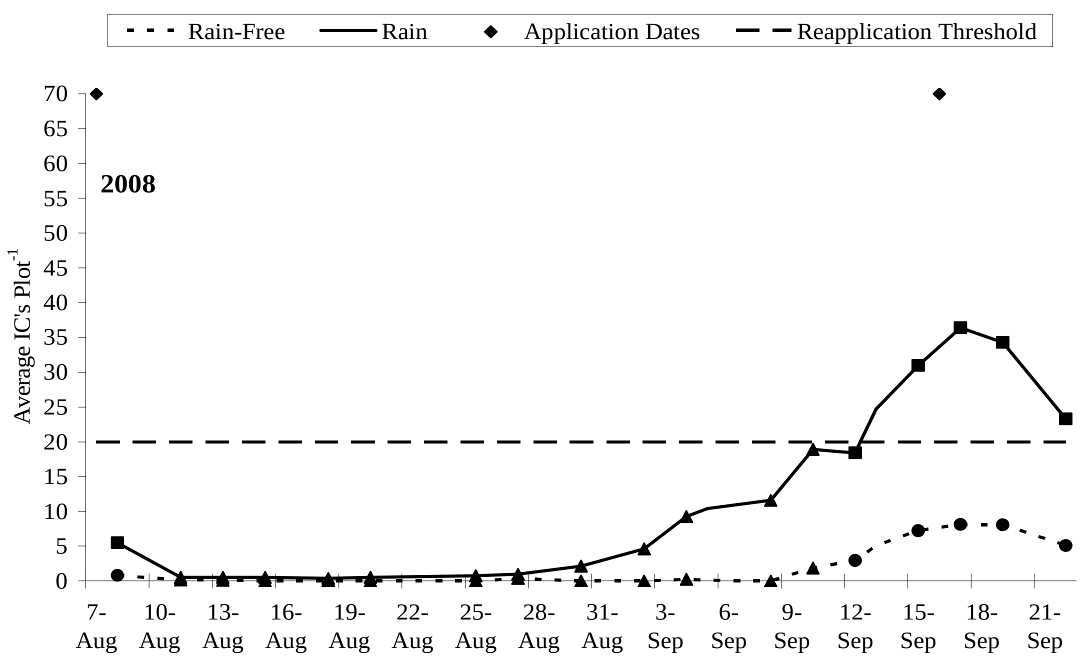
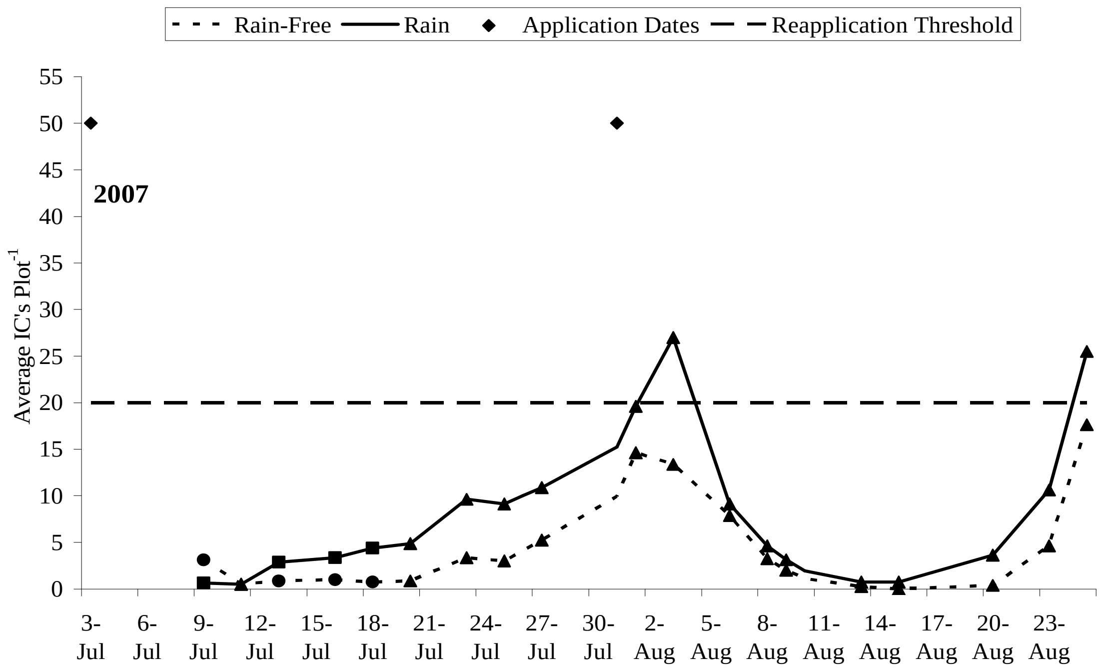


Figure 4. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with boscalid (Emerald) and subjected to simulated rain versus rain-free plots in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



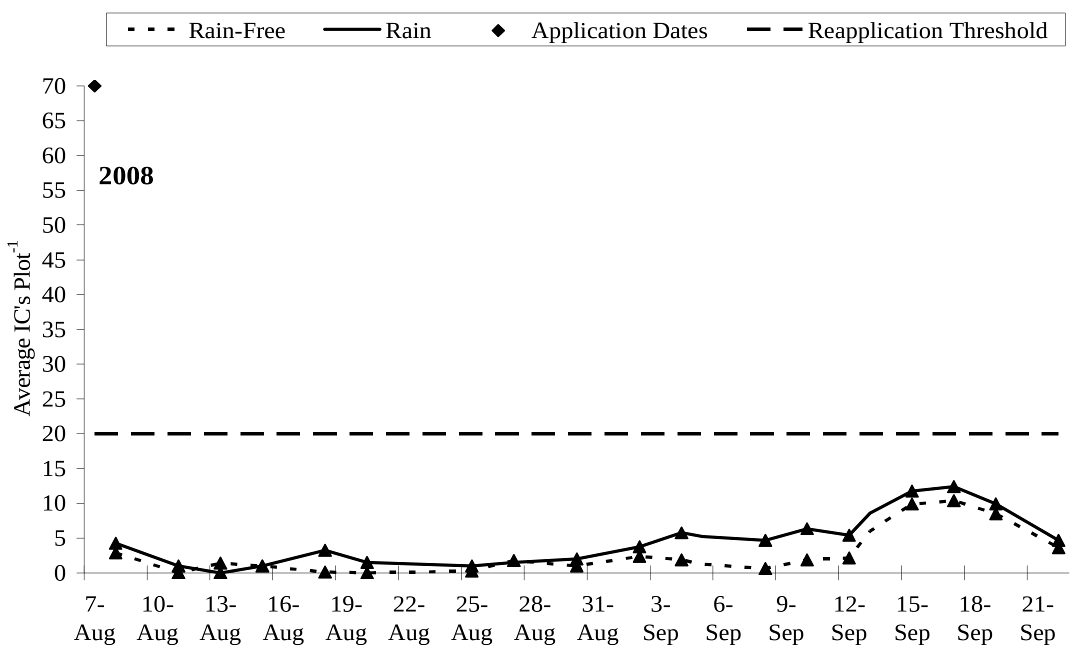
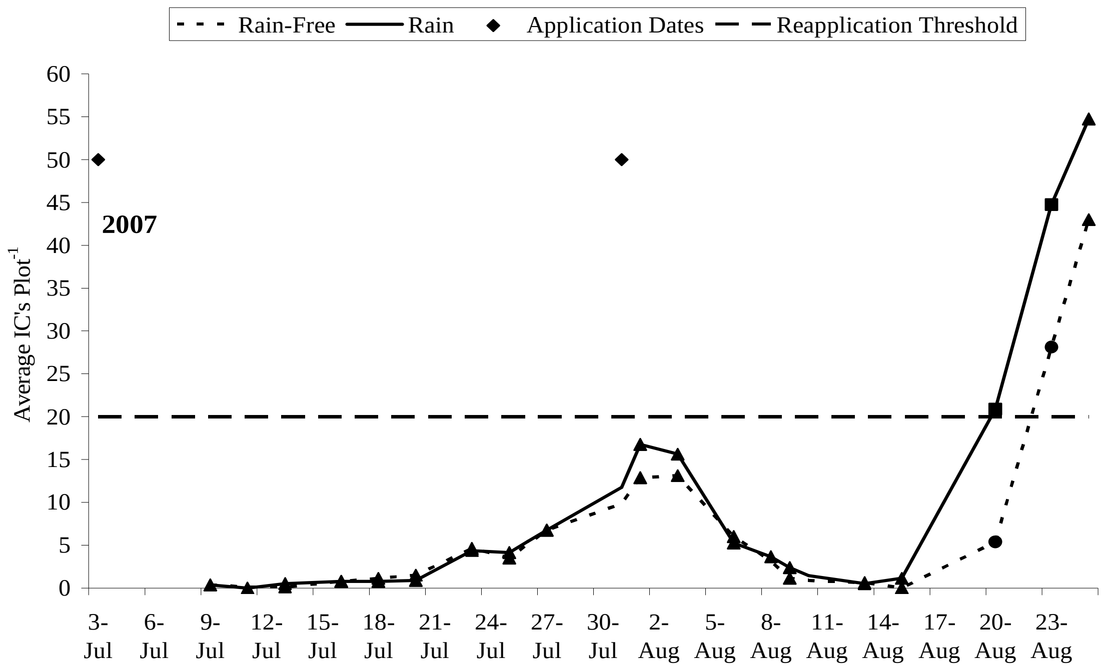


Figure 5. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with iprodione (Chipco 26 GT) and subjected to simulated rain versus rain-free plots in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



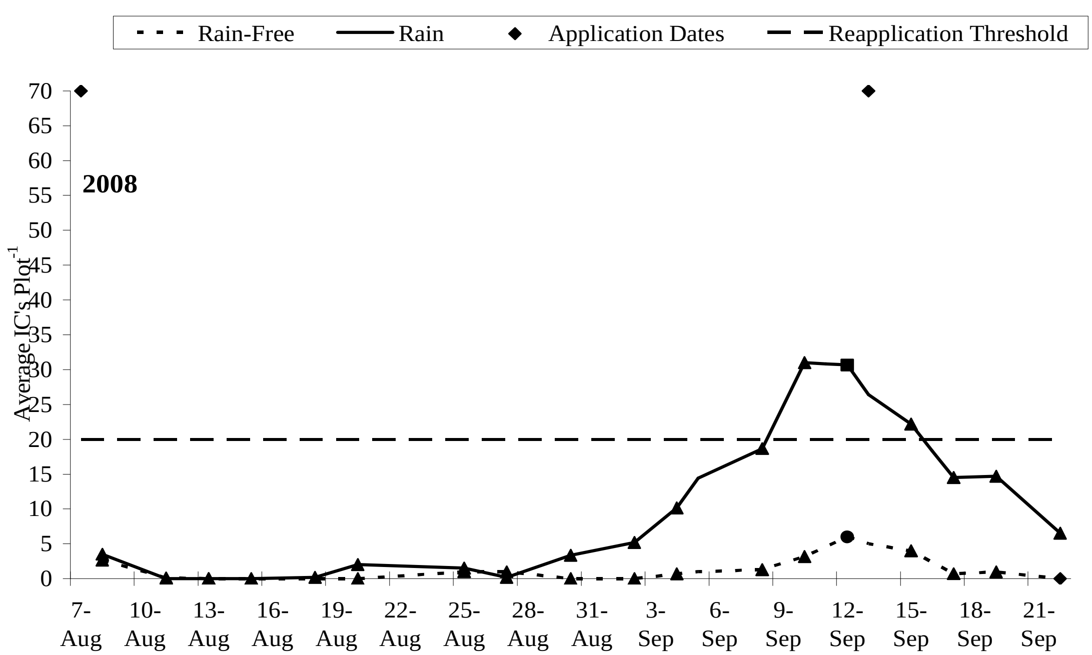


Figure 6. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with chlorothalonil + propiconazole (Daconil Ultrex + Banner MAXX) and subjected to simulated rain versus rain-free plots in 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.

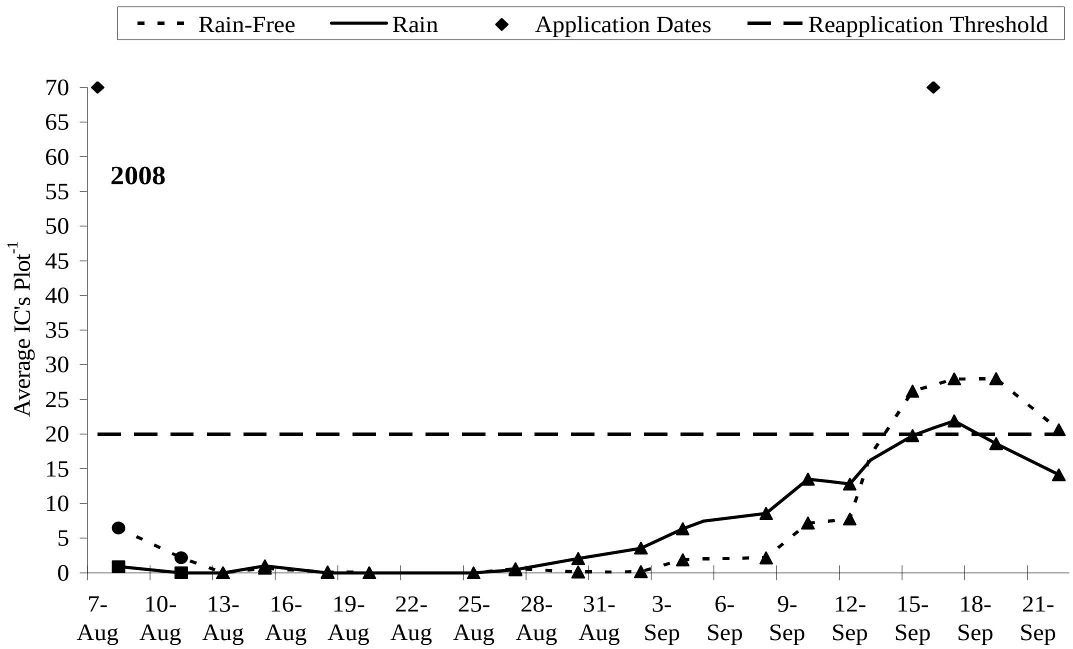
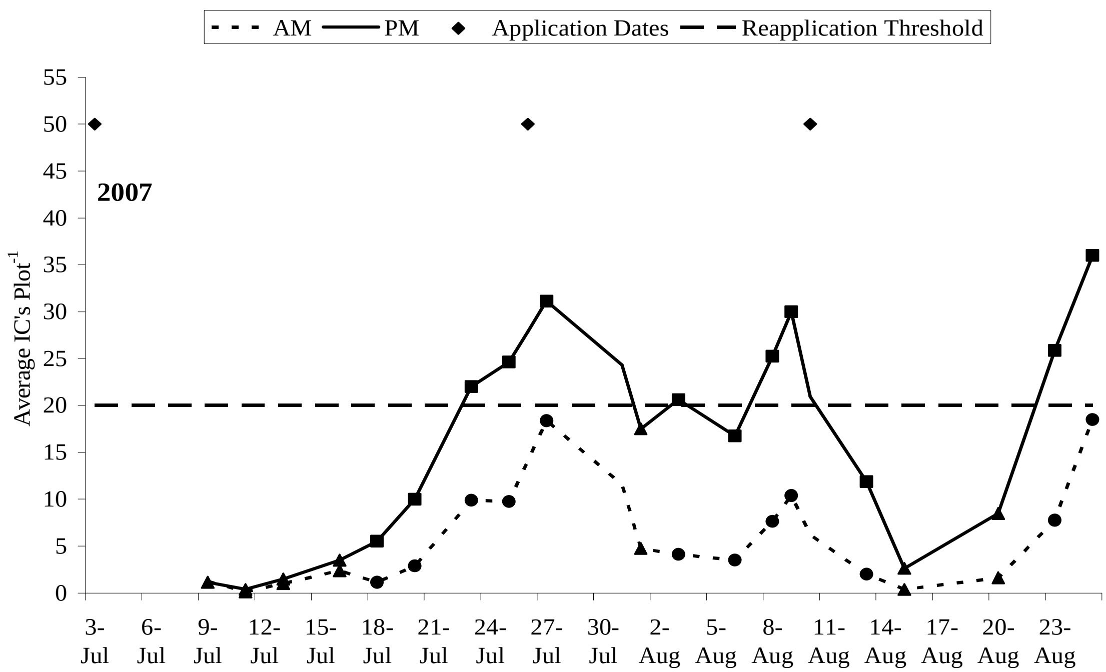


