EFFECTS OF MOWING PRACTICES AND DEW REMOVAL ON
FUNGICIDE EFFICACY FOR DOLLAR SPOT CONTROL

A Thesis in
Agronomy

by
Tanner Delvalle

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

May 2011
The thesis of Tanner Delvalle was reviewed and approved* by the following:

Peter J. Landschoot
Professor of Turfgrass Science
Thesis Advisor

John E. Kaminski
Associate Professor of Turfgrass Nutrition

Wakar Uddin
Associate Professor of Plant Pathology

David M. Sylvia
Professor of Crop and Soil Sciences
Head of the Department of Crop and Soil Sciences

*Signatures are on file with the Graduate School
ABSTRACT

Dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) is a severe disease problem on creeping bentgrass (*Agrostis stolonifera* L.) fairways in the northeastern United States. Although dollar spot can be managed with fungicides, golf course managers attempt to limit fungicide use on fairways due to cost considerations and concerns over fungicide resistance. The objective of this study was to evaluate the effects of dew removal and mowing frequency on fungicide performance for dollar spot control. In 2009 and 2010, a factorial experiment involving daily dew removal or no dew removal, mowing frequency (2, 4, and 6 d wk$^{-1}$), and fungicides (chlorothalonil, propiconazole, and iprodione) was conducted on creeping bentgrass and annual bluegrass (*Poa annua* L.) maintained as a golf course fairway. Fungicides were applied once at the beginning of each test, and daily dew removal and mowing treatments were performed between 0700 and 0800 h. Dollar spot was assessed by counting infection centers in each plot. Area under the disease progress curve data showed that daily dew removal resulted in fewer dollar spot infection centers compared to not removing dew during late summer 2009 and 2010 for all mowing frequency and fungicide treatments. As mowing frequency increased from 2 to 6 d wk$^{-1}$, dollar spot decreased when both dew removal and no dew removal treatments were included in the data analyses. However, when data analyses included only treatments in which dew was removed daily, differences in dollar spot incidence among mowing frequencies were not detected at $P \leq 0.05$ using Tukey’s Honestly Significant Difference Test. This finding suggests that the effect of mowing frequency on dollar spot...
suppression is related to dew removal. Dew removal in iprodione-treated plots mowed 4
\textit{d wk}^{-1} \text{ during late summer 2009 provided up to 10 additional days to reach a 15-infection-center plot}^{-1} \text{ threshold level compared to iprodione plots in which dew was not removed. Similar trends were noticed for propiconazole and chlorothalonil treatments at certain times during the test. The number of days required for infection centers to reach the threshold varied with fungicide treatment, mowing frequency, and season. Results of this study demonstrate that fungicide performance for dollar spot control can be extended when daily dew removal is employed, and in some cases, when mowing frequency is increased on dew-covered turf. However, benefits of dew removal practices on fungicide performance can vary with weather conditions, fungicide, threshold level, and possibly other factors.
# TABLE OF CONTENTS

LIST OF FIGURES........................................................................................................ vi

LIST OF TABLES.......................................................................................................... viii

ACKNOWLEDGEMENTS................................................................................................. xiv

Chapter 1. LITERATURE REVIEW.............................................................................. 1

  Introduction................................................................................................................. 1
  Symptoms of Dollar Spot............................................................................................. 1
  Environmental Conditions Favoring Dollar Spot..................................................... 2
  Leaf Wetness Effects on Dollar Spot......................................................................... 4
  Influence of Mowing on Dollar Spot........................................................................ 6
  Nitrogen Management and Dollar Spot...................................................................... 9
  Influence of Plant Growth Regulators on Dollar Spot............................................. 10
  General Effects of Fungicides on Dollar Spot......................................................... 11

Chapter 2. EFFECTS OF DEW REMOVAL AND MOWING FREQUENCY ON
FUNGICIDE EFFICACY FOR DOLLAR SPOT CONTROL ........................................ 13

  Materials and Methods.............................................................................................. 16
  Results......................................................................................................................... 20
  Discussion.................................................................................................................. 32

LITERATURE CITED.................................................................................................. 38

APPENDIX.................................................................................................................... 44
LIST OF FIGURES

1. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 2 d wk\(^{-1}\) mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at \(P \leq 0.05\). Data from non-treated controls were omitted from the analysis……………………………………………………..26

2. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 2 d wk\(^{-1}\) mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at \(P \leq 0.05\). Data from non-treated controls were omitted from the analysis……………………………………………………..27

3. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 4 d wk\(^{-1}\) mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at \(P \leq 0.05\). Data from non-treated controls were omitted from the analysis……………………………………………………..28
4. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 4 d wk⁻¹ mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis………………………………………………………………………29

5. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 6 d wk⁻¹ mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis………………………………………………………………………30

6. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 2 d wk⁻¹ mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis………………………………………………………………………31
LIST OF TABLES

1. ANOVA of $\log_{10}$ transformed area under disease progress curve (AUDPC) data from late summer 2009, late spring 2010, and late summer 2010. AUDPC values based on the number of dollar spot infection centers plot$^{-1}$ ……………………………………………..22

2. Area under disease progress curve (AUDPC) values for each mowing frequency treatment averaged across all fungicide treatments. AUDPC values based on the number of dollar spot infection centers plot$^{-1}$, and were collected during late summer 2009 and late summer 2010………………………………………….………………23

3. In vitro sensitivities of various Sclerotinia homoeocarpa isolates to propiconazole collected near University Park, Pennsylvania 2009………………………………….53

4. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009………………..54

5. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009……………………………………..55
6. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Non-fungicide-treated plots were excluded.

7. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots receiving dew removal on days not mowed were not included.

8. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots in which dew was not removed on days not mowed and non-fungicide-treated plots were excluded.

9. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots in which dew was not removed on days not mowed were excluded.
10. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. .............................................. 60

11. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Non-fungicide-treated plots were excluded. ................................................................. 61

12. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. .............................................. 62

13. Influence of the interaction between dew removal and various fungicides on the number of dollar spot infection centers on Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. ................................................................. 63

14. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010. ...................... 64
15. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010………………………………………65

16. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010. Non-fungicide-treated plots were excluded…………………………………………………………………………66

17. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010……………………………………67

18. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010. Non-fungicide-treated plots were excluded…………………………………………………………………………68

19. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010……………………………………69
20. Influence of the interaction between mowing frequency and various fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010………………………………………………………………………………………………….70

21. Influence of the interaction between dew removal and various fungicides on the number of dollar spot infection centers on Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010………………………………………………………………………………………………….72

22. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010………………….73

23. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010………………………………….75

24. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010. Non-fungicide-treated plots were excluded………………………………………………………………………………………………….76
25. Influence of dew removal on the number of dollar spot infection centers on
   'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University,
   University Park, Pennsylvania, Late Summer 2010…………………………………77

26. Influence of dew removal on the number of dollar spot infection centers on
   'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University,
   University Park, Pennsylvania, Late Summer 2010. Non-fungicide-treated plots were
   excluded……………………………………………………………………………..78

27. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle'
   creeping bentgrass managed as a fairway, Pennsylvania State University, University
   Park, Pennsylvania, Late Summer 2010……………………………………………..79
ACKNOWLEDGEMENTS

First, I would like to thank my family who provided constant support for me throughout all of my endeavors.

I would like to thank my committee of advisors, Dr. Peter Landschoot, Dr. John Kaminski, and Dr. Wakar Uddin for their help and guidance. It was an honor to work closely with these dedicated scientists. I would also like to thank Dr. Maxim Schlossberg, Dr. Andrew McNitt, Dr. Marvin Risius, and Mr. Jeff Borger for their help as well. A special thank you must also go to Thomas Serensits for his help and guidance while completing this project.

I also would like to acknowledge Chase Rogan, Mike Shelley, and Kyung Han for their help on various parts of this project. Last but not least, I would like to thank Dave Livingston for his help and guidance at the Joseph Valentine Research Center over the two years of this study.
CHAPTER 1

LITERATURE REVIEW

Introduction

Dollar spot, caused by *Sclerotinia homoeocarpa* F.T. Bennett, is a foliar disease of turfgrass that can cause a large amount of damage annually throughout the northeastern United States. This disease is particularly severe on golf course fairways, and can be difficult to control due to environmental factors and cultural practices favoring disease epidemics, as well as poor host resistance. Although dollar spot can be controlled with fungicides, golf course managers try to limit fungicide use on fairways due to economic considerations, concerns over fungicide resistance, and annual limits of active ingredient mandated by the Environmental Protection Agency (EPA). Golf courses spend more money on dollar spot management than on any other turfgrass disease (Vargas, 1994).

Symptoms of Dollar Spot

*Sclerotinia homoeocarpa* infects most turfgrass species throughout the world, and causes disease on both high and low maintenance turf (Couch, 1995). Dollar spot may exhibit different symptoms depending on the mowing height of turf. On low-mown turf (≤ 1.3 cm), small circular spots of bleached-out turf ranging from 1 to 5 cm in diameter are visible during early stages of infection. On higher-mown turf, spots are more diffuse.
and can expand to greater than 15 cm in diameter. In severe cases, spots may coalesce into large patches (Smiley et al., 2000; Smith, 1955).

On individual leaves, dollar spot may exhibit bleached or light-brown lesions. These lesions typically have a reddish-brown periphery, depending on the species of turf, and have an hour-glass shape (Smiley et al., 2000; Vargas, 1994).

Environmental Conditions Favoring Dollar Spot

Environmental factors play a significant role in the development and progression of dollar spot. Controlled temperature experiments conducted by Endo (1963) revealed that *S. homoeocarpa* was able to grow from 4.5 to 32° C, but only caused infection on bentgrass from 15.5 to 26.8° C. Maximum disease activity has been shown to occur between 21 and 27° C (Couch, 1995; Endo, 1963). Along with temperature, high relative humidity levels are essential for growth of *S. homoeocarpa* (Smiley et al., 2000). Conditions which are most conducive to dollar spot progression include warm, humid days with cool nights which result in heavy dew formation (Smiley et. al., 2000; Watschke et al., 1995).

Several predictive models have been created to help turfgrass managers with the timing of fungicide applications for dollar spot control. One of the first models created for dollar spot disease was developed in Ontario, Canada by Hall (1984), and utilized daily rainfall and average daily air temperature as predictor variables. This model was based on observable “steps” in the epidemic rate of the disease. Each step began when a decline in the epidemic rate was followed by an increase in the epidemic rate. This 1981
model indicated that a step would occur after two consecutive wet days if the average temperature for the given period was greater than 22° C, or after three or more consecutive wet days with average temperatures greater than 15° C. This model correctly predicted nine of 11 steps in dollar spot epidemics over the two-year study. The two exceptions involved situations in which average temperatures were lower than those in the model, and were small steps occurring late in the disease epidemic (Hall, 1984).

A predictive model similar to Hall’s model was created by Mills and Rothwell (1982) in Ontario, Canada which used temperature and relative humidity to predict dollar spot. This model specified a fungicide application when the maximum air temperature was greater than 25° C and the maximum relative humidity was greater than 90% for any three out of seven days.

Burpee and Goulty (1986) evaluated both the Hall and Mills and Rothwell models to determine their effectiveness in predicting dollar spot. Both models failed to accurately predict increases in the incidence of dollar spot in Ontario, Canada. The Mills and Rothwell model generated a large amount of predictions (48 within a 70-day period in 1983, and 35 within a 44-day period in 1984); however, disease incidence increased only on 20 and 18 days in 1983 and 1984 evaluation periods, respectively. The Hall model failed to predict 10 out of 12 steps in 1983, and 5 out of 6 steps in 1984 (Burpee and Goulty, 1986).

DeGaetano and Rossi (2007) combined both the Hall model and Mills and Rothwell model, along with inferring leaf wetness data into a new model. National Weather Service hourly meteorological observations from 1950 to 2004 were used in this
model, and it was used to identify trends that were favorable for dollar spot development. On average, 24 more days in 2004 were conducive for dollar spot development than in 1975. They suggested that increasing favorability for dollar spot development is due to increased rainfall frequency (DeGaetano and Rossi, 2007).