Figure 7. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with chlorothalonil (Daconil Ultrex) and subjected to AM versus PM mowing in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



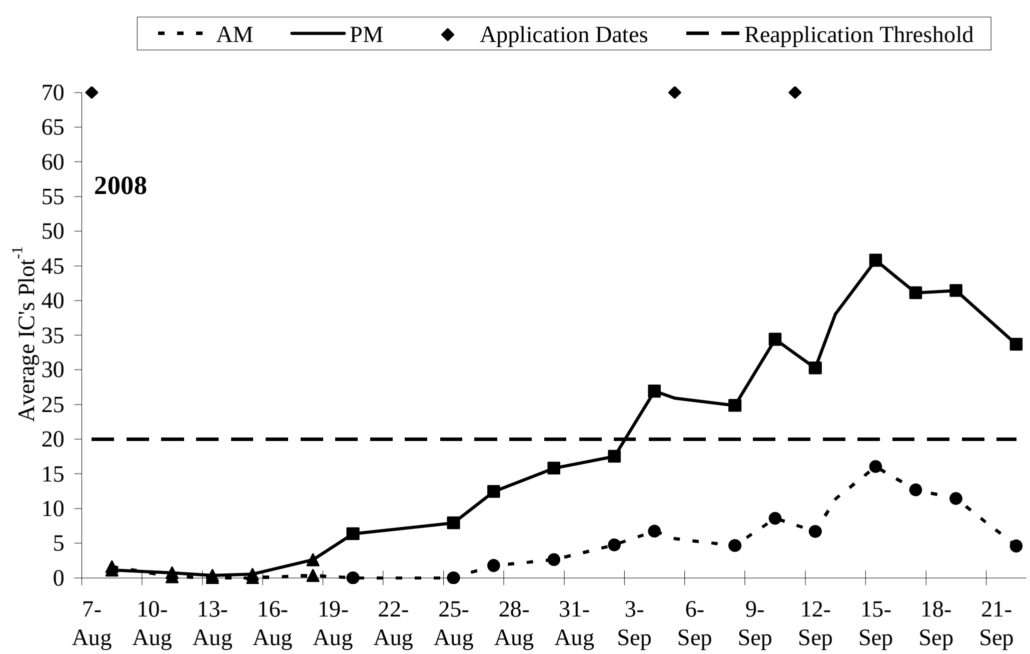
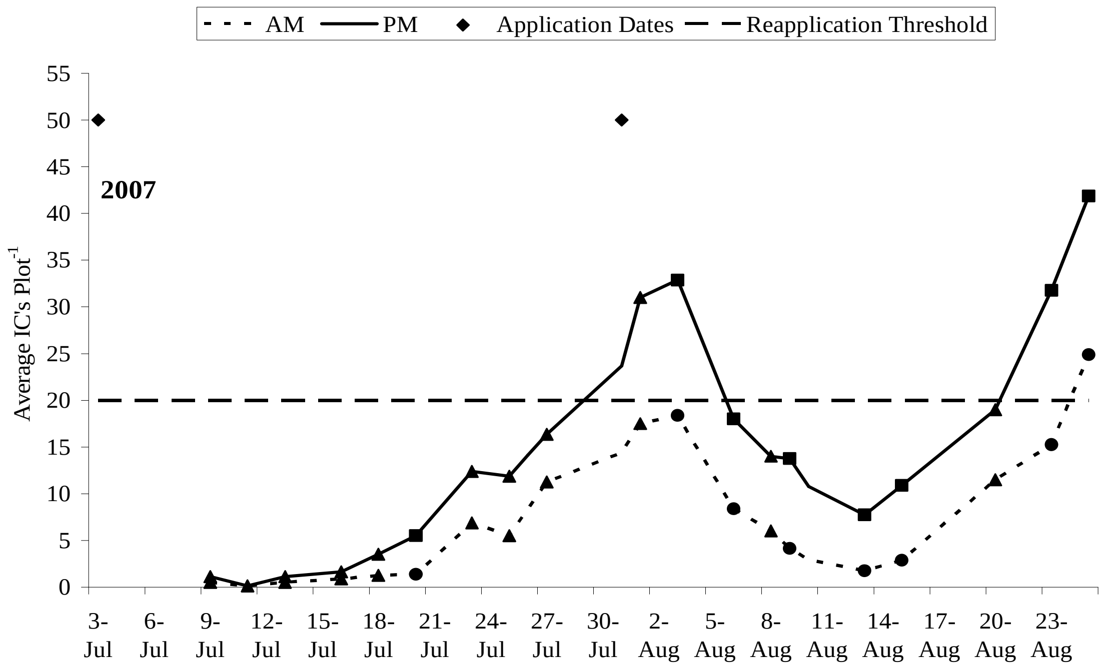


Figure 8. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with propiconazole (Banner MAXX) and subjected to AM versus PM mowing in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



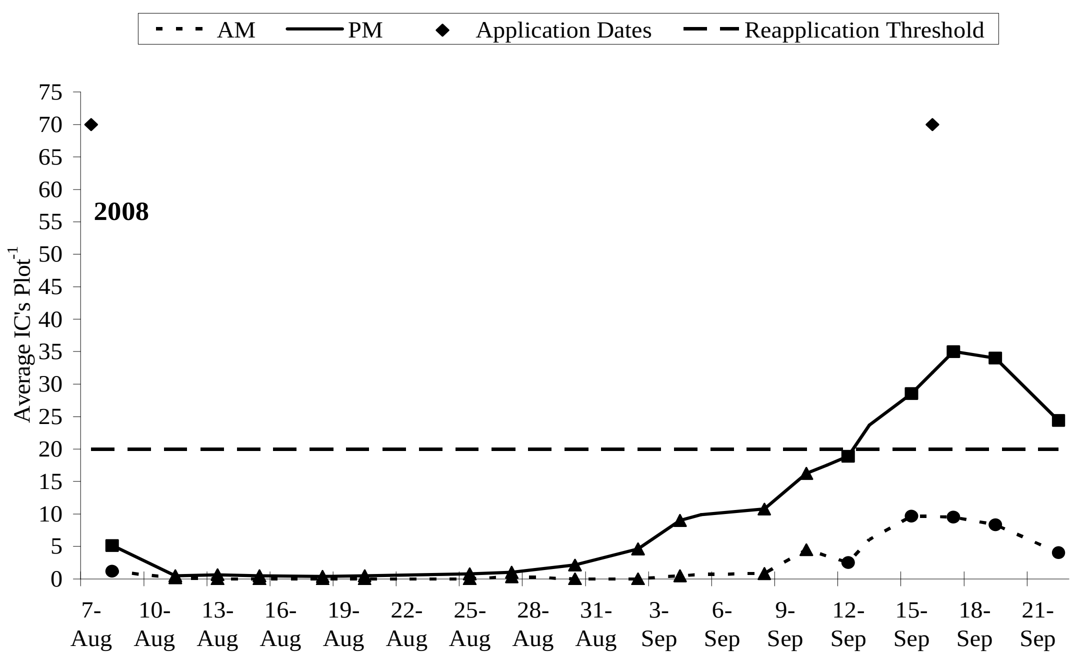
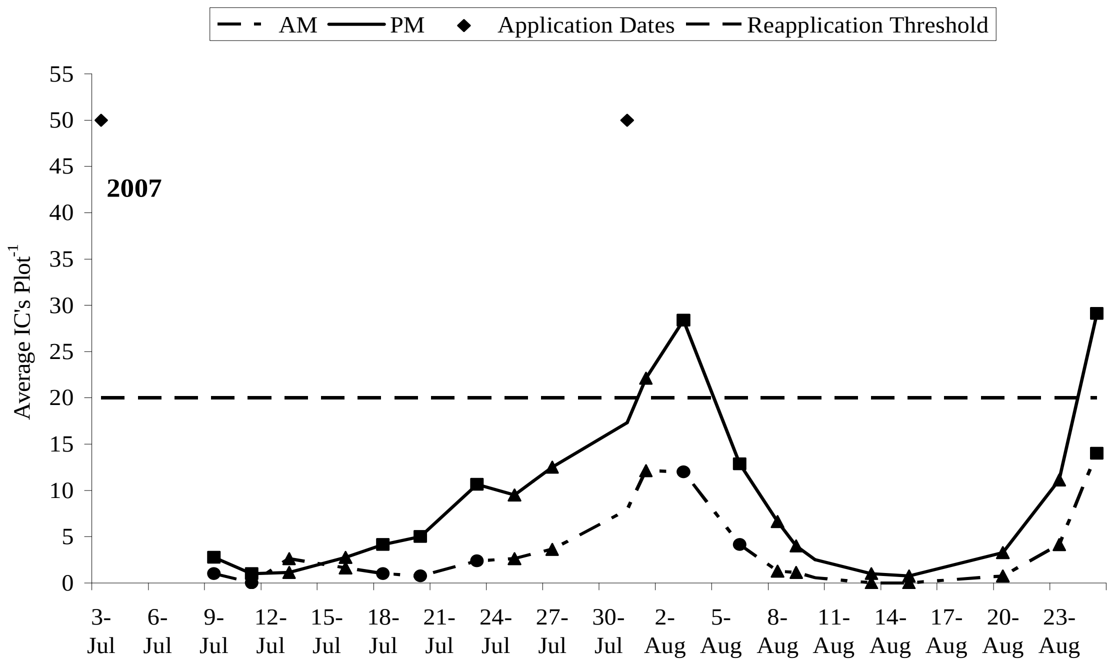


Figure 9. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with boscalid (Emerald) and subjected to AM versus PM mowing in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



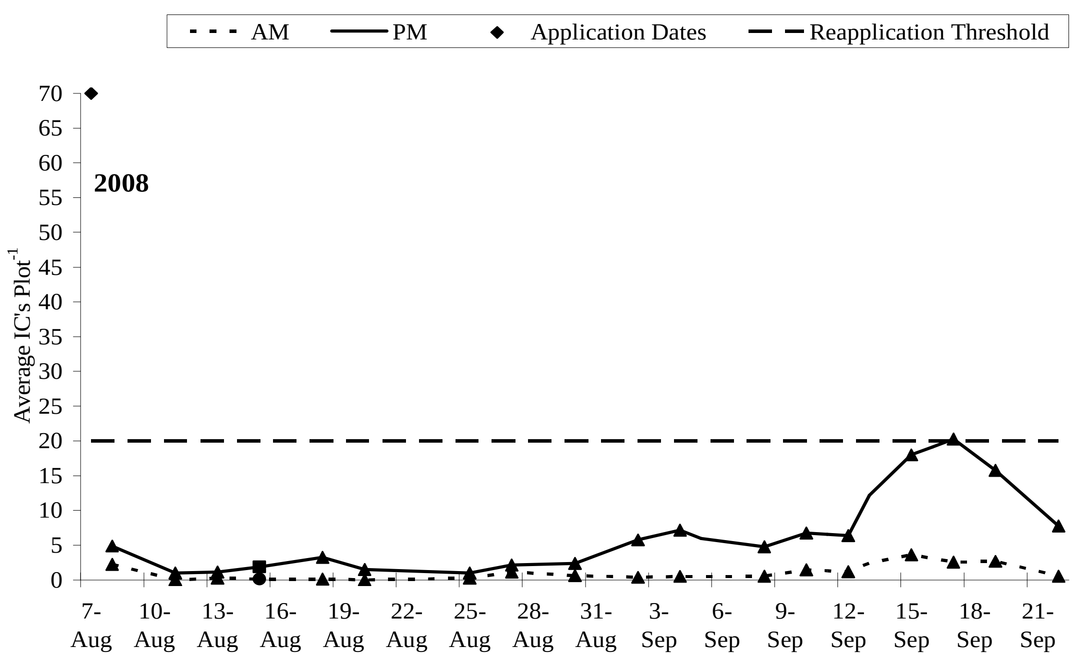
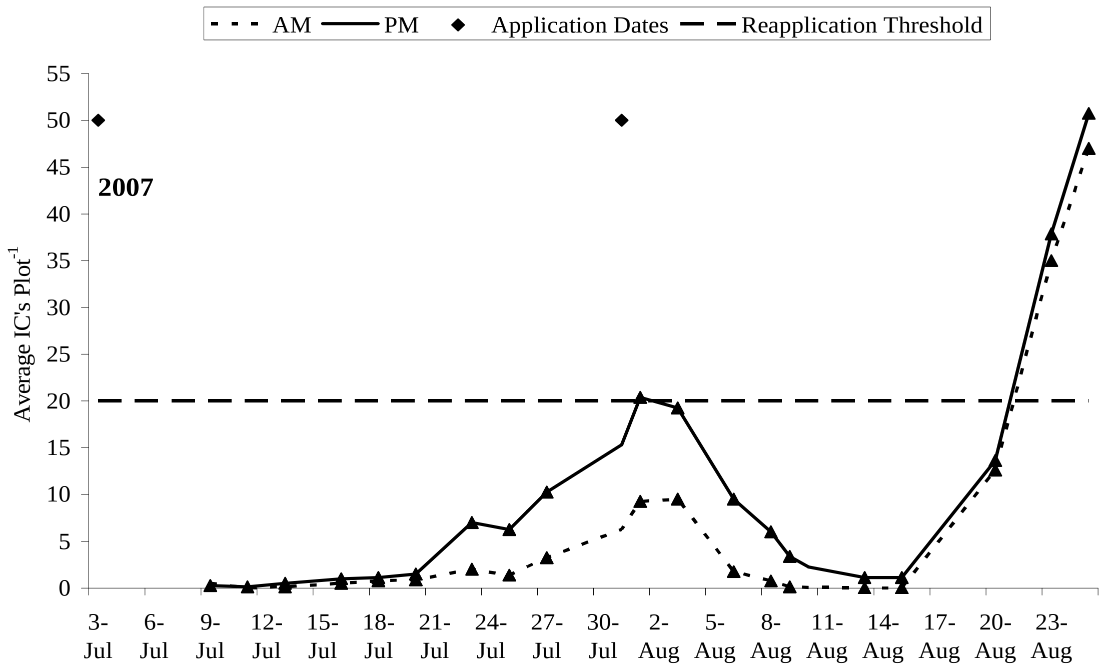


Figure 10. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with iprodione (Chipco 26 GT) and subjected to AM versus PM mowing in 2007 and 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.



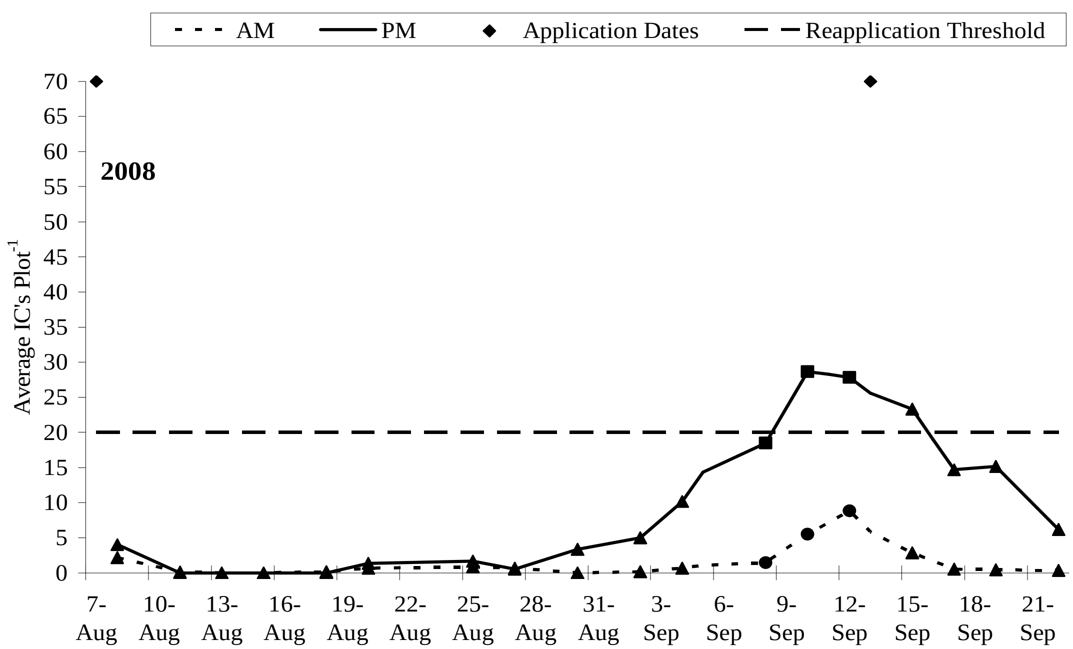


Figure 11. *Sclerotinia homoeocarpa* infection centers (IC's) in plots treated with chlorothalonil + propiconazole (Daconil Ultrex + Banner MAXX) and subjected to AM versus PM mowing in 2008. Pre-planned orthogonal contrasts on dates marked by different symbols are significantly different based on Fisher's protected LSD Test at $P \leq 0.05$.

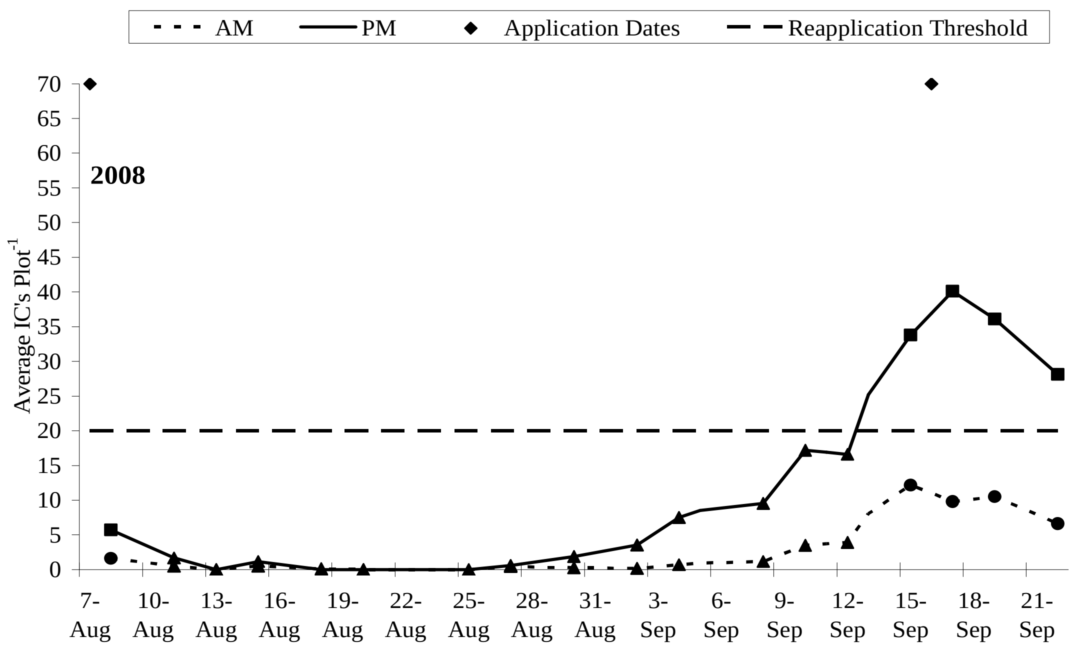
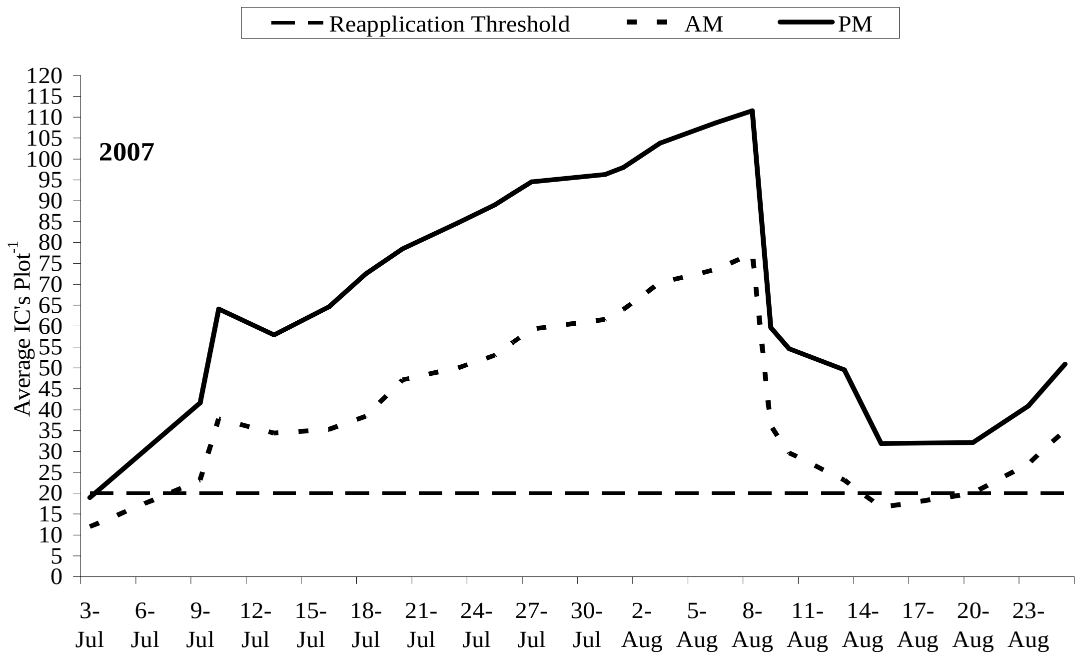


Figure 12. *Sclerotinia homoeocarpa* infection centers (IC's) in non fungicide-treated plots subjected to AM versus PM mowing timing in 2007 and 2008.



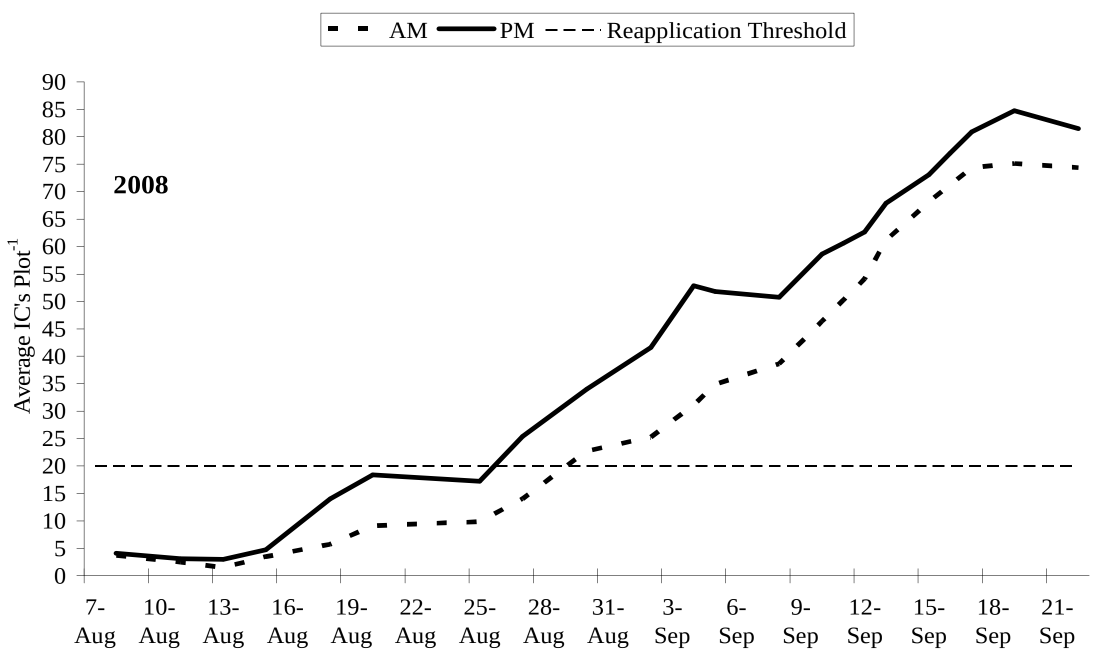


Table 1. The number of days and percent of days below the threshold for fungicide- treated plots subjected to simulated rain and rain-free in 2007 and 2008.

Fungicide	2007				2008				2007				2008			
	Rain		Rain-Free		Rain		Rain-Free		AM		PM		AM		PM	
	no. [x]	% [y]	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Chlorothalonil	31	66	47	100	24	55	44	100	32	68	47	100	25	57	44	100
Propiconazole	39	83	46	98	35	80	44	100	36	77	47	100	35	80	44	100
Boscalid	42	89	47	100	44	100	44	100	42	89	47	100	43	98	44	100
Iprodione	44	94	45	96	36	82	44	100	44	94	45	96	37	84	44	100
Chlorothalonil + Propiconazole	* [z]	*	*	*	36	82	41	93	*	*	*	*	35	80	44	100

[x] Total number of days below the threshold.
[y] Average percentage of all dates below the threshold.
[z] * Treatment assessed in 2008 only.

Chapter II: Curative Dollar Spot Control in Fairway Height Creeping Bentgrass as Influenced by Fungicide Spray Volume and Application Timing

<u>*Synopsis*</u>

More money is spent managing dollar spot (*Sclerotinia homoeocarpa* F. T. Bennett) with fungicides than any other turfgrass disease. The importance of spray volume and application timing of a fungicide targeting dollar spot has received limited study. The objectives of this two year field study were to assess the influence of two spray volumes (468 and 935 L water ha^{-1}) and two application timings (AM in the presence of canopy dew and PM to a dry canopy) for three fungicide treatments targeting dollar spot curatively. Chlorothalonil (tetrachloroisophthalonitrile; 8.1 kg a.i. ha^{-1}), propiconazole [1-[[2(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]1-H-1,2,4-triazole; 0.5 kg a.i. ha^{-1}], and a tank-mix of chlorothalonil + propiconazole (same rates) were compared on mature stands of either ‘Crenshaw’ (2007 and 2008) or ‘Backspin’ (2008) creeping bentgrass (*Agrostis stolonifera* L.). The fungicides were applied curatively and in one direction. The only consistent finding in this study was that the level of dollar spot control provided by the tank-mix of chlorothalonil + propiconazole was unaffected by spray volume or application timing in all sites in both years. For chlorothalonil alone, dollar spot control generally was improved when applied in the high spray volume in Backspin in 2008; however, the opposite was true in Crenshaw in 2008. There were no spray volume differences for chlorothalonil in 2007. Propiconazole provided improved dollar spot control when applied in the high spray volume compared to the low spray volume on four rating dates in 2007 and one date 2008 (Backspin). Conversely, propiconazole provided

better disease control when applied in the low spray volume on three rating dates in Crenshaw (2008). Contradictory results also were obtained for application timing treatments. Chlorothalonil generally was more effective when applied AM in 2007 and 2008 (Backspin), but better control was observed on three rating dates in PM treated Crenshaw in 2008. For propiconazole, PM and AM applications generally were associated with improved dollar spot control when applied to Crenshaw in 2007 and 2008, respectively. There were no application timing differences observed in propiconazole-treated Backspin in 2008. Other factors, such as previous fungicide use history, environmental conditions, cultivar grown and progression and/or severity of epidemics, may be influential in governing the effectiveness of chlorothalonil and propiconazole when applied in different spray volumes and application timings when targeting dollar spot in creeping bentgrass.

Introduction

In 1999, the United States Environmental Protection Agency (US EPA) placed restrictions (29.19 kg a.i. ha^{-1} per year to fairways) on the use of chlorothalonil (Vincelli and Dixon, 2003). It was determined by the US EPA that chlorothalonil had negative effects on non-target aquatic ecosystems (US EPA, 1999). This is important because chlorothalonil is an integral fungicide for use in dollar spot resistance management programs, since no cases of *S. homoeocarpa* resistance have been reported for this fungicide. Conversely, *S. homoeocarpa* has developed resistance to most other chemicals used to control dollar spot (Smiley et al., 2005). Furthermore, given the high cost of fungicides and environmental concerns of the public, there is a great deal of interest in finding ways to improve product effectiveness and thus reduce the amount of chemicals applied to turfgrasses. These and other circumstances created a need to seek new methods for providing higher levels of effectiveness when applying chlorothalonil as well as other fungicides. Two application factors that have been shown to impact the effectiveness of chlorothalonil are spray volume and application timing (Couch, 1984; McDonald et al., 2006). Spray volume is defined as the amount of water that a product is dissolved or suspended into before it is applied to a given area. Determining the optimal spray volume and application timing may provide a longer period of *S. homoeocarpa* suppression, which could lead to less fungicide use.