**Leaf Wetness Effects on Dollar Spot**

Leaf wetness or leaf moisture is one of the dominant factors in the development of epidemics caused by plant-pathogenic leaf-infecting fungi. Leaf wetness promotes new growth of the plant, resulting in more leaf tissue for infection and favors disease development by promoting an environment conducive for fungal growth and infection (Agrios, 2005). Leaf wetness may originate from rainfall, irrigation, and/or high relative humidity and soil moisture conditions. When the atmosphere is humid, dew formation (condensate and plant-generated moisture) originates mostly from the air above the leaf canopy, but under semiarid conditions, it may originate from the soil (Huber and Gillespie, 1992). Free water droplets may also serve as “stepping stones” for hyphal filaments to bridge from one leaf to another (Jackson and Howard, 1966).

Components of dew may include condensate, exudates from wounds on leaves, and guttation fluid (Williams et al., 1998). Williams et al. (1998) showed that up to 33% of dew formed on a creeping bentgrass fairway is derived of fluids from the plant. Guttation fluid may be comprised of water, amino acids, carbohydrates, various elements, organic acids, and/or ions (Curtis, 1944; Goatley and Lewis, 1966). The presence of these components may enhance pathogen growth.
The duration in which dew remains on turf is also important and is referred to as leaf wetness duration. The length of time dew remains on turf has been shown to increase incidence or severity of several fungal diseases including dollar spot (Ellram et al., 2007; Walsh, 2000; Williams et al., 1996, Uddin et al., 2003). Ellram et al. (2007) and Walsh (2000) found that dollar spot lesion diameter increased as leaf wetness duration increased from 6 to 18 h, and from 12 to 48 h, respectively.

Given the fact that prolonged periods of leaf wetness enhance disease development, the displacement of dew and interruption of the leaf wetness period is an important cultural practice implemented by turf managers. Strategies to displace dew include, but are not limited to, mowing, rolling, poling, dragging with a hose, using a squeegee, or light irrigation. Wetting agents are also sometimes applied to reduce the amount of free moisture that may develop on leaf surfaces. The removal of dew using one or more of these cultural practices has been shown to aid in the control of brown patch and dollar spot (Dickinson, 1930; Williams et al., 1996). Williams and Powell (1995) reported that mowing and rolling were most effective at displacing dew in comparison to syringing and dragging with a hose. They also found that removal of dew by mowing was most effective in reducing dollar spot compared with other treatments, as a 78% reduction in the number of infection centers was achieved when compared to untreated controls. Other dew removal treatments provided significant reductions in dollar spot, but did not differ from one another. Williams et al. (1996) reported up to an 81 percent reduction in dollar spot severity on fairway height turf by removing dew with mower reels disengaged in comparison to not removing dew.
The time of day at which dew is removed has also been shown to be a significant factor in dollar spot suppression. Ellram et al. (2007) reported that dew typically formed from 2100 h to 2200 h and evaporated by 1000 h during late summer. The authors reported daily dew removal at 0400 h resulted in the least amount of dollar spot compared with all other treatments, and was due to the fact that the leaf wetness duration was essentially cut in half (2200 h to 1000 h). Removal of dew daily at 2200 h was intermediate in reducing dollar spot, while daily dew removal treatments at 1000 h, and dew removal on alternate days at 1000 h or 2200 h resulted in the most disease incidence. The results of this study also showed that turf mowed daily resulted in less dollar spot compared to turf mowed on alternate days or turf in which dew was removed with a squeegee on alternate days.

Wetting agents are also used to reduce the excess accumulation of dew on turf. McDonald et al. (2006a) showed that a wetting agent (Primer Select, Aquatrols Corporation of America, Paulsboro, NJ) provided acceptable dollar spot suppression once out of 16 rating dates. The authors concluded that the ability of wetting agents to suppress dollar spot is likely due to their ability to reduce leaf wetness duration.

**Influence of Mowing on Dollar Spot**

Mowing is another cultural practice that influences dollar spot development and severity. The act of mowing causes wounding of leaf tissue, resulting in a breach in a turfgrass plant’s defense system, and provides a site for fungal ingress and infection (Smiley et al., 2000). Following this reasoning, more disease would be expected on turf
mowed with dull or damaged blades compared to sharp and undamaged blades. However, Ellram, et al. (2007) failed to demonstrate that turf mowed with dull mower blades had more dollar spot than turf mowed with sharp mower blades. This finding suggests that dollar spot severity may not be greatly influenced by mower wounding.

Morning mowing reduces the amount of dew present on turfgrass, and influences dollar spot severity. Ellram et al. (2007) conducted a study examining the effect of dew removal by mowing and found that turf mowed daily when dew was present resulted in less dollar spot than turf mowed on alternate days. However, plots mowed at 1000 h daily (when no dew was present) or on alternate days at 1000 h did not significantly differ in dollar spot incidence (Ellram et al., 2007). Ellram et al. (2007) attributed this finding to the increased frequency of dew removal by using a mower and not by wounding (Ellram et al., 2007). Previous research confirms these findings, as Williams et al. (1996) found that dew removal by mowing at 0700 h reduced the number of dollar spot infection centers by up to 78% on select rating dates compared with plots mowed at 1400 h. Ellram et al. (2007) also found that mowing at 0400 h daily was most effective at reducing dollar spot, suggesting that the removal of dew is the key component in dollar spot reduction. Dew removal at 0400 h was shown to divide the period of leaf wetness duration in half during a typical summer night (Ellram et al., 2007).

In a study designed to examine the effect of simulated rainfall and mowing on fungicide performance, Pigati et al. (2010) found that mowing in the morning versus afternoon mowing significantly impacted dollar spot. Up to 65% fewer infection centers were observed in plots mowed in the morning compared with plots mowed in the
afternoon when averaged across all fungicides used in the study. Pigati et al. (2010) concluded that morning mowing improves fungicide performance by reducing leaf wetness duration and physically removing or displacing *S. homoeocarpa* mycelia. The authors also suggested dollar spot could be reduced by removing mycelia in infected leaf tissue through collection of clippings in mowing baskets.

A recent study at the University of Connecticut examined the effect of mowing frequency, independent of dew removal, on seasonal fungicide use (Putman, 2008). In this study, turf was mowed either 2, 4, or 6 d wk$^{-1}$ with a walk behind mower set to a height of 1.3 cm. Dew was removed daily on all plots between 0700 and 0900 h. All mowing treatments were performed in the afternoon when the turf canopy was dry. In this study, dew was removed in the morning, while all mowing treatments were performed in the afternoon when the turf canopy was dry. The author found that mowing frequency did not impact fungicide efficacy, and speculated that the influence of fungicide-protected leaf tissue removal on efficacy was minimal due to the short duration of fungicide residual in turfgrass. In the absence of fungicides, mowing frequency impacted dollar spot severity on 5 of 17 dates, with dollar spot severity lowest on plots mowed 2 d wk$^{-1}$ versus plots mowed 4 or 6 d wk$^{-1}$. Putman (2008) suggested that the increase in dollar spot with more frequent mowing may be due to a weakening of host defenses and altering plant growth habit, thereby creating an environment more favorable for disease-causing activities of the pathogen.

Another important aspect of mowing with respect to disease management is clipping removal. When clippings are not collected, they may contribute additional
nitrogen to the turf, which may decrease dollar spot severity. Conversely, clippings may serve as a substrate for pathogens, and leaving clippings on lower-cut turf may result in increased dollar spot (Smiley et al., 2000). Dispersal of clippings may translocate inoculum to new areas for infestation; and clippings have been shown to be an effective way to inoculate turf with dollar spot (Horvath et al., 2007).

Research on the role of clipping management on dollar spot has yielded conflicting results. Williams et al. (1996) found no significant differences between leaving clippings on the turf and removing clippings in relation to dollar spot on a creeping bentgrass fairway. Dunn et al. (1996) reported that returning clippings to a perennial ryegrass fairway suppressed dollar spot. Dollar spot suppression likely occurred because clippings contain a substantial amount of nitrogen, which has been shown to reduce dollar spot severity.

**Nitrogen Management and Dollar Spot**

Maintaining adequate to high levels of nitrogen in turf when dollar spot is active is an important part of an integrated disease management program (Smiley et al., 2000). Endo (1966) found that increased rates of nitrogen (from 0 to 61 kg ha\(^{-1}\)) reduced dollar spot incidence by up to 76%. Endo (1966) also reported that *S. homoeocarpa* grew vigorously on yellow, senescent leaves; but did not grow on or infect green tissue. The author suggested that *S. homoeocarpa* may obtain required nutrients from plants lacking nitrogen better than plants with adequate nitrogen. Other researchers found that when dollar spot pressure is severe, a strong negative correlation exists between foliar nitrogen
and disease severity (Davis and Dernoeden, 2002; Landschoot and McNitt, 1997; Markland et al., 1969; Williams et al., 1996).

**Influence of Plant Growth Regulators on Dollar Spot**

Plant growth regulators (PGRs) are typically applied to turf to reduce mowing requirements. There are currently five different classes of PGRs, designated as classes A through E (Turgeon, 2005). Class A and B PGRs suppress turf growth by inhibiting gibberellin biosynthesis (Turgeon, 2005). Class A PGRs inhibit cell elongation by inhibiting gibberellin biosynthesis late in the gibberellin biosynthetic pathway, as Class B PGRs inhibit cell elongation early in the gibberellin biosynthetic pathway. Class C PGRs inhibit cell division, whereas Class D PGRs are herbicides with growth-regulating properties, and Class E PGRs are phytohormones (Turgeon, 2005). Common growth inhibiting PGRs include flurprimidol (Class B), paclobutrazol (Class B), and trinexapac-ethyl (Class A) (Turgeon, 2005).

PGRs have been shown to enhance fungicide efficacy, but this effect appears to be more dependent on the active ingredient of the PGR than on the reduction of fungicide-protected leaf tissue removal. Paclobutrazol and flurprimidol have been shown to increase the efficacy of chlorothalonil, iprodione, boscalid, and propiconazole on dollar spot (Burpee et al., 1996; Fidanza et al., 2006; Putman, 2008). Trinexapac-ethyl has shown inconsistent, or no influence on fungicide efficacy despite the fact that it can reduce turf growth as effectively as paclobutrazol (Burpee et al., 1996; Fidanza et al., 2006; Putman, 2008).
Both paclobutrazol and flurprimidol have been shown to be fungistatic to *S. homoeocarpa* at lower concentrations than trinexapac-ethyl (Burpee et al., 1996). Burpee et al. (1996) noted that both paclobutrazol and flurprimidol are chemically related to fungicides that inhibit demethylation of lanosterol or 24-methylene dihydrolanosterol in the fungal sterol biosynthesis pathway.

Results of studies examining the effects of trinexapac-ethyl on dollar spot vary widely. Applications of trinexapac-ethyl every 4 wk beginning in May have resulted in less dollar spot than an untreated control (Golembiewski and Danneberger, 1997). Stewart et al. (2008) found that trinexapac-ethyl alone did not have consistent disease suppression when applied alone. Additionally, Stewart et al. (2008) did not observe a consistent impact of trinexapac-ethyl on the efficacy of chlorothalonil or propiconazole for dollar spot control. Similar inconsistent results were found in a study designed to investigate the influence of PGRs on dollar spot when incorporated into fungicide programs (Fidanza et al., 2006). Trinexapac-ethyl alone or with fungicides did not reduce or increase dollar spot incidence (Fidanza et al., 2006).