Ashbaugh and Larsen (1982), investigated the effect of spray volume (i.e., 203, 407, 1017, and 2034 L ha^{-1} of water) on the efficacy of triadimefon [1-(4-chlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl) butanone]; iprodione [3-(3,5-dichlorophenyl)-N-(1-methylethyl)2,4-dioxo-1-imidazoline-carboximide]; and chlorothalonil when targeting dollar spot. In the aforementioned study, treatments were applied after the disease had appeared (i.e., curatively) to creeping bentgrass maintained as a putting green and no differences in spray volume were observed for any fungicide. Gregos et al. (2000) also reported that spray volume (i.e., 407, 814, and 1628 L ha^{-1}) had no effect on fungicide efficacy when targeting dollar spot preventively for the following fungicides: chlorothalonil; iprodione; thiophanate methyl {dimethyl [(1,2-phenylene)bis-(iminocarbonothioyl)] bis [carbamate]}; myclobutanil [2-(4-chlorophenyl)-2-(1H-1,2,4-triazol-1-yl methyl) hexanenitrile]; cyproconazole [2-(4-chlorophenyl)-3-cyclopropyl-1-(1,2,4-triazol-1-yl)butan-2-ol]; propiconazole; fenarimol [alpha-(2-chlorophenyl)-alpha-(4-chlorophenyl)-5-

pyrimidinemethanol]; triadimefon; and vinclozolin [(RS)-3-(3,5-dichlorophenyl)-5-methyl-vinyl-1,3-oxazolidine-2,4-dione; 3-(3,5-dichlorophenyl)5-ethenyl-5-methyl-2,4-oxazolidinedione]. The effectiveness of triadimefon and chlorothalonil applied curatively in two spray volumes (407 and 814 L ha^{-1} of water) also was evaluated by Vincelli et al. (2003). Again, spray volume had no effect on fungicide efficacy when targeting dollar spot in fairway height creeping bentgrass. Couch (1984), however, found a direct relationship between spray volume and fungicide efficacy. Couch (1984) evaluated the effect of spray volume on curative dollar spot control in creeping bentgrass maintained as a putting green. Chlorothalonil, iprodione, and triadimefon were evaluated using seven spray volumes (203, 407, 814, 1628, 3255, 6510, and 13020 L ha^{-1}) and three different nozzle types. Results from the aforementioned study showed that chlorothalonil was most effective when applied in 407 L ha^{-1} when using a conventional flat-fan nozzle. Iprodione was equally effective when applied in 203, 407 814, and 1628 L ha^{-1} of water, and triadimefon was most effective when applied in 814 L ha^{-1}. In a study by McDonald et al. (2006), the level of dollar spot control in creeping bentgrass as influenced by spray volume and application timing were investigated. In that study, propiconazole, chlorothalonil, and a tank-mix combination of both fungicides were evaluated. Fungicides were applied in either 468 (50 GPA) or 1020 L (109 GPA) water ha^{-1}. Applications were made at three different times on the same day: AM with dew present, AM with dew displaced, and PM to a dry canopy. Results of this study showed that chlorothalonil generally was more effective in controlling dollar spot when applied in the lower spray volume (i.e., 468 L ha^{-1}; 50 GPA). When dew was displaced, chlorothalonil provided better dollar spot control on some rating dates in one of two years, when compared to the AM dew present treatment. Furthermore, chlorothalonil applied to a dry canopy in the PM generally resulted in increased efficacy, when compared to morning applications when dew was present. The performance of propiconazole alone and the propiconazole plus chlorothalonil tank-mix, however, were not influenced by spray volume, application timing or the presence or absence of dew.

Unpublished studies suggest that a higher spray volume may be more efficacious when targeting *S. homoeocarpa* for curative fungicide treatment (M. Fidanza, Pennsylvania State University, personal communication). The study by McDonald et al. (2006) focused on preventive dollar spot control. Furthermore, McDonald et al. (2006) applied each fungicide treatment at right angles (i.e., two passes across each plot) rather than in one direction, which probably improved coverage. This study will mimic the investigation reported by McDonald et al. (2006), but will differ in procedure as follows: (1) fungicide treatments will be applied curatively (i.e., post plant infection), rather than preventively; and (2) the fungicides will be applied in one direction without overlap, which more closely simulates how fungicides are applied professionally on golf courses. Hence, the objectives of this study were to assess the effectiveness of chlorothalonil, propiconazole and a tank-mix of chlorothalonil + propiconazole when applied in two spray volumes (468 and 935 L ha^{-1}) and two application timings (AM in the presence of canopy dew and PM to a dry canopy). The fungicides were applied curatively to target dollar spot in creeping bentgrass maintained as a fairway and were applied in one direction.

Materials and Methods

This field 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^{-1} soil. In 2007, treatments were applied to 'Crenshaw' creeping bentgrass, which was established in September 2006. In 2008, treatments were initiated on two different dates in separate stands of 'Crenshaw' and 'Backspin' creeping bentgrass. The 'Crenshaw' site was established in September 2007, whereas, 'Backspin' was established in September 2006. The study sites were mowed three times weekly to a height of about 12 mm and clippings were removed. Study sites were not mowed within 24 h of a fungicide application. Turf was irrigated as needed to prevent drought stress, but water was not applied within 24 h of any fungicide application. Since nitrogen fertilizer can influence dollar spot severity, no nitrogen was applied during the study period to any site. Because dollar spot was annually and chronically severe in Backspin and Crenshaw, all sites had received numerous applications of fungicides in previous years as well as the current study year. While a diverse selection of fungicides were applied to the study sites, boscalid (3-pyridinecarboxamide, 2-chloro-N-(4'-chloro(1,1'-biphenyl)-2-yl), chlorothalonil and propiconazole were most common.

Chlorothalonil (Daconil Ultrex 87.5 WDG; Syngenta Crop Protection, Inc., Greensboro, NC) was applied at a rate of 8.1 kg a.i. ha^{-1}(3.2 oz prod/1000 ft^2); propiconazole (Banner MAXX 1.24 ME; Syngenta Crop Protection, Inc., Greensboro, NC) was applied at a rate of 0.5 kg a.i. ha^{-1} (1.0 fl oz prod/1000 ft^2); and the tank-mix of chlorothalonil plus propiconazole was applied at the aforementioned rates. The fungicides were applied at two different times as follows: in the morning with ample dew present in the turf canopy (AM), and in the afternoon when the turf canopy was completely dry (PM). Dew was measured immediately prior to all fungicide applications using the method described by Williams et al. (1998). All fungicides were applied using a CO_2 pressurized backpack sprayer (262 kPa; 35 psi) equipped with two nozzles spaced 46.8 cm (18 in) apart. During application, the sprayer passed over each plot once, thus simulating the method used on most golf courses. The sprayer was equipped with two, 8004 or 8008 TeeJet (Spraying Systems, Wheaton, IL) flat-fan nozzles calibrated to deliver fungicides in a water volume of 468 L ha^{-1} (50 GPA) or 935 L ha^{-1} (100 GPA), respectively.

In 2007, fungicides were applied initially on 9 July, when dollar spot was active, but disease pressure was low. In both years, AM treatments were applied between 0700 and 0800 h and PM treatments were applied between 1200 and 1400 h. In 2007, when one of the treatments, usually chlorothalonil, lost residual effectiveness all treatments were reapplied on 24 July and again on 10 August. In 2008, fungicides were applied to Backspin initially on 27 June, when dollar spot was active, but disease pressure was low. All treatments were reapplied to Backspin on 13 July 2008. Chlorothalonil- treated plots had reached the reapplication threshold four days earlier (i.e., 9 July), but reapplication was delayed to allow for plots treated with propiconazole and the tank-mix to lose residual effectiveness in Backspin. Fungicides were applied to the Crenshaw site initially on 17 July 2008 when dollar spot was active and disease pressure was greater than in the Backspin. In Crenshaw, a fungicide was reapplied when each treatment lost effectiveness on the following dates: chlorothalonil (31 July and 12 August); propiconazole (4 and 27 August); and chlorothalonil + propiconazole (4 August and 3 September).

Dollar spot was assessed by counting the number of *S. homoeocarpa* infection centers (IC's) plot^{-1}. In 2007, a reapplication threshold was arbitrarily established at 30 IC's plot^{-1} to ensure plots were not severely damaged, but was lowered to 20 IC's in 2008. Plots measured 1.2 m by 1.8 m and were arranged in a randomized complete block with four replications. There was a 30 cm creeping bentgrass border between all plots to minimize dew displacement when walking from one plot to another. Disease data were examined for normality using the SAS Plot procedure (SAS version 9.1; SAS Institute, Cary, NC). Disease data were square-root transformed to satisfy the assumption that data were normally distributed prior to conducting a two-way analysis of variance (ANOVA). Significantly different means were separated by Fisher's protected least significant difference test at $P \leq 0.05$ using the SAS Mixed procedure. Pre-planned orthogonal contrasts were used to examine the importance of spray volume and application timing on fungicide performance.

Results

Crenshaw 2007

All treatments initially were applied on 9 July, and were reapplied (24 July and 10 August) when dollar spot levels exceeded 30 IC's. Data collection ceased on 29 August 2007. There were no significant spray volume differences for chlorothalonil (Appendix II Table 2). On two, late season rating dates (i.e., 24 and 27 August), chlorothalonil-treated plots subjected to the PM application timing had significantly more IC’s compared to plots subjected to AM application (Table 3). No other timing differences occurred in chlorothalonil-treated plots. Plots treated with propiconazole in the low spray volume (468 L ha^{-1}) developed more IC’s compared to the high spray volume (935 L ha^{-1}) plots on the earliest rating dates (i.e., 20, 23, and 27 July), but not thereafter (Table 4). There was a non-significant trend for less dollar spot in plots treated with propiconazole in the high spray volume between 2 and 13 August (Table 4). The AM applications of propiconazole resulted in significantly less dollar spot control early in the study (i.e., 20, 23, and 27 July and 2 August), when compared to PM applications, but not later (Table 5). There was, however, a non-significant trend for less disease in PM treated plots with propiconazole between 6 and 20 August. There were no significant spray volume or application timing differences among chlorothalonil + propiconazole tank-mix treatments in 2007 (Appendix II Table 3).

Backspin 2008

All treatments initially were applied on 27 June and a second application was made on 13 July. The second application was made four days after chlorothalonil-treated plots had exceeded the threshold (20 IC’s $plot^{-1}$), and was delayed to allow for other fungicide treatments to lose residual effectiveness. Data collection ceased on 8 August 2008.

In chlorothalonil -treated plots there were greater numbers of IC’s on 8 of 17 rating dates in low versus high spray volume plots (Table 6). Significant differences between spray volume treatments in chlorothalonil-treated plots were first observed on 7 July. On most dates between 7 and 28 July there were more IC’s in low versus high spray volume plots (Table 8). From the time of initial loss in effectiveness (i.e., 7 July) until the time of fungicide reapplication (i.e., 13 July), there were more IC's on three rating dates in low (8.9, 28.4, and 51.9 IC's) compared to high (4.3, 13.4, and 38.4 IC's) spray volume plots. Beginning on 21 July, plots treated with chlorothalonil using the low spray volume had significantly more IC's compared to high spray volume plots until 28 July, or about 15 days since the second application (i.e., 13 July). After 30 July, and until data collection ceased, there was a non-significant trend for less dollar spot in the high spray volume plots.

There was one rating date in propiconazole-treated plots where more IC's were observed in plots subjected to the low versus high spray volume (11 July). Two days before reapplication (i.e. 13 July), low spray volume propiconazole- treated plots had significantly more IC's (19.5 IC's) than high spray volume plots (6.8 IC's; Table 9). No significant IC differences were observed between spray volumes following the reapplication of propiconazole, but there was a non-significant trend for less dollar spot in high spray volume plots. There were no spray volume differences for the chlorothalonil + propiconazole treatment applied to Backspin on all rating dates (Appendix II Table 6).

On 12 of 17 rating dates, chlorothalonil plots treated in the PM had more IC's than AM treated plots (Table 10). Plots subjected to PM and AM applications of chlorothalonil began to lose effectiveness 10 (i.e., 7 July) and 12 days (i.e., 9 July) after initial application, respectively. Differences between treatments occurred on three rating dates prior to the reapplication of chlorothalonil (i.e., 7, 9, and 11 July). On the aforementioned dates, IC's were greater in PM (11.1, 26.6, and 52.8 IC's) versus AM (2.0, 15.1, and 37.5 IC's) plots treated with chlorothalonil. After reapplication of chlorothalonil on 13 July, dollar spot levels declined until 23 July in plots of both timings. During this period, chlorothalonil plots treated in the PM had higher (33.6 and 25.3 IC's) dollar spot levels than AM treated plots (22.9 and 14.3 IC's) on 15 and 16 July. Beginning on 23 July and continuing to 6 August, there were more IC's on six of seven rating dates in PM (34.0 to 124.6 IC's) than AM (20.5 to 108.6IC's) plots treated with chlorothalonil. There were no significant differences between AM and PM mowing timings in propiconazole or chlorothalonil + propiconazole-treated plots on any rating date in Backspin (Appendix II Tables 7 and 8).

Crenshaw 2008

All treatments were applied on 17 July 2008 and each fungicide was reapplied as follows: chlorothalonil on 31 July and 12 August; propiconazole on 4 and 27 August; and chlorothalonil + propiconazole on 4 August and 3 September. Data collection ceased on 17 September. There was a considerable amount of dollar spot at the time of the initial application and dollar spot severity was greater in the Crenshaw than Backspin. Unlike what was observed in Backspin, chlorothalonil and propiconazole generally performed better when applied in the low spray volume in Crenshaw.

Significant spray volume differences were detected in chlorothalonil-treated plots on 9 of 25 rating dates (Table 11). Dollar spot levels fell following the first chlorothalonil application, as was observed in previous studies. Both low and high spray volume chlorothalonil- treated plots began to lose effectiveness 11 days (i.e., 28

July) after application. On the aforementioned rating date, there were significantly more IC's in high (19.4 IC's) compared to low (10.9 IC's) spray volume plots (Table 13). Dollar spot levels reached the threshold on 31 July and chlorothalonil was reapplied. Dollar spot levels fell gradually, but again increased and exceeded the threshold on 11 August. During the period between the second and third application of chlorothalonil, there were no dates in which significant differences were observed between the two spray volumes. Chlorothalonil was reapplied the third time on 12 August, and on the following day there were significantly fewer IC's in low (17.0 IC's) versus high (27.3 IC's) spray volume plots. Dollar spot levels decreased until 25 August, when effectiveness declined in both spray volume treatments. After 25 August, spray volume differences were observed on seven dates (30 August, and 4, 8, 10, 12, 15, and 17 September). On the aforementioned dates, there were fewer IC's in plots subjected to the low (i.e., 13.1, 30.3, 67.8, 71.1, 74.7, 78.4, and 82.4 IC's) versus the high spray volume (24.8, 42.8, 95.5, 100.3, 105.3, 110.6, and 116.1 IC's). Although dollar spot levels were well above the threshold at this time, the disease was allowed to progress to determine if differences would continue to be observed. Except on 5 August, all chlorothalonil- treated plots receiving the high spray volume had higher levels of dollar spot than low spray volume plots.

After the initial application of propiconazole (i.e., 17 July), both low and high spray volume plots began to lose effectiveness on 28 July. There were, however, no spray volume differences observed between the first and second propiconazole application. Following the second propiconazole application (i.e., 4 August), IC's increased for one rating date, and then decreased and the creeping bentgrass began to recover. Dollar spot levels were lowest on 15 August. At this time, fewer IC's were observed in low (2.4 IC's) versus the high (7.1 IC's) spray volume plots (Table 14). Dollar spot began to increase in the study area following 15 August. On 20 August, there were fewer IC's in plots subjected to the low (8.0 IC's) versus high (18.0 IC's) spray volume. Propiconazole was reapplied a third time on 27 August, but no spray volume differences were observed after 20 August. Throughout most of the study, there was a non-significant trend in which there were fewer IC's in low versus high spray volume plots treated with propiconazole. However, significant differences were observed on only two dates (i.e., 15 and 20 August). There were no spray volume differences on any date in Crenshaw treated with the tank-mix of chlorothalonil + propiconazole (Appendix II Table 10).

Chlorothalonil provided better dollar spot control when applied in the PM on three rating dates between 28 July to 1 August 2008 in Crenshaw, but not on any date before or after (Table 15). There were application timing differences in propiconazole- treated plots on five dates (i.e., 13, 15, 18, 20, and 27 August; Table 16). On the aforementioned dates, dollar spot levels were lower in AM versus PM plots treated with propiconazole. There were no application timing differences among plots treated with the tank-mix of chlorothalonil + propiconazole (Appendix II Table 11).

Dew Measurements 2007 and 2008

Dew measurements were obtained on the morning just prior to each fungicide application in all years and sites (Figure 1). Application dates and dew measurements for Crenshaw in 2007 were: 9 July = 1120.0 L ha^{-1}; 24 July = 127.5 L ha^{-1}; and 10

September = 860.0 L ha^{-1}. Application dates and dew measurements for Backspin in 2008 were: 27 June = 1033.3 L ha^{-1} and 13 July = 950.0 L ha^{-1}. Application dates and dew measurements for Crenshaw in 2008 were: 17 July = 1833.3 L ha^{-1}; 31 July = 1296.7 L ha^{-1}; 4 August = 2010.4 L ha^{-1}; 12 August = 1546.2 L ha^{-1}; 27 August = 1345.9 L ha^{-1}; and 3 September = 1885.9 L ha^{-1}.

Discussion

It again should be noted that in the study reported by McDonald et al. (2006), treatments were applied preventively and dollar spot pressure was not allowed to exceed 8 to 10 IC's before treatments were reapplied. Moreover, the fungicide treatments were sprayed in two directions at right angles to ensure uniform coverage. In this study, treatments were applied curatively and reapplications generally were made when there were high (> 20 IC's) levels of dollar spot. Furthermore, fungicide treatments were applied in one direction rather than at right angles. Most differences between spray volumes and applications timings were observed in plots treated with chlorothalonil and propiconazole applied separately. The chlorothalonil + propiconazole tank-mix treatment, however, was unaffected by either spray volume or application timing in all three sites in both 2007 and 2008. Indeed, only the tank-mix treatment performed the same in the current study and that reported by McDonald et al. (2006).

In 2007, only propiconazole was impacted by both spray volume and application timing. On the first five rating dates between 16 July and 2 August, there generally was more dollar spot in plots treated with propiconazole in the low spray volume and in the AM. On two rating dates, there was more dollar spot in PM than

AM treated chlorothalonil plots, but there were no spray volume differences in chlorothalonil-treated plots in 2007. Conversely, McDonald et al. (2006) found that propiconazole was unaffected by spray volume and application timing and that chlorothalonil consistently performed better when applied in the low spray volume to a dry turf in the PM.

Treatments were initiated early summer in Backspin (i.e., 27 June) and later in Crenshaw (17 July) in 2008. Dollar spot levels were greater in Crenshaw than Backspin and the results between sites were contradictory. In Backspin, chlorothalonil generally provided better dollar spot control when applied in the low spray volume and in the AM, which was opposite of that reported by McDonald et al (2006). On one date in the Backspin, propiconazole provided better dollar spot control when applied in the high spray volume, and there was a non-significant trend of similar results on all other rating dates. There were no significant timing differences for propiconazole in Backspin, but there was a non-significant trend for greater dollar spot levels in PM treated plots on most dates between 5 August and 17 September. Conversely, in Crenshaw in 2008, chlorothalonil was more effective when applied in the low spray volume on 9 of 11 dates and in the PM on three early rating dates. Similarly, propiconazole was more effective when applied in the low spray volume on two dates in Crenshaw (15 and 20 August) and in PM plots on most dates between 13 and 27 August. The 2008 Crenshaw results for chlorothalonil were similar to the findings of McDonald et al. (2006).

Dew measurements ranged from 128 to 2010 L ha^{-1} and the average amount of canopy dew present in each year was 702 (2007), 991 (2008 Backspin), and 1652

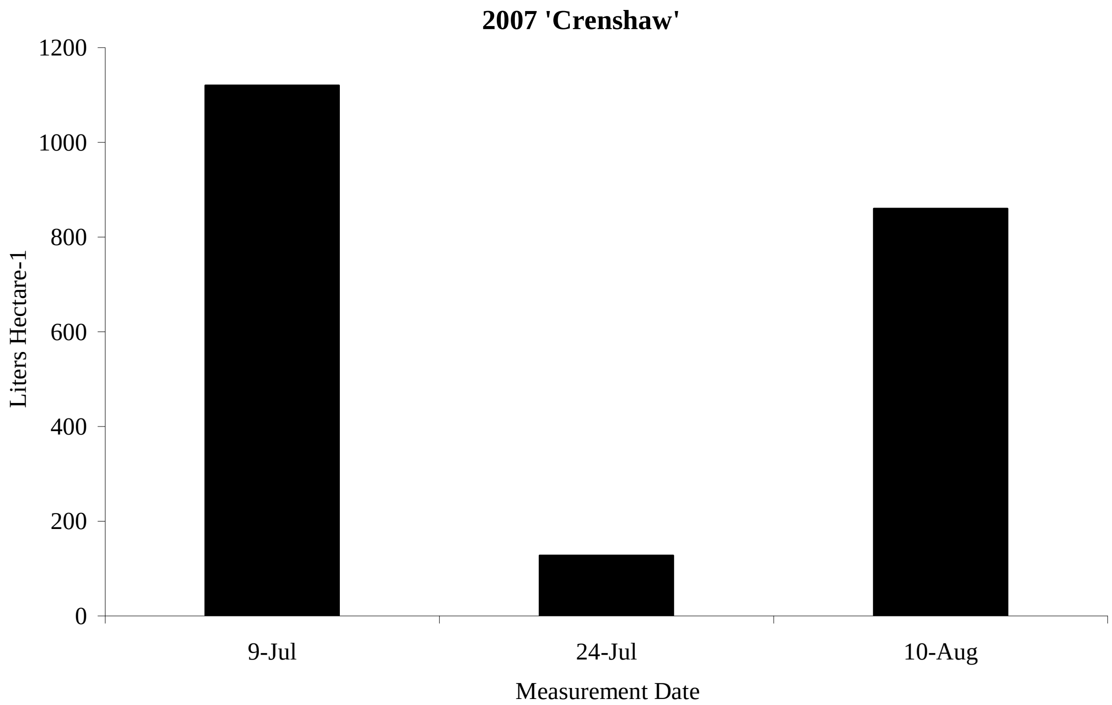
L ha^{-1} (2008 Crenshaw 2008). McDonald et al. (2006), working in the same general area as the current study, found that the amount of canopy dew ranged between 982 and 2548 L ha^{-1}, with a mean of 1842 L ha^{-1}. Hence, canopy dew levels generally were much lower in the current study compared to that reported by McDonald et al. (2006). It does not seem likely, however, that the differences in dew measurements between the two investigations would have accounted for the mixed results observed in the current study.

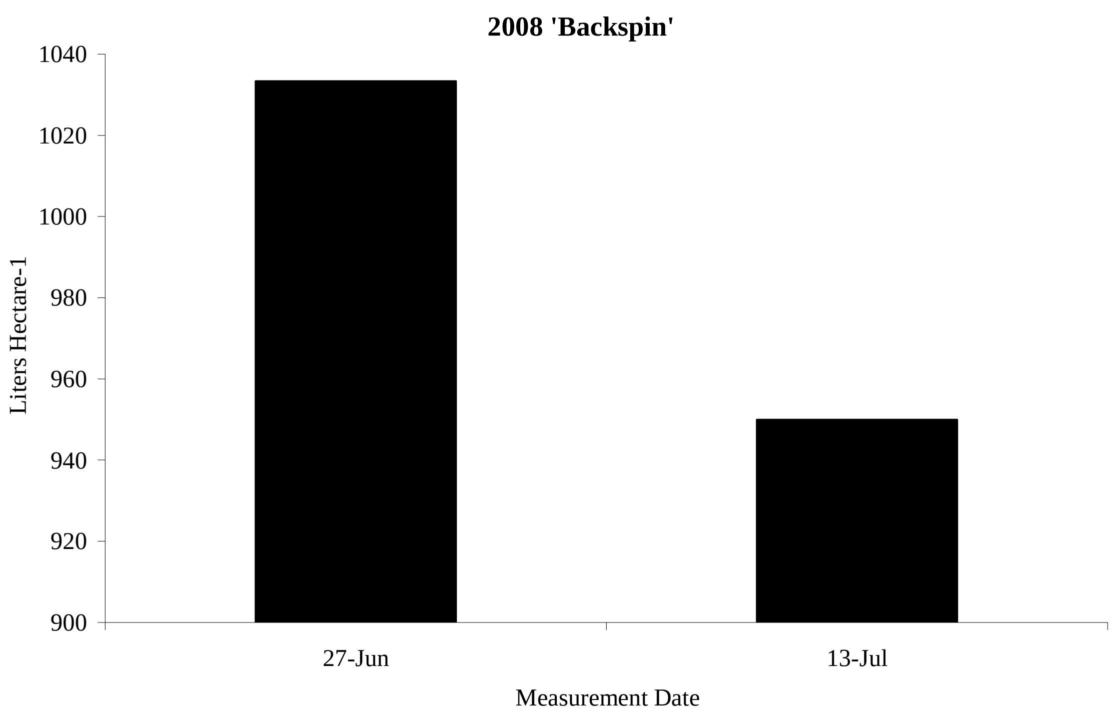
The field study reported by McDonald et al. (2006) was conducted over a three year period in three different cultivars of creeping bentgrass. McDonald et al. (2006) consistently observed better dollar spot control with chlorothalonil applied in 468 L ha^{-1} (50 GPA) in the PM versus 1020 L ha^{-1} (109 GPA) in the AM. The magnitude of the differences observed, however, was small and they concluded that superintendents could apply chlorothalonil in 468 L ha^{-1} just as effectively as in 1020 L ha^{-1}. McDonald et al. (2006) did not observe any spray volume or application timing treatment effects with either propiconazole or the tank-mix of chlorothalonil + propiconazole. They concluded that it was likely that propiconazole was rapidly taken up by contacted foliage, regardless of spray volume or application timing. As previously noted, the current study was designed to evaluate spray volume and timings similar to McDonald et al. (2006). However, in the current study the fungicides were applied curatively rather than preventively. Additionally, there were much higher disease levels at the time fungicides were reapplied, and the chemicals were applied in only one direction. While chlorothalonil results from the Crenshaw site in 2008 were similar to those of McDonald et al. (2006), other data presented here were contradictory. McDonald et al. (2006) applied the fungicides at right angles, which likely resulted in much improved coverage versus a one direction application. The better coverage using the method employed by McDonald et al. (2006) would likely impact chlorothalonil performance more since it is a contact protectant, which will not be taken into tissue and redistributed. Furthermore, McDonald et al. (2006) applied fungicides prior to the advent of disease expression and never allowed dollar spot to exceed a threshold of 8 to 10 IC's before a fungicide was reapplied. Hence, the much lower level of disease pressure and improved coverage of fungicides probably accounted for the differences observed between the current and aforementioned study. For the tank-mix of chlorothalonil + propiconazole, both studies showed that the spray volumes and application timings evaluated did not affect the level of dollar spot control..

In general, 2007 and 2008 (Backspin) data from chlorothalonil and propiconazole-treated plots were similar and contradicted McDonald et al. (2006); whereas, chlorothalonil data from Crenshaw in 2008 were similar to the aforementioned study. The largest difference among studies reported here was that dollar spot was much more severe in Crenshaw in 2008 than in either 2007 or in Backspin in 2008.

Hence, results between years and among sites in the current study were mixed and inconclusive for chlorothalonil and propiconazole applied separately, but not for the tank-mix. The lack of consistency may be attributed to the higher levels of disease activity present in the curative approach of this study and possibly the one direction application methodology. There likely are several other unknown factors, which influenced results. For example, variable environmental conditions, the level of disease severity at the time of fungicide application as well as disease potential (i.e., increasing versus decreasing) within an epidemic may have greatly influenced treatment performance and thus impacted results. Furthermore, it is probable that the usage of different fungicide chemistries overtime and the potential for pathogen strains with variable sensitivities to different chemistries within a site could impact fungicide performance. The type of nozzle and spray equipment, the fungicide formulation and water pH also could influence fungicide performance. It also should be noted that Ashbaugh and Larsen (1984) and Vincelli et al. (2003) found no spray volume differences for a variety of fungicides targeting dollar spot curatively in one year field studies. Hence, there is no compelling evidence at this time to recommend the use of a higher (935 L ha^{-1}) versus lower (468 L ha^{-1}) spray volume for targeting dollar spot, especially when tank-mixing chlorothalonil + propiconazole. Using a lower spray volume would be advantageous since less water would be used, the time it takes to apply a fungicide would be reduced and labor and equipment costs would be reduced. For golf course superintendants who experience difficulty in controlling dollar spot on greens, it is recommended that fungicides be applied prior to the time of symptom expression (i.e., preventively) and in two directions to ensure more thorough canopy coverage. As noted by Vincelli and Dixon (2007), dollar spot control was improved when using nozzles that provide complete coverage, when compared to nozzle types that provide incomplete coverage. Hence, improving coverage will improve the level of dollar spot control as well as consistency. Obviously, this would be a logistical problem for spraying fairways, where much greater areas of land are involved. The time treatments were applied in this study (i.e., AM versus PM) also yielded mix results. Data from the simulated rain study in this thesis as well as the findings of Williams et al. (1996) and Ellram et al.(2007) have shown that AM mowing reduces dollar spot severity. In addition, McDonald et al. (2006) found that displacing dew in the morning prior to application can sometimes improve fungicide effectiveness. Hence, it also is recommended that superintendents mow prior to fungicide application, when spraying in the morning in the presence of dew. These findings and conclusions apply only to chlorothalonil, propiconazole, and a tank-mix of the two fungicides applied in the spray volumes and timings evaluated and when targeting dollar spot in creeping bentgrass.

Figure 1. Dew measurements (L ha^{-1}) taken prior to each fungicide application in 2007 and 2008.