**General Fungicide Effects on Dollar Spot**

Although dollar spot severity can be reduced by the implementation of various cultural practices, fungicides are typically used on golf courses to maintain uniform and playable turf conditions. Fungicides may be applied preventatively or curatively for dollar spot suppression. Sequential applications of fungicides on a preventative basis typically provide best disease suppression.
Fungicides can be classified as contacts, penetrants, and systemics. Contact fungicides cover leaf surfaces so that fungi cannot grow on and infect leaf tissue (Smiley et al., 2000). Systemic fungicides are absorbed by the plant and can move both in the xylem and phloem. Penetrant fungicides are also absorbed by the plant. Local penetrants move only short distances once inside of a plant, whereas acropetal penetrants move upward in the xylem. Penetrants typically have a longer disease suppression timeframe than contact fungicides (Latin, 2006). Chlorothalonil, a contact fungicide, has been shown to suppress dollar spot for about 14 d when using a disease threshold of 1% (Latin, 2006). In the same study, propiconazole, an acropetal penetrant, suppressed dollar spot for nearly 28 days; whereas iprodione, a localized penetrant, suppressed disease between 14 and 28 days (Latin, 2006).

Chlorothalonil is the most widely used contact fungicide in the United States (McDonald et al., 2006b). This may be due to the fact that there have been no published cases of disease resistance to chlorothalonil. The Environmental Protection Agency has placed restrictions for maximum application rates and seasonal totals for chlorothalonil (Vinicelli and Dixon, 2003). These restrictions along with the frequency at which applications of chlorothalonil should be made for acceptable disease control must be taken into account when combating dollar spot.
CHAPTER 2

Effects of dew removal and mowing frequency on fungicide efficacy
for dollar spot control

Dollar spot, caused by *Sclerotinia homoeocarpa* F.T. Bennett, is a foliar disease of turfgrass that causes significant damage annually throughout the northeastern United States. This disease is particularly severe on golf course fairways, and can be difficult to control due to environmental factors and cultural practices favoring disease epidemics. Although dollar spot can be controlled with fungicides, golf course managers try to limit fungicide use on fairways due to economic considerations and concerns over fungicide resistance.

Certain cultural practices are important in suppressing dollar spot, and are often used by golf course managers as part of an integrated disease management program. The practices of dew removal, mowing, irrigation, nitrogen fertilization, and use of plant growth regulators have been shown to influence the severity of dollar spot (Burpee et al., 1996; Ellram et al., 2007; Landschoot and McNitt 1997; McDonald et al., 2006a; Williams et al., 1996). Most studies dealing with the effects of cultural practices on dollar spot have been conducted without fungicides. Because many golf course managers use cultural practices in conjunction with fungicides in their dollar spot control programs,
knowledge of how these practices influence fungicide efficacy would be beneficial in developing a more effective integrated disease management program.

Periodic removal of dew (condensate and plant-generated moisture, including wound exudates and guttation fluid containing amino acids, sugars, potassium, and other compounds) from leaf surfaces is an important means of suppressing dollar spot symptoms. Williams et al. (1996) reported up to an 81% reduction in dollar spot severity by removing dew through mowing and by using a mower with reels disengaged. In a later study, Ellram et al. (2007) showed that removing dew on a daily basis was more effective in reducing dollar spot incidence than dew removal on alternate days. Although dew removal is an important cultural practice for suppressing dollar spot, little research has been conducted to establish the role of dew removal on fungicide efficacy. In one of the few studies dealing with the influence of dew removal on fungicide efficacy, McDonald et al. (2006a) demonstrated that chlorothalonil applied to a turf canopy following early-morning dew removal only occasionally provided better dollar spot control than applications on turf with dew present.

To date, little research has been performed on the influence of mowing practices on fungicide performance. In a study designed to examine the effect of mowing frequency independent of dew removal on seasonal fungicide use, Putnam (2008) concluded that mowing frequency did not impact fungicide performance. The author speculated that the influence of fungicide-protected leaf tissue removal on performance was minimal due to the short duration of fungicide residual in turfgrass. In the absence of fungicides, mowing frequency impacted dollar spot severity on 5 of 17 dates, with
dollar spot severity lowest on plots mowed 2 d wk\(^{-1}\) versus plots mowed 4 or 6 d wk\(^{-1}\). Putman (2008) suggested that the increase in dollar spot with more frequent mowing may be due to a weakening of host defenses and altering plant growth habit, thereby creating an environment more favorable for disease-causing activities of the pathogen.

A recent study examining the effects of simulated rain and mowing timing on fungicide performance showed that mowing in the morning versus afternoon mowing significantly reduced dollar spot across all fungicide treatments (Pigati et al., 2010). The authors reported 54 to 65% fewer infection centers in plots mowed in the morning compared with plots mowed in the afternoon when averaged across chlorothalonil, propiconazole, bosalid, and iprodione treatments. Pigati et al. (2010) concluded that morning mowing not only reduces leaf wetness duration, but also physically removes or displaces *S. homoeocarpa* mycelia. The authors also suggested dollar spot could be reduced by removing mycelia in infected leaf tissue through collection of clippings in mowing baskets.

The objective of this research was to determine if daily dew removal in conjunction with mowing frequency (2, 4, or 6 d wk\(^{-1}\)) on turfgrass managed as a golf course fairway improved or diminished fungicide efficacy in relation to dollar spot control.
MATERIALS AND METHODS