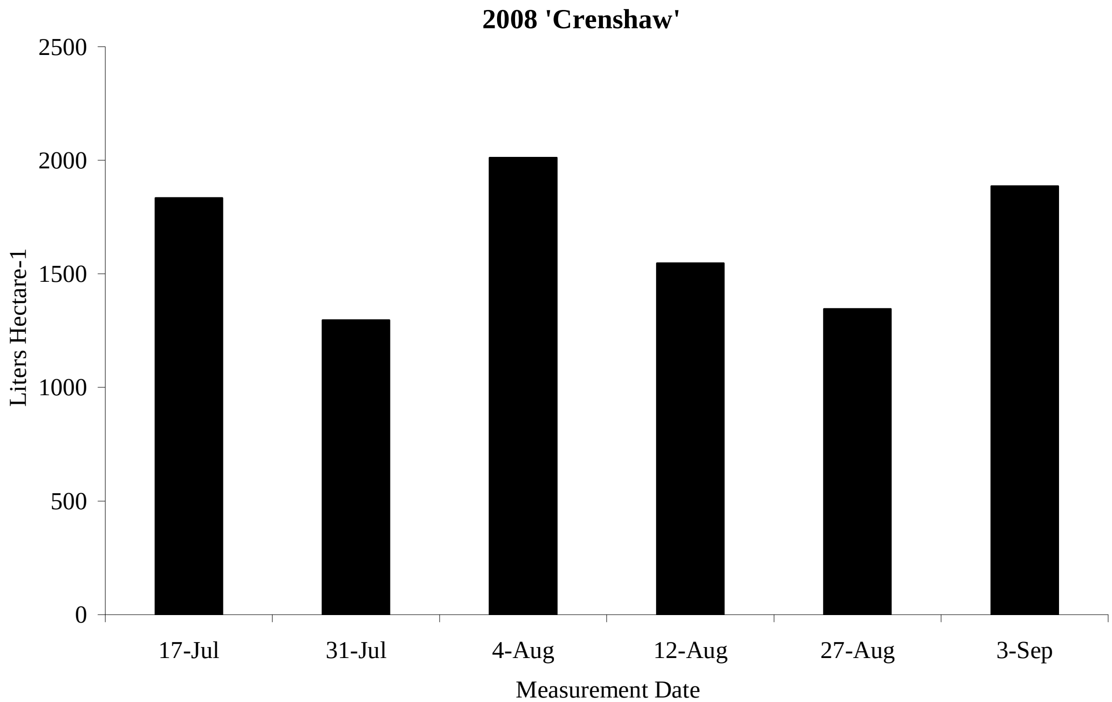

2008 'Crenshaw'
Liters Hectare-1
2500
2000
1500
1000
500
0
17-Jul
31-Jul
4-Aug
12-Aug
27-Aug
3-Sep
Measurement Date

Table 1. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two spray volume treatments (468 vs. 935 L ha^{-1}) in 'Crenshaw' creeping bentgrass, 2007.

Contrast (468 vs. 935 L ha^{-1})	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	NS	NS	NS
Propiconazole	**	**	**	***	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
Chlorothalonil	NS	NS	NS	NS	NS	NS	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS

[x] Treatments were applied 9 and 24 July and 10 August 2007.
[y] The number of infection centers in each plot was counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels, and non-significant, respectively.

Table 2. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two application timing treatments (AM vs. PM) in ‘Crenshaw’ creeping bentgrass, 2007.

Contrast (AM vs. PM)	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	NS	NS	NS
Propiconazole	NS	***	**	*	*	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
Chlorothalonil	NS	NS	NS	NS	***	*	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS

[x] Treatments were applied 9 and 24 July and 10 August 2007.

[y] The number of infection centers in each plot was counted.

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

Table 3. Effect of two application timings on chlorothalonil performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2007.

Chlorothalonil [x] (Timing)	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
AM	0.1 a [z]	1.8 a	9.5 a	0.3 a	3.6 a	8.8 a	26.0 a
PM	0.1 a	0.8 a	10.8 a	0.1 a	4.4 a	9.1 a	26.1 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
AM	49.9 a	25.3 a	16.5 a	0.5 a	14.8 b	36.6 b	79.9 a
PM	54.5 a	27.8 a	23.1 a	1.3 a	28.9 a	51.1 a	81.6 a

[x] Chlorothalonil was applied 9 and 24 July and 10 August 2007.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 4. Effect of two spray volumes on propiconazole performance when targeting dollar spot in fairway height ‘Crenshaw’ creeping bentgrass, 2007.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]						
(L ha^{-1})	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
468	0.6 b [z]	4.8 a	16.9 a	1.5 a	5.1 a	6.4 a	25.6 a
935	2.0 a	2.3 b	6.4 b	0.0 b	2.5 a	3.9 a	18.0 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
468	45.5 a	20.3 a	13.3 a	1.3 a	9.3 a	19.0 a	45.0 a
935	39.3 a	17.3 a	13.9 a	1.3 a	7.5 a	16.0 a	43.4 a

[x] Propiconazole was applied 9 and 24 July and 10 August 2007.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Table 5. Effect of two application timings on propiconazole performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2007.

Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
AM	1.1 a [z]	5.5 a	17.0 a	1.3 a	5.8 a	7.5 a	27.9 a
PM	1.5 a	1.5 b	6.3 b	0.3 b	1.9 b	2.8 a	15.8 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
AM	49.3 a	22.8 a	15.5 a	1.8 a	7.6 a	15.4 a	37.4 a
PM	35.5 a	14.8 a	11.6 a	0.8 a	9.1 a	19.6 a	51.0 a

[x] Propiconazole was applied 9 and 24 July and 10 August 2007.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 6. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two spray volume treatments (468 vs. 935 L ha^{-1}) in 'Backspin' creeping bentgrass, 2008.

Contrast (468 vs. 935 L ha^{-1})	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
Chlorothalonil [x]	NS [z]	NS	*	***	**	*	NS	NS	**
Propiconazole	NS	NS	NS	NS	*	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS

	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug
Chlorothalonil	*	*	*	NS	NS	NS	NS	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS

[x] All treatments were applied 27 June and 13 July 2008.
[y] The number of infection centers in each plot was counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 7. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two application timing treatments (AM vs. PM) in 'Backspin' creeping bentgrass, 2008.

Contrast	*S. homoeocarpa* infection centers [y]								
(AM vs. PM)	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
Chlorothalonil [x]	* [z]	NS	***	***	**	*	**	NS	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
Chlorothalonil	***	***	**	*	NS	*	*	NS	
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	

[x] All treatments were applied 27 June and 13 July 2008.
[y] The number of infection centers in each plot was counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 8. Effect of two spray volumes on chlorothalonil performance when targeting dollar spot in fairway height 'Backspin' creeping bentgrass, 2008.

Chlorothalonil [x] ($L\ ha^{-1}$)	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
468	4.1 a [z]	1.8 a	8.9 a	28.4 a	51.9 a	34.3 a	22.1 a	17.3 a	15.4 a
935	2.1 a	0.6 a	4.3 b	13.4 b	38.4 b	22.3 b	17.4 a	12.0 a	8.4 b
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
468	30.5 a	39.5 a	54.6 a	77.5 a	79.4 a	108.3 a	111.3 a	120.4 a	
935	24.0 b	33.1 b	44.0 b	65.8 a	71.8 a	99.9 a	102.9 a	112.9 a	

[x] Chlorothalonil was applied 27 June and 13 July 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 9. Effect of two spray volumes on propiconazole performance when targeting dollar spot in fairway height ‘Backspin’ creeping bentgrass, 2008.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]								
(L ha^{-1})	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
468	1.4 a [z]	1.0 a	0.1 a	4.8 a	19.5 a	5.4 a	3.8 a	0.9 a	0.8 a
935	2.8 a	1.6 a	0.9 a	2.1 a	6.8 b	1.9 a	0.8 a	0.4 a	0.4 a
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
468	1.5 a	4.5 a	8.3 a	17.4 a	29.6 a	51.3 a	54.3 a	64.8 a	
935	0.5 a	0.9 a	5.4 a	10.6 a	18.9 a	42.0 a	45.0 a	55.3 a	

[x] Propiconazole was applied 27 June and 13 July 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Table 10. Effect of two application timings on chlorothalonil performance when targeting dollar spot in fairway height 'Backspin' creeping bentgrass, 2008.

Chlorothalonil [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
AM	1.1 b [z]	0.3 a	2.0 b	15.1 b	37.5 b	22.9 b	14.3 b	11.9 a	11.1 a
PM	5.1 a	2.1 a	11.1 a	26.6 a	52.8 a	33.6 a	25.3 a	17.4 a	12.6 a
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
AM	20.5 b	30.3 b	42.6 b	64.5 b	77.0 a	95.6 b	98.6 b	108.6 a	
PM	34.0 a	42.4 a	56.0 a	78.8 a	74.1 a	112.5 a	115.5 a	124.6 a	

[x] Chlorothalonil was applied 27 June and 13 July 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 11. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two spray volume treatments (468 vs. 935 L ha^{-1}) in 'Crenshaw' creeping bentgrass, 2008.

Contrast	*S. homoeocarpa* infection centers [y]								
(468 vs. 935 L ha^{-1})	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	*	NS	NS	NS	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
Chlorothalonil	NS	NS	*	NS	NS	NS	NS	NS	
Propiconazole	NS	NS	NS	*	NS	***	NS	NS	
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
Chlorothalonil	*	NS	*	**	**	**	**	**	
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	

[x] All treatments were applied on 17 July; chlorothalonil was reapplied on 31 July and 12 August; propiconazole was reapplied on 4 and 27 August; and chlorothalonil + propiconazole was reapplied on 4 August and 3 September 2008.
[y] The number of infection centers in each plot was counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 12. Pre-planned orthogonal contrast significance levels for three fungicides contrasted against two application timing treatments (AM vs. PM) in ‘Crenshaw’ creeping bentgrass, 2008.

Contrast (AM vs. PM)	*S. homoeocarpa* infection centers								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	*	*	**	NS	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
Chlorothalonil	NS	NS	NS	NS	NS	NS	NS	NS	
Propiconazole	NS	NS	**	*	*	**	NS	*	
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
Chlorothalonil	NS	NS	NS	NS	NS	NS	NS	NS	
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	

[x] All treatments were applied on 17 July; chlorothalonil was reapplied on 31 July and 12 August; propiconazole was reapplied on 4 and 27 August; and chlorothalonil + propiconazole was reapplied on 4 August and 3 September 2008.
[y] The number of infection centers in each plot was counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Table 13. Effect of two spray volumes on chlorothalonil performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2008.

Chlorothalonil [x] ($L\ ha^{-1}$)	*S. homoeocarpa* infection centers [y]								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
468	10.8 a [z]	2.8 a	2.4 a	0.5 a	10.9 b	19.1 a	33.0 a	20.5 a	7.9 a
935	11.4 a	1.3 a	1.1 a	0.4 a	19.4 a	25.0 a	38.5 a	17.6 a	9.9 a

	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug
468	9.9 a	24.3 a	17.0 b	10.6 a	3.6 a	0.6 a	1.6 a	4.0 a
935	13.8 a	32.4 a	27.3 a	15.3 a	4.1 a	1.1 a	3.1 a	7.5 a

	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep
468	13.1 b	32.0 a	30.3 b	67.8 b	71.1 b	74.7 b	78.4 b	82.4 b
935	24.8 a	44.3 a	42.8 a	95.5 a	100.3 a	105.3 a	110.6 a	116.1 a

[x] Chlorothalonil was applied on 17 and 31 July and 12 August 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 14. Effect of two spray volumes on propiconazole performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2008.

Propiconazole [x] (L ha^{-1})	*S. homoeocarpa* infection centers [y]								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
468	7.0 a [z]	1.4 a	0.1 a	0.1 a	2.6 a	5.3 a	19.1 a	35.0 a	32.1 a
935	10.8 a	2.5 a	2.3 a	0.4 a	5.8 a	13.0 a	24.5 a	48.0 a	39.0 a

	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug
468	18.6 a	7.6 a	6.0 a	2.4 b	7.5 a	8.0 b	21.3 a	28.8 a
935	25.0 a	14.1 a	11.8 a	7.1 a	11.6 a	18.0 a	25.9 a	34.9 a

	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep
468	11.3 a	7.8 a	1.3 a	18.3 a	35.0 a	36.8 a	38.6 a	40.5 a
935	20.3 a	14.6 a	8.1 a	18.5 a	47.4 a	49.7 a	52.2 a	54.8 a

[x] Propiconazole was applied on 17 July and 4 and 27 August 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 15. Effect of two application timings on chlorothalonil performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2008.

Chlorothalonil [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
AM	10.9 a [z]	1.9 a	1.5 a	0.4 a	18.9 a	27.6 a	44.9 a	23.3 a	10.1 a
PM	11.3 a	2.1 a	2.0 a	0.5 a	11.4 b	16.5 b	26.6 b	14.9 a	7.6 a
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
AM	10.1 a	28.0 a	20.9 a	11.9 a	4.9 a	0.6 a	3.1 a	6.9 a	
PM	13.5 a	28.6 a	23.4 a	14.0 a	2.9 a	1.1 a	1.6 a	4.6 a	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
AM	21.9 a	40.4 a	36.9 a	86.6 a	91.0 a	95.5 a	100.3 a	105.3 a	
PM	16.0 a	35.9 a	36.1 a	76.6 a	80.5 a	84.5 a	88.7 a	93.1 a	

[x] Chlorothalonil was applied on 17 and 31 July and 12 August 2008.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Table 16. Effect of two application timings on propiconazole performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2008.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]								
(Timing)	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
AM	9.0 a [z]	1.9 a	1.1 a	0.0 a	2.6 a	7.9 a	21.9 a	37.1 a	32.4 a
PM	8.8 a	2.0 a	1.3 a	0.5 a	5.8 a	10.4 a	21.8 a	45.9 a	38.8 a
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
AM	16.6 a	8.0 a	3.0 b	2.3 b	6.0 b	10.1 b	18.9 a	26.0 b	
PM	27.0 a	13.8 a	14.8 a	7.3 a	13.1 a	15.9 a	28.3 a	37.6 a	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
AM	12.4 a	7.5 a	2.1 a	18.4 a	36.5 a	38.3 a	40.2 a	42.3 a	
PM	19.1 a	14.9 a	7.3 a	18.4 a	45.9 a	48.2 a	50.6 a	53.1 a	

[x] Propiconazole was applied on 17 July and 4 and 27 August 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, *P*≤ 0.05.

Appendix I

Appendix I Table 1. Analysis of variances of three variables and their interactions in the simulated rain study, 2007.

	S. homoeocarpa infection centers										
Variable	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug	3 Aug
Mowing	NS [z]	NS	NS	NS	**	*	*	*	NS	*	*
Rain	NS	NS	*	NS	*	NS	NS	*	NS	NS	NS
Chemical	NS	NS	NS	*	NS	***	***	***	***	**	***
Rain*Mowing	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rain*Chemical	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Rain*Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Appendix I Table 1 (cont'd). Analysis of variances of three variables and their interactions in the simulated rain study, 2007.

	S. homoeocarpa infection centers							
Variable	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug
Mowing	* [z]	*	**	*	**	*	NS	*
Rain	NS	*	**	*	*	NS	*	*
Chemical	*	***	***	***	***	***	***	***
Rain*Mowing	NS	NS	NS	NS	NS	NS	NS	NS
Mowing*Chemical	NS	NS	*	*	**	*	NS	NS
Rain*Chemical	*	**	**	*	*	NS	NS	NS
Rain*Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS	NS

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

Appendix I Table 2. Pre-planned orthogonal contrast significance levels for four fungicides contrasted against two rain treatments (i.e., simulated rain vs. rain-free), 2007.

Contrast (Rain vs. Rain-Free)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	*	**	*	** [z]	*	NS
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iprodione	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boscalid	**	NS	*	*	**	NS	NS	NS	NS	NS
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
Chlorothalonil	*	**	***	***	***	NS	NS	**	***	
Propiconazole	NS	NS	NS	NS	NS	*	NS	*	*	
Iprodione	NS	NS	NS	NS	NS	NS	**	*	NS	
Boscalid	NS	NS	NS	NS	NS	NS	NS	NS	NS	

[x] Chlorothalonil was applied 3 and 26 July and 10 August; whereas, all other fungicide treatments were applied 3 and 31 July 2007.

[y] The number of infection centers in each plot were counted.