This experiment was conducted at the Joseph Valentine Turfgrass Research Center, University Park, PA on three separate occasions (test 1, late summer 2009; test 2, late spring 2010; and test 3, late summer 2010) in areas adjacent to one another. The turf was a 7-year-old mixed stand of ‘Penneagle’ creeping bentgrass (approximately 80%) and annual bluegrass (*Poa annua* L.) (approximately 20%) maintained as a golf course fairway. The soil is a Hagerstown silt loam (fine, mixed, mesic, Typic Hapludalf) with a pH of 6.6, 224 kg ha⁻¹ Mehlich-3 P, 0.16 cmol exchangeable K kg⁻¹ of soil, and a CEC of 11.1 cmolc kg⁻¹ of soil. Prior to the initiation of the experiment, the turf was mowed 3 d wk⁻¹ at a bench setting of 1.3 cm with a Toro ReelMaster 5400-D fairway mower (The Toro Company, Bloomington, MN). Clippings were collected in baskets and removed from the site. The experiment site was fertilized with 18.3 kg N ha⁻¹ as urea (46-0-0) in April of 2009. Chlorothalonil (Daconil Ultrex 82.5 WDG, Syngenta Crop Protection, Greensboro, NC) was applied to the site at 4.53 kg a.i. ha⁻¹ on three occasions during June and July, 2009 to control dollar spot prior to initiation of test 1 on 21 August, 2009. Following termination of test 1 in September, the site was aerated, verticut, and fertilized with 48.82 kg N ha⁻¹ from urea, and was mowed 3 d wk⁻¹ with the Toro ReelMaster 5400-D until the end of the growing season. In 2010, the experiment site was fertilized with 18.3 kg N ha⁻¹ as urea (46-0-0) in April. No fungicides were applied to the site prior to the initiation of test 2 in May of 2010, and chlorothalonil was applied at 4.53 kg a.i. ha⁻¹ on 10-d intervals until the initiation of the test 3 in August of 2010.
The experiment was a 2 x 3 x 4 factorial arranged as a strip-split plot design with three replications. The experiment was conducted three times between 2009 and 2010. The main plots included two dew removal treatments (dew removed 7 d wk\(^{-1}\) or no dew removed), strips were three mowing frequency treatments (2, 4, and 6 d wk\(^{-1}\)), and subplots included four fungicide treatments. Dew was removed 7 d wk\(^{-1}\) by driving the Toro ReelMaster 5400-D across the dew removal treatment plots prior to mowing, with mowing units lowered and resting on the turf, but with reels disengaged.

Mowing schedules were Monday, Tuesday, Wednesday, Thursday, Friday, and Saturday for the 6 d wk\(^{-1}\) mowing treatment; Monday, Wednesday, Friday, and Saturday for the 4 d wk\(^{-1}\) treatment; and Tuesday and Friday for the 2 d wk\(^{-1}\) treatment. Each mowing frequency treatment plot was 3.66 x 3.05 m. All mowing events were performed between 0700 and 0800 h using the Toro ReelMaster 5400-D fairway mower adjusted to a bench setting of 1.3 cm. Clippings were collected in baskets and removed from the site.

Fungicide treatments were applied once at the initiation of each of the three tests. Treatments included chlorothalonil (Daconil Ultrex 82.5 WDG,) applied at 8.18 kg a.i. ha\(^{-1}\); propiconazole (ProPensity 1.3 ME, Sipcam Agro USA, Inc. Roswell, GA) applied at 0.65 kg a.i. ha\(^{-1}\); iprodione (Chipco 26 GT, Bayer Environmental Science, Montvale, NJ) applied at 2.13 kg a.i. ha\(^{-1}\); and a non-treated control. Subplots for fungicides treatments were 0.91 x 3.05 m. Fungicide treatments were applied with a CO\(_2\)-pressurized (276 kPa) bicycle sprayer equipped with a single boom fitted with a 9504E flat-fan nozzle calibrated to deliver 407 L water ha\(^{-1}\).
For each of the three tests, the entire experiment site was mowed with the Toro ReelMaster 5400-D fairway mower approximately 1 h prior to fungicide application. Dates of fungicide applications were 21 August 2009, 28 May 2010, and 24 August 2010. Dollar spot symptoms were not visible on the dates fungicides were applied. Each test area was mowed 1 d after fungicide treatments were applied. Dew removal treatments commenced 2 d following fungicide application, and mowing frequency treatments began 3 d following fungicide application. The quantity of dew was assessed at the time of dew removal on each day of the three test periods using a method devised by Williams et al. (1996). This procedure involved placing a 0.31 x 0.31m wooden frame on the turf, and using dry, pre-weighed tissue papers to absorb dew within the frame. The tissues were weighed immediately to determine the amount of liquid absorbed within the frame, and converted to L dew ha\(^{-1}\).

Dollar spot developed naturally in all tests, and was assessed as the number of infection centers per plot. An infection center is defined as a necrotic area of turf which is indicative of dollar spot disease. Dollar spot incidence was assessed three times in late summer of 2009 (test 1) (1 September, 10 September, and 17 September 2009), seven times in late spring of 2010 (test 2) (7 June, 10 June, 14 June, 17 June, 21 June, 23 June, 28 June, and 1 July), and seven times in late summer of 2010 (test 3) (4 September, 8 September, 11 September, 16 September, 18 September, 22 September, and 25 September). Each test concluded when individual infection centers could no longer be distinguished in the most severely affected plots. Tests were terminated on 17 September 2009, 1 July, 2010, and 25 September, 2010.
A threshold level of 15 infection centers within a 2.78 m$^2$ plot area was selected as a reference point for comparing fungicide responses to dew removal and mowing frequency treatments. Although this threshold is probably higher than that used by golf course managers on most Pennsylvania golf courses, no universally accepted threshold exists for creeping bentgrass fairways in the northeastern United States.

Disease severity data from each rating date, and area under the disease progress curve (AUDPC) values for each test were subjected to analysis of variance. The formula used for AUDPC was as follows:

$$\text{AUDPC} = \sum_{i=1}^{n} \left[ \frac{(x_i - x_{i-1})}{2} \right] (t_i - t_{i-1})$$

$n$ = the number of ratings taken  
$x$ = the number of infection centers at each rating  
$t_i - t_{i-1}$ = time (days) between ratings

All statistical analysis was performed using PROC MIXED of SAS v. 9.1 (SAS Institute, Cary, NC). Data were log transformed prior to analysis to better conform to assumptions for analysis of variance (ANOVA). Log transformations were performed by adding 0.00001 to every infection center count, given the fact that there were counts of zero. Multiple comparison tests were performed using Tukey’s Honestly Significant Difference Test ($\alpha = 0.05$).
RESULTS

Temperature and humidity conditions varied over the three test periods, and likely influenced the nature of dollar spot epidemics. Late summer of 2009 (test 1) was characterized by warm temperatures and periods of high humidity. Dollar spot incidence increased steadily and quickly during this period. Temperatures during late spring of 2010 (test 2) were abnormally high, and humidity was low. Dollar spot developed slowly during this period and never reached levels found in late summer 2009 and 2010. Late summer 2010 (test 3) began with very warm temperatures and low humidity conditions, but by the third week of September, temperatures became cooler and humidity levels increased. The dollar spot epidemic during test 3 was characterized by about 23 days of very low disease activity, followed by a rapid increase in dollar spot incidence over the next nine days.