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

Appendix I Table 3. Effect of simulated rain on chlorothalonil performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Chlorothalonil [x] (Simulated Rain)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Rain	0.9 a [z]	0.5 a	2.1 a	3.8 a	5.3 a	9.9 a	20.9 a	24.6 a	31.3 a	17.9 a
Rain- free	1.5 a	0.0 a	0.4 a	2.1 a	1.4 b	3.0 b	11.0 b	9.8 b	18.3 b	4.4 a
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
Rain	21.1 a	17.0 a	26.4 a	33.3 a	10.9 a	2.6 a	8.0 a	28.0 a	39.5 a	
Rain- free	3.6 b	3.3 b	6.5 b	7.1 b	3.5 b	3.0 a	0.4 a	5.6 b	15.0 b	

[x] Chlorothalonil was applied 3 and 26 July and 10 August 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 4. Effect of simulated rain on propiconazole performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]									
(Simulated Rain)	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Rain	0.6 a [z]	0.1 a	1.0 a	1.5 a	2.6 a	4.4 a	12.1 a	11.5 a	16.5 a	28.6 a
Rain- free	1.0 a	0.1 a	0.6 a	1.0 a	2.1 a	2.5 a	7.1 a	5.9 a	11.1 a	19.9 a
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
Rain	30.5 a	16.9 a	14.4 a	13.0 a	6.8 a	9.4 a	18.8 a	32.5 a	41.4 a	
Rain- free	20.8 a	9.5 a	5.6 a	4.9 a	2.8 a	4.4 b	11.8 a	14.5 b	25.4 b	

[y] Propiconazole was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 5. Effect of simulated rain on boscalid performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Boscalid [x] (Simulated Rain)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Rain	0.6 b [z]	0.5 a	2.9 a	3.4 a	4.4 a	4.9 a	9.6 a	9.1 a	10.9 a	19.6 a
Rain- free	3.1 a	0.5 a	0.9 b	1.0 b	0.8 b	0.9 a	3.4 a	3.0 a	5.3 a	14.6 a
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
Rain	27.0 a	9.1 a	4.6 a	3.1 a	0.8 a	0.8 a	3.6 a	10.6 a	25.5 a	
Rain- free	13.4 a	7.9 a	3.3 a	2.0 a	0.3 a	0.0 a	0.4 a	4.6 a	17.6 a	

[x] Boscalid was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 6. Effect of simulated rain on iprodione performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Iprodione [x] (Simulated Rain)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Rain	0.4 a [z]	0.0 a	0.5 a	0.8 a	0.8 a	0.9 a	4.4 a	4.1 a	6.8 a	16.8 a
Rain- free	0.4 a	0.1 a	0.1 a	0.8 a	1.1 a	1.5 a	4.6 a	3.5 a	6.8 a	12.9 a

	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug
Rain	15.6 a	5.3 a	3.6 a	2.4 a	0.5 a	1.1 a	20.9 a	44.8 a	54.8 a
Rain- free	13.1 a	6.0 a	3.1 a	1.1 a	0.6 a	0.0 a	5.4 b	28.1 b	43.0 a

[x] Iprodione was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 7. Analysis of variances of three variables and their interactions in the simulated rain study, 2008.

	S. homoeocarpa infection centers										
Variable	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug	2 Sep	4 Sep
Mowing	NS [z]	NS	NS	NS	NS	NS	*	*	NS	NS	*
Rain	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chemical	NS	NS	NS	NS	NS	NS	*	***	***	***	***
Rain*Mowing	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Rain*Chemical	*	*	NS	NS	NS	NS	NS	***	*	NS	NS
Rain*Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS

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

Appendix I Table 7 (cont'd). Analysis of variances of three variables and their interactions in the simulated rain study, 2008.

	S. homoeocarpa infection centers						
Variable	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Mowing	NS [z]	NS	*	*	*	NS	NS
Rain	NS	NS	*	**	*	NS	NS
Chemical	***	***	***	***	***	***	***
Rain*Mowing	NS	NS	NS	NS	NS	NS	NS
Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS
Rain*Chemical	**	***	*	***	***	***	***
Rain*Mowing*Chemical	NS	NS	NS	NS	NS	NS	NS

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

Appendix I Table 8. Pre-planned orthogonal contrast significance levels for five fungicides contrasted against two rain treatments (i.e., simulated rain vs. rain-free), 2008.

Contrast (Rain vs. No Rain)	*S. homoeocarpa* infection centers [y]								
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	*	**	** [z]	***	***
Propiconazole	*	NS	NS	NS	NS	NS	NS	NS	NS
Iprodione	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boscalid	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	**	***	NS	NS	NS	NS	NS	NS	NS
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Chlorothalonil	**	**	*	**	**	***	***	**	***
Propiconazole	NS	NS	NS	NS	*	**	**	*	*
Iprodione	NS	NS	NS	NS	*	NS	NS	NS	NS
Boscalid	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS

[x] All treatments were applied 7 August; chlorothalonil was reapplied 5 and 11 September; iprodione was reapplied 13 September; and propiconazole and chlorothalonil + propiconazole were reapplied 16 September 2008.
[y] The number of infection centers in each plot were counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix I Table 9. Effect of simulated rain on chlorothalonil performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Chlorothalonil [x]	*S. homoeocarpa* infection centers [y]								
(Simulated Rain)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Rain	1.6 a [z]	0.9 a	0.0 a	0.0 a	3.0 a	6.4 a	7.8 a	13.1 a	18.1 a
Rain-free	1.1 a	0.0 a	0.3 a	0.5 a	0.0 b	0.0 b	0.2 b	1.1 b	0.3 b
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Rain	20.0 a	30.6 a	29.4 a	42.2 a	36.4 a	60.8 a	51.9 a	51.4 a	37.8 a
Rain-free	2.3 b	3.0 b	0.1 b	0.8 b	0.5 b	1.0 b	1.8 b	1.4 b	0.4 b

[x] Chlorothalonil was applied 7 August and 5 and 11 September 2008.

[y] The number of infection centers in each plot were counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 10. Effect of simulated rain on propiconazole performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]								
(Simulated Rain)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Rain	5.5 a [z]	0.5 a	0.5 a	0.5 a	0.4 a	0.5 a	0.8 a	1.0 a	2.1 a
Rain-free	0.8 b	0.2 a	0.1 a	0.0 a	0.0 a	0.0 a	0.0 a	0.4 a	0.0 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Rain	4.6 a	9.3 a	11.6 a	18.9 a	18.4 a	31.0 a	36.4 a	34.3 a	23.3 a
Rain-free	0.0 a	0.3 a	0.0 a	1.8 a	3.0 b	7.2 b	8.1 b	8.1 b	5.1 b

[x] Propiconazole was applied 7 August and 16 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 11. Effect of simulated rain on boscalid performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Boscalid [x]	*S. homoeocarpa* infection centers [y]								
(Simulated Rain)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Rain	2.8 a [z]	1.0 a	0.0 a	1.0 a	3.3 a	1.5 a	1.0 a	1.5 a	2.0 a
Rain-free	3.5 a	0.0 a	1.4 a	1.0 a	0.1 a	0.0 a	0.3 a	1.8 a	1.0 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Rain	3.8 a	5.8 a	4.7 a	6.3 a	5.4 a	11.8 a	12.4 a	9.9 a	4.7 a
Rain-free	2.4 a	1.9 a	0.6 a	1.9 a	2.1 a	9.9 a	10.4 a	8.5 a	3.6 a

[x] Boscalid was applied 7 August 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 12. Effect of simulated rain on iprodione performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Iprodione [x]	*S. homoeocarpa* infection centers [y]								
(Simulated Rain)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Rain	3.5 a [z]	0.0 a	0.0 a	0.0 a	0.2 a	2.0 a	1.5 a	0.2 a	3.3 a
Rain-free	2.7 a	0.1 a	0.0 a	0.0 a	0.0 a	0.0 a	1.0 a	1.0 a	0.0 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Rain	5.2 a	10.2 a	18.7 a	31.0 a	30.7 a	22.2 a	14.5 a	14.7 a	6.5 a
Rain-free	0.0 a	0.7 a	1.3 a	3.2 a	6.0 b	4.0 a	0.7 a	1.0 a	0.0 a

[x] Iprodione was applied 7 August and 13 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 13. Effect of simulated rain on chlorothalonil + propiconazole tank-mix performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Chlorothalonil + Propiconazole [x] (Simulated Rain)	*S. homoeocarpa* infection centers [y]								
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Rain	0.9 b [z]	0.0 b	0.0 a	1.0 a	0.0 a	0.0 a	0.0 a	0.4 a	2.0 a
Rain-free	5.3 a	2.2 a	0.0 a	0.7 a	0.1 a	0.0 a	0.0 a	0.6 a	0.1 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Rain	3.5 a	6.3 a	8.5 a	13.5 a	12.8 a	19.8 a	21.9 a	18.6 a	14.1 a
Rain-free	0.2 a	1.9 a	2.2 a	7.2 a	7.8 a	26.2 a	28.0 a	28.0 a	20.6 a

[x] Chlorothalonil + Propiconazole was applied 7 August and 16 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$

Appendix I Table 14. Pre-planned orthogonal contrast significance levels for four fungicides contrasted against two mowing timings (i.e., AM vs. PM), College Park, MD 2007.

Contrast	*S. homoeocarpa* infection centers [y]									
(AM vs. PM)	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	**	**	**	** [z]	*	NS
Propiconazole	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Iprodione	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boscalid	*	*	NS	NS	*	*	*	NS	NS	NS
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
Chlorothalonil	*	**	***	***	***	NS	NS	**	**	
Propiconazole	*	*	NS	*	**	***	NS	*	*	
Iprodione	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Boscalid	*	*	NS	NS	NS	NS	NS	NS	*	

[x] Chlorothalonil was applied 3 and 26 July and 10 August; whereas, all other fungicide treatments were applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] *, **, ***, and NS refer to the 0.05, 0.01, 0.001 significance levels and non-significant, respectively.

Appendix I Table 15. Effect of two mowing timings (i.e., AM vs. PM) on chlorothalonil performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Chlorothalonil [x] (Timing)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
AM	1.3 a [z]	0.1 a	1.0 a	2.4 a	1.1 b	2.9 b	9.9 b	9.8 b	18.4 b	4.8 a
PM	1.1 a	0.4 a	1.5 a	3.5 a	5.5 a	10.0 a	22.0 a	24.6 a	31.1 a	17.5 a

	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug
AM	4.1 b	3.5 b	7.6 b	10.4 b	2.0 b	0.4 a	1.6 a	7.8 b	18.5 b
PM	20.6 a	16.8 a	25.3 a	30.0 a	11.9 a	2.6 a	8.5 a	25.9 a	36.0 a

[x] Chlorothalonil was applied 3 and 26 July and 10 August 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 16. Effect of two mowing timings (i.e., AM vs. PM) on propiconazole performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
AM	0.5 a [z]	0.1 a	0.5 a	0.9 a	1.3 a	1.4 b	6.9 a	5.5 a	11.3 a	17.5 a
PM	1.1 a	0.1 a	1.1 a	1.6 a	3.5 a	5.5 a	12.4 a	11.9 a	16.4 a	31.0 a

	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug
AM	18.4 b	8.4 b	6.0 a	4.1 b	1.8 b	2.9 b	11.5 a	15.3 b	24.9 b
PM	32.9 a	18.0 a	14.0 a	13.8 a	7.8 a	10.9 a	19.0 a	31.8 a	41.9 a

[x] Propiconazole was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted..
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 17. Effect of two mowing timings (i.e., AM vs. PM) on boscalid performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Boscalid [x]	*S. homoeocarpa* infection centers [y]									
(Timing)	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
AM	1.0 b [z]	0.0 b	2.6 a	1.6 a	1.0 b	0.8 b	2.4 b	2.6 a	3.6 a	12.1 a
PM	2.8 a	1.0 a	1.1 a	2.8 a	4.1 a	5.0 a	10.6 a	9.5 a	12.5 a	22.1 a
	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug	
AM	12.0 b	4.1 b	1.3 a	1.1 a	0.0 a	0.0 a	0.8 a	4.1 a	14.0 b	
PM	28.4 a	12.9 a	6.6 a	4.0 a	1.0 a	0.8 a	3.3 a	11.1 a	29.1 a	

[x] Boscalid was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 18. Effect of two mowing timings (i.e., AM vs. PM) on iprodione performance when targeting dollar spot in fairway height creeping bentgrass, 2007.

Iprodione [x] (Timing)	*S. homoeocarpa* infection centers [y]									
	9 Jul	11 Jul	13 Jul	16 Jul	18 Jul	20 Jul	23 Jul	25 Jul	27 Jul	1 Aug
AM	0.5 a [z]	0.0 a	0.1 a	0.5 a	0.8 a	0.9 a	2.0 a	1.4 a	3.3 a	9.3 a
PM	0.3 a	0.1 a	0.5 a	1.0 a	1.1 a	1.5 a	7.0 a	6.3 a	10.3 a	20.4 a

	3 Aug	6 Aug	8 Aug	9 Aug	13 Aug	15 Aug	20 Aug	23 Aug	25 Aug
AM	9.5 a	1.8 a	0.8 a	0.1 a	0.0 a	0.0 a	12.6 a	35.0 a	47.0 a
PM	19.3 a	9.5 a	6.0 a	3.4 a	1.1 a	1.1 a	13.6 a	37.9 a	50.8 a

[x] Iprodione was applied 3 and 31 July 2007.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 19. Pre-planned orthogonal contrast significance levels for five fungicides contrasted against two mowing timings (i.e., AM vs. PM), 2008.

Contrast	*S. homoeocarpa* infection centers [y]								
(AM vs. PM)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
Chlorothalonil [x]	NS [z]	NS	NS	NS	NS	**	*** [z]	***	**
Propiconazole	NS	NS	NS	NS	NS	NS	NS	NS	NS
Iprodione	NS	NS	NS	NS	NS	NS	NS	NS	NS
Boscalid	NS	NS	NS	*	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	*	NS	NS	NS	NS	NS	NS	NS	NS
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
Chlorothalonil	**	**	**	**	**	**	**	**	**
Propiconazole	NS	NS	NS	NS	*	*	*	*	*
Iprodione	NS	NS	*	*	*	NS	NS	NS	NS
Boscalid	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chlorothalonil + Propiconazole	NS	NS	NS	NS	NS	*	*	*	*

[x] All treatments were applied 7 August; chlorothalonil was reapplied 5 and 11 September; iprodione was reapplied 13 September; and propiconazole and chlorothalonil + propiconazole were reapplied 16 September 2008.

[y] The number of infection centers in each plot were counted.

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

Appendix I Table 20. Effect of two mowing timings (i.e., AM vs. PM) on chlorothalonil performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Chlorothalonil [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
AM	1.6 a [z]	0.2 a	0.0 a	0.0 a	0.3 a	0.0 b	0.0 b	1.8 b	2.6 b
PM	1.1 a	0.8 a	0.3 a	0.5 a	2.6 a	6.4 a	7.9 a	12.5 a	15.8 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
AM	4.8 b	6.7 b	4.6 b	8.6 b	6.7 b	16.0 b	12.7 b	11.4 b	4.6 b
PM	17.5 a	26.9 a	24.9 a	34.4 a	30.3 a	45.8 a	41.1 a	41.4 a	33.7 a

[x] Chlorothalonil was applied 7 August and 5 and 11 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 21. Effect of two mowing timings (i.e., AM vs. PM) on propiconazole performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Propiconazole [x]	*S. homoeocarpa* infection centers [y]								
(Timing)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
AM	1.2 a [z]	0.2 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
PM	5.1 a	0.5 a	0.6 a	0.5 a	0.4 a	0.5 a	0.8 a	1.0 a	2.1 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
AM	0.0a	0.5 a	0.8 a	4.5 a	2.5 b	9.7 b	9.5 b	8.3 b	4.0 b
PM	4.6 a	9.0 a	10.8 a	16.3 a	18.9 a	28.5 a	35.0 a	34.0 a	24.4 a

[y] Propiconazole was applied 7 August and 16 September 2008.