Dew measurements revealed greater mean daily dew volumes in the late summer test periods in 2009 and 2010 versus the late spring test period in 2010. In late summer of 2009 (21 August to 17 September), the mean daily dew volume was 1605 L ha\(^{-1}\) when dew was present. In late spring of 2010 (28 May to 1 July), the mean daily dew volume was only 950 L ha\(^{-1}\), whereas in late summer of 2010 (24 August to 25 September), the mean daily dew volume was 1788 L ha\(^{-1}\) when dew was present.

Analysis of variance of all dollar spot infection center AUDPC data and preplanned orthogonal contrasts with non-fungicide-treated controls omitted are presented in Table 1. Due to the lack of dollar spot suppression in non-treated controls,
and the particular interest in how dew removal and mowing treatments influenced fungicide efficacy, only contrasts with non-treated controls omitted are discussed.

The dew removal contrast indicates the effect of daily dew removal was significant for AUDPC data in test 1 ($P=0.0002$) and test 3 ($P < 0.0001$), but not for test 2 ($P=0.0772$) (Table 1). Dollar spot infection centers were more numerous in treatments where dew was not removed compared to treatments in which dew was removed for all mowing frequency and fungicide treatments in test 1 and test 3 (Fig. 1-6).

Two mowing frequency contrasts are presented in Table 1; the first contrast includes both dew removal treatments (dew removed daily and dew not removed), whereas the second mowing contrast includes only those plots in which dew was removed daily. The first contrast shows a significant mowing effect for AUDPC data in test 1 ($P=0.0499$) and test 3 ($P=0.0005$), but not in test 2 ($P=0.1382$). In test 1, the 2 d wk$^{-1}$ mowing treatment had more dollar spot infection centers than the 6 d wk$^{-1}$ mowing treatment (Table 2). However, no differences were observed between plots mowed 2 d wk$^{-1}$ and 4 d wk$^{-1}$ or 4 d wk$^{-1}$ and 6 d wk$^{-1}$. In test 3, a greater number of dollar spot infection centers were found in plots mowed 2 d wk$^{-1}$ compared to those mowed 4 d wk$^{-1}$ or 6 d wk$^{-1}$, but no differences were detected between the 4 d wk$^{-1}$ and 6 d wk$^{-1}$ treatments (Table 2).

The second mowing contrast, in which only the daily dew removal treatment was included in the AUDPC data analysis, indicates a significant mowing effect in test 3 ($P=0.0378$). However, when data from test 3 were subjected to the Tukey’s Honestly Significant Difference Test, no differences among mowing treatments were detected.
Table 1. ANOVA of log_{10} transformed area under disease progress curve (AUDPC) data from late summer 2009, late spring 2010, and late summer 2010. AUDPC values based on the number of dollar spot infection centers plot^{-1}.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>F value</th>
<th>P &gt; F</th>
<th>F value</th>
<th>P &gt; F</th>
<th>F value</th>
<th>P &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew Removal (Dew) †</td>
<td>1</td>
<td>58.66</td>
<td>0.0003</td>
<td>12.72</td>
<td>0.0704</td>
<td>105.02</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mowing Frequency (Mow) ‡</td>
<td>2</td>
<td>5.81</td>
<td>0.0655</td>
<td>3.37</td>
<td>0.1387</td>
<td>20.60</td>
<td>0.0003</td>
</tr>
<tr>
<td>Fungicide §</td>
<td>3</td>
<td>65.17</td>
<td>&lt;0.0001</td>
<td>88.19</td>
<td>0.0001</td>
<td>175.95</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>2</td>
<td>0.79</td>
<td>0.4977</td>
<td>0.81</td>
<td>0.5068</td>
<td>1.41</td>
<td>0.2898</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>6</td>
<td>1.12</td>
<td>0.3693</td>
<td>2.03</td>
<td>0.0863</td>
<td>0.26</td>
<td>0.9540</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>3</td>
<td>3.89</td>
<td>0.0166</td>
<td>1.77</td>
<td>0.1695</td>
<td>0.87</td>
<td>0.4669</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide Contrast ¶</td>
<td>6</td>
<td>0.34</td>
<td>0.9104</td>
<td>1.11</td>
<td>0.3754</td>
<td>0.52</td>
<td>0.7886</td>
</tr>
<tr>
<td>Dew</td>
<td>1</td>
<td>63.32</td>
<td>0.0002</td>
<td>11.47</td>
<td>0.0772</td>
<td>92.52</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mow</td>
<td>2</td>
<td>6.96</td>
<td>0.0499</td>
<td>3.38</td>
<td>0.1382</td>
<td>17.90</td>
<td>0.0005</td>
</tr>
<tr>
<td>Mow (plots with daily dew removal only) #</td>
<td>2</td>
<td>4.37</td>
<td>0.0985</td>
<td>1.89</td>
<td>0.2647</td>
<td>4.63</td>
<td>0.0378</td>
</tr>
<tr>
<td>Fungicide</td>
<td>2</td>
<td>37.19</td>
<td>&lt;0.0001</td>
<td>52.72</td>
<td>0.0001</td>
<td>54.14</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>2</td>
<td>1.10</td>
<td>0.3922</td>
<td>1.96</td>
<td>0.2552</td>
<td>0.70</td>
<td>0.5196</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>4</td>
<td>0.51</td>
<td>0.7279</td>
<td>2.23</td>
<td>0.0954</td>
<td>0.17</td>
<td>0.9524</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>2</td>
<td>2.86</td>
<td>0.0767</td>
<td>1.38</td>
<td>0.2704</td>
<td>0.41</td>
<td>0.6635</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>4</td>
<td>0.19</td>
<td>0.9392</td>
<td>0.22</td>
<td>0.9272</td>
<td>0.45</td>
<td>0.7715</td>
</tr>
</tbody>
</table>

† Dew removal treatments were performed using a Toro 5400 fairway reel mower with reels disengaged.
‡ Mowing treatments were performed by mowing plots 2, 4, or 6 d wk^{-1} using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ Fungicides included chlorothalonil (8.18 kg ha^{-1}), iprodione (2.13 kg ha^{-1}), propiconazole (0.65 kg ha^{-1}), and a non-treated control.
¶ Contrasts excluded non-fungicide-treated control treatment.
# Contrast excluded non-fungicide-treated control treatment and treatment with no dew removed.
Table 2. Area under disease progress curve (AUDPC) values for each mowing frequency treatment averaged across all fungicide treatments. AUDPC values based on the number of dollar spot infection centers plot\(^{-1}\), and were collected during late summer 2009 and late summer 2010.