[y] The number of infection centers in each plot were counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 22. Effect of two mowing timings (i.e., AM vs. PM) on boscalid performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Boscalid [x]	*S. homoeocarpa* infection centers [y]								
(Timing)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
AM	2.3 a [z]	0.0 a	0.3 a	0.1 b	0.1 a	0.0 a	0.3 a	1.1 a	0.6 a
PM	4.9 a	1.0 a	1.1 a	1.9 a	3.3 a	1.5 a	1.0 a	2.1 a	2.4 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
AM	0.4 a	0.5 a	0.5 a	1.5 a	1.2 a	3.6 a	2.5 a	2.7 a	0.5 a
PM	5.8 a	7.1 a	4.8 a	6.8 a	6.4 a	18.0 a	20.3 a	15.8 a	7.8 a

[x] Boscalid was applied 7 August 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 23. Effect of two mowing timings (i.e., AM vs. PM) on iprodione performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Iprodione [x]	*S. homoeocarpa* infection centers [y]								
(Timing)	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
AM	2.2 a [z]	0.1 a	0.0 a	0.0 a	0.2 a	0.7 a	0.8 a	0.7 a	0.0 a
PM	4.0 a	0.0 a	0.0 a	0.0 a	0.0 a	1.3 a	1.7 a	0.5 a	3.3 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
AM	0.2 a	0.7 a	1.5 b	5.5 b	8.8 b	2.8 a	0.5 a	0.5 a	0.3 a
PM	5.0 a	10.2 a	18.5 a	28.7 a	27.8 a	23.3 a	14.7 a	15.2 a	6.2 a

[x] Iprodione was applied 7 August and 13 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix I Table 24. Effect of two mowing timings (i.e., AM vs. PM) on chlorothalonil + propiconazole performance when targeting dollar spot in fairway height creeping bentgrass, 2008.

Chlorothalonil + Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug
AM	1.6 b [z]	0.5 a	0.0 a	0.5 a	0.1 a	0.0 a	0.0 a	0.4 a	0.3 a
PM	5.7 a	1.7 a	0.0 a	1.2 a	0.0 a	0.0 a	0.0 a	0.6 a	1.9 a
	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	19 Sep	22 Sep
AM	0.2 a	0.7 a	1.2 a	3.5 a	3.9 a	12.2 b	9.8 b	10.5 b	6.6 b
PM	3.5 a	7.5 a	9.5 a	17.2 a	16.6 a	33.8 a	40.1 a	36.1 a	28.1 a

[x] Chlorothalonil + propiconazole was applied 7 August and 16 September 2008.
[y] The number of infection centers in each plot were counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix II

Appendix II Table 1. Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in 'Crenshaw' creeping bentgrass, 2007.

	S. homoeocarpa infection centers						
Variable	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
Chemical	**[z]	***	***	NS	**	**	***
Timing	NS	**	NS	NS	NS	NS	NS
Chemical*Timing	NS	**	*	NS	NS	NS	NS
Volume	NS	NS	NS	NS	NS	NS	NS
Chemical*Volume	NS	NS	*	**	NS	NS	NS
Timing*Volume	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing*Volume	NS	***	*	NS	NS	NS	NS

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

Appendix II Table 1 (cont'd). Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in 'Crenshaw' creeping bentgrass, 2007.

Variable	*S. homoeocarpa* infection centers						
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
Chemical	***	***	***	*	***	***	***
Timing	NS	NS	NS	NS	*	NS	NS
Chemical*Timing	NS	NS	NS	NS	*	NS	NS
Volume	NS	NS	NS	NS	NS	NS	NS
Chemical*Volume	NS	NS	NS	NS	NS	NS	NS
Timing*Volume	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing*Volume	NS	NS	NS	NS	NS	NS	NS

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

Appendix II Table 2. Effect of two spray volumes on chlorothalonil performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2007.

Chlorothalonil [x]	*S. homoeocarpa* infection centers [y]						
(L ha^{-1})	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
468	0.1 a [z]	1.0 a	10.3 a	0.1 a	4.1 a	8.0 a	23.3 a
935	0.1 a	1.5 a	10.0 a	0.3 a	3.9 a	9.9 a	28.9 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
468	52.4 a	25.3 a	20.6 a	1.0 a	23.6 a	42.5 a	80.4 a
935	52.0 a	27.8 a	19.0 a	0.8 a	20.0 a	45.3 a	81.1 a

[x] Chlorothalonil was applied 9 and 24 July, and 10 August 2007.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

Appendix II Table 3. Effect of two spray volumes on chlorothalonil plus propiconazole tank-mix Performance when targeting dollar spot in fairway height ‘Crenshaw’ creeping bentgrass, 2007.

Chlorothalonil + Propiconazole [x] (L ha^{-1})	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
468	0.1 a [z]	0.6 a	1.1 a	0.0 a	0.1 a	0.0 a	0.3 a
935	0.5 a	0.5 a	3.0 a	0.3 a	0.1 a	0.1 a	0.6 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
468	3.8 a	0.5 a	0.1 a	0.3 a	0.1 a	0.1 a	11.9 a
935	1.6 a	0.6 a	0.1 a	0.1 a	0.1 a	0.5 a	10.1 a

[x] Tank-mix was applied 9 and 24 July, and 10 August 2007.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 4. Effect of two application timings on chlorothalonil plus propiconazole tank-mix performance when targeting dollar spot in fairway height ‘Crenshaw’ creeping bentgrass, 2007

Chlorothalonil + Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]						
	16 Jul	20 Jul	23 Jul	27 Jul	2 Aug	6 Aug	8 Aug
AM	0.4 a [z]	0.6 a	1.5 a	0.0 a	0.3 a	0.1 a	0.1 a
PM	0.3 a	0.5 a	2.6 a	0.3 a	0.0 a	0.0 a	0.8 a
	9 Aug	13 Aug	15 Aug	20 Aug	24 Aug	27 Aug	29 Aug
AM	1.1 a	0.0 a	0.1 a	0.1 a	0.1 a	0.3 a	4.3 a
PM	4.3 a	1.1 a	0.1 a	0.3 a	0.1 a	0.4 a	17.8 a

[x] Tank-mix was applied 9 and 24 July, and 10 August 2007.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 5. Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in ‘Backspin’ creeping bentgrass, 2008.

	S. homoeocarpa infection centers								
Variable	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
Chemical	NS [z]	NS	***	***	***	***	***	***	***
Timing	NS	NS	**	**	**	NS	*	NS	NS
Chemical*Timing	NS	NS	**	*	NS	NS	NS	NS	NS
Volume	NS	NS	NS	**	***	NS	NS	NS	*
Chemical*Volume	NS	NS	NS	**	NS	NS	NS	NS	*
Timing*Volume	*	NS	NS	NS	*	NS	NS	NS	NS
Chemical*Timing*Volume	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Appendix II Table 5 (cont'd). Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in 'Backspin' creeping bentgrass, 2008.

	S. homoeocarpa infection centers							
Variable	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug
Chemical	*** [z]	***	***	***	***	***	***	***
Timing	**	**	*	*	NS	NS	NS	NS
Chemical*Timing	**	*	NS	NS	NS	NS	NS	NS
Volume	NS	*	*	*	NS	NS	NS	NS
Chemical*Volume	NS	NS	NS	NS	NS	NS	NS	NS
Timing*Volume	NS	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing*Volume	NS	NS	NS	NS	NS	NS	NS	NS

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

Appendix Table 6. Effect of two spray volumes on chlorothalonil plus propiconazole tank-mix performance when targeting dollar spot in fairway height ‘Backspin’ creeping bentgrass, 2008.

Chlorothalonil + Propiconazole [x] ($L\ ha^{-1}$)	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
468	0.8 a [z]	0.4 a	0.1 a	1.3 a	6.5 a	0.5 a	0.3 a	0.3 a	0.0 a
935	0.1 a	0.1 a	0.3 a	0.6 a	1.8 a	0.8 a	0.3 a	0.0 a	0.0 a
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
468	0.1 a	0.8 a	2.1 a	7.1 a	11.4 a	29.3 a	32.3 a	44.0 a	
935	0.0 a	0.3 a	0.3 a	0.3 a	4.3 a	19.6 a	22.6 a	34.3 a	

[x] Tank-mix was applied 27 June and 13 July 2008.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 7. Effect of two application timings on propiconazole performance when targeting dollar spot in fairway height ‘Backspin’ creeping bentgrass, 2008.

Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
AM	1.9 a [z]	2.1 a	0.0 a	2.0 a	12.1 a	2.9 a	0.9 a	0.3 a	0.3 a
PM	2.3 a	0.5 a	1.0 a	4.9 a	14.1 a	4.4 a	3.6 a	1.0 a	0.9 a
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
AM	0.5 a	0.9 a	6.8 a	12.1 a	22.6 a	46.3 a	49.3 a	60.0 a	
PM	1.5 a	4.5 a	6.9 a	15.9 a	25.9 a	47.0 a	50.0 a	60.0 a	

[x] Propiconazole was applied 27 June and 13 July 2008.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 8. Effect of two application timings on chlorothalonil plus propiconazole tank-mix performance when targeting dollar spot in fairway height ‘Backspin’ creeping bentgrass, 2008

Chlorothalonil + Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	29 Jun	2 Jul	7 Jul	9 Jul	11 Jul	15 Jul	16 Jul	18 Jul	21 Jul
AM	0.1 a [z]	0.5 a	0.3 a	0.6 a	1.5 a	0.3 a	0.1 a	0.0 a	0.0 a
PM	0.8 a	0.0 a	0.1 a	1.3 a	6.8 a	1.0 a	0.4 a	0.3 a	0.0 a
	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	
AM	0.0 a	0.3 a	0.1 a	1.3 a	4.5 a	20.6 a	23.6 a	36.0 a	
PM	0.1 a	0.8 a	2.3 a	6.1 a	11.1 a	28.3 a	31.3 a	42.3 a	

[x] Tank-mix was applied 27 June and 13 July 2008.

[y] The number of infection centers in each plot was counted.

[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 9. Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in ‘Crenshaw’ creeping bentgrass, 2008.

	S. homoeocarpa infection centers											
Variable	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug	8 Aug	11 Aug	13 Aug
Chemical	NS [z]	NS	NS	NS	***	***	***	***	***	**	***	***
Timing	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing	NS	NS	NS	NS	*	*	*	NS	NS	NS	NS	NS
Volume	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Chemical*Volume	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Timing*Volume	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS	NS
Chemical*Timing*Volume	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Appendix II Table 9 (cont'd). Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in 'Crenshaw' creeping bentgrass, 2008.

	S. homoeocarpa infection centers						
Variable	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	30 Aug	2 Sep
Chemical	*** [z]	***	***	***	***	**	***
Timing	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing	NS	NS	NS	NS	NS	NS	NS
Volume	*	NS	**	NS	NS	*	NS
Chemical*Volume	NS	NS	**	NS	NS	NS	NS
Timing*Volume	NS	NS	NS	NS	NS	NS	NS
Chemical*Timing*Volume	*	NS	NS	NS	NS	*	NS

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

Appendix II Table 9 (cont'd). Analysis of variances of three variables and their interactions for chemical, spray volume, and application timing significance levels in 'Crenshaw' creeping bentgrass, 2008.

Variable	*S. homoeocarpa* infection centers					
	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep
Chemical	***	***	***	***	***	***
Timing	NS	NS	NS	NS	NS	NS
Chemical*Timing	NS	NS	NS	NS	NS	NS
Volume	*	*	*	*	**	**
Chemical*Volume	NS	NS	NS	NS	NS	NS
Timing*Volume	NS	NS	NS	NS	NS	NS
Chemical*Timing*Volume	*	NS	NS	NS	NS	NS

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

Appendix II Table 10. Effect of two spray volumes on chlorothalonil plus propiconazole tank-mix performance when targeting dollar spot in fairway height ‘Crenshaw’ creeping bentgrass, 2008.

Chlorothalonil + Propiconazole [x] (L ha^{-1})	*S. homoeocarpa* infection centers [y]								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
468	8.6 a [z]	1.9 a	3.8 a	1.1 a	4.3 a	6.0 a	9.4 a	20.1 a	12.8 a
935	10.2 a	2.5 a	1.6 a	0.1 a	1.2 a	1.7 a	8.5 a	20.8 a	17.8 a
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
468	6.4 a	0.1 a	0.5 a	0.3 a	0.0 a	0.0 a	1.6 a	2.6 a	
935	8.4 a	1.1 a	0.8 a	0.4 a	1.0 a	1.1 a	4.9 a	6.8 a	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
468	7.0 a	25.6 a	7.1 a	4.4 a	0.1 a	10.5 a	17.9 a	24.4 a	
935	8.9 a	32.3 a	17.3 a	7.5 a	3.3 a	16.5 a	34.8 a	46.7 a	

[x] Tank-mix was applied on 17 July 4 August and 3 September 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher’s protected least significant difference test, $P \leq 0.05$.

Appendix II Table 11. Effect of two application timings on chlorothalonil plus propiconazole tank-mix performance when targeting dollar spot in fairway height 'Crenshaw' creeping bentgrass, 2008

Chlorothalonil + Propiconazole [x] (Timing)	*S. homoeocarpa* infection centers [y]								
	18 Jul	21 Jul	23 Jul	25 Jul	28 Jul	30 Jul	1 Aug	5 Aug	6 Aug
AM	12.2 a [z]	2.3 a	1.7 a	0.1 a	0.3 a	0.7 a	6.3 a	18.9 a	15.5 a
PM	6.6 a	2.0 a	3.6 a	1.1 a	5.1 a	7.0 a	11.6 a	22.0 a	15.1 a
	8 Aug	11 Aug	13 Aug	15 Aug	18 Aug	20 Aug	25 Aug	27 Aug	
AM	5.9 a	1.0 a	0.8 a	0.0 a	0.5 a	0.0 a	3.1 a	4.7 a	
PM	8.9 a	0.3 a	0.5 a	0.6 a	0.5 a	1.1 a	3.4 a	4.8 a	
	30 Aug	2 Sep	4 Sep	8 Sep	10 Sep	12 Sep	15 Sep	17 Sep	
AM	8.0 a	29.9 a	11.1 a	3.5 a	2.0 a	16.9 a	30.6 a	42.9 a	
PM	7.9 a	28.0 a	13.4 a	8.4 a	1.4 a	10.1 a	22.0 a	28.1 a	

[x] Tank-mix was applied on 17 July 4 August and 3 September 2008.
[y] The number of infection centers in each plot was counted.
[z] Means in a column follows by the same letter are not significantly different according to Fisher's protected least significant difference test, $P \leq 0.05$.

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