<table>
<thead>
<tr>
<th>Mowing Frequency(^{†})</th>
<th>Late Summer 2009 (test 1)</th>
<th>Late Summer 2010 (test 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 d wk(^{-1})</td>
<td>630 a (^{‡})</td>
<td>184 a</td>
</tr>
<tr>
<td>4 d wk(^{-1})</td>
<td>509 ab</td>
<td>79 b</td>
</tr>
<tr>
<td>6 d wk(^{-1})</td>
<td>261 b</td>
<td>54 b</td>
</tr>
</tbody>
</table>

\(^{†}\) Mowing frequency treatments were performed by mowing plots 2, 4, or 6 d wk\(^{-1}\) using a Toro 5400 fairway reel mower set to a height of 1.3 cm.

\(^{‡}\) Values followed by the same letter are not significantly different according to Tukey’s Honestly Significant Difference Test (\(P \leq 0.05\)). Data were log\(_{10}\) transformed prior to analysis, but actual means are shown. Data from non-treated controls were omitted from analysis.
Analysis of variance indicates a significant fungicide effect in all three tests (Table 1). The fact that iprodione yielded fewer infection centers in all three tests when compared to chlorothalonil and propiconazole was expected, and thus, was of minor interest. Chlorothalonil is a contact fungicide with a relatively short duration of dollar spot control at the rate used in this study, and generally showed a greater number of infection centers compared to iprodione and propiconazole as epidemics progressed. *Sclerotinia homoeocarpa* isolates from the Joseph Valentine Turfgrass Research Center are known to have reduced sensitivity to propiconazole, and this was reflected in greater numbers of infection centers in propiconazole treatments when compared with iprodione treatments (see Table 3 in Appendix for In vitro sensitivity data). Data showing comparisons of fungicides alone are not presented.

The number of days required for each fungicide treatment to reach the 15-infection center 2.78 m\(^{-1}\) threshold level varied with dew removal and mowing frequency treatments. For all fungicides, daily dew removal increased the number of days needed to reach the threshold level. Dew removal in iprodione treatments provided up to 10 additional days to reach the threshold compared to iprodione treatments in which dew was not removed. In some instances, iprodione treatments in the dew removed plots never reached the threshold up to 27 and 31 days after treatment in test 1 and test 3, respectively.

For propiconazole treatments, dew removal provided up to nine additional days to reach the threshold level compared to propiconazole treatments in which dew was not
removed. On two occasions in test 3, propiconazole dew removal treatments never reached the threshold level for the 4 d wk\(^{-1}\) and 6 d wk\(^{-1}\) mowing frequencies.

Chlorothalonil treatments in dew removal plots provided up to 10 additional days to reach the threshold level compared to chlorothalonil treatments in which dew was not removed. On all occasions, chlorothalonil treatments reached the threshold level within the timeframe of each test.
**Fig. 1.** Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 2 d wk\(^{-1}\) mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at \(P \leq 0.05\). Data from non-treated controls were omitted from the analysis.
**Fig. 2.** Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 2 d wk$^{-1}$ mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis.
Fig. 3. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 4 d wk$^{-1}$ mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis.
Fig. 4. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 4 d wk\(^{-1}\) mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at \(P \leq 0.05\). Data from non-treated controls were omitted from the analysis.
Fig. 5. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 6 d wk⁻¹ mowing frequency treatment in late summer 2009 (test 1). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis.
Fig. 6. Effect of daily dew removal treatment and fungicide (chlorothalonil, iprodione, and propiconazole) on dollar spot infection centers for the 6 d wk$^{-1}$ mowing frequency treatment in late summer 2010 (test 3). Area under disease progress curve values with different letters are significantly different at $P \leq 0.05$. Data from non-treated controls were omitted from the analysis.
DISCUSSION

Dollar spot severity data collected during the late summers of 2009 and 2010 indicated that daily dew removal and increased mowing frequency from 2 to 6 d wk\(^{-1}\) on dew-covered turf resulted in a reduction of dollar spot and improvement in the performance of all three fungicides used in this study. Daily dew removal during late spring 2010 did not show a significant influence on dollar spot infection centers. Although unclear, this may have been due to the lower mean daily dew volume on turf foliage (950 L ha\(^{-1}\)) during this test period when compared to the late summer test periods of 2009 (21 August to 17 September) (1605 L ha\(^{-1}\)) and 2010 (24 August to 25 September) (1788 L ha\(^{-1}\)). The higher dew volumes in late summer may have increased dollar spot by extending the leaf wetness period and accentuating differences between dew removal treatments for fungicide-treated turf (Huber and Gillespie, 1992). Other factors, such as temperate and humidity, may also have influenced the results.

Daily dew removal in late summer reduced dollar spot regardless of mowing frequency or fungicide treatment. When plots were mowed 4 d wk\(^{-1}\) in late summer 2009, dollar spot based on AUDPC data for dew-removal treatments was reduced 51% for chlorothalonil, 59% for propiconazole, and 78% for iprodione when compared to plots in which dew was not removed. The percent reduction of dollar spot severity for the 2 d wk\(^{-1}\) mowing frequency during the same period was 55% for chlorothalonil, 47% for propiconazole, and 62% for iprodione. Although these percentages include severity data that may be above the threshold levels used by some golf course managers, they
illustrate the beneficial effects of dew removal on reducing dollar spot in fungicide-treated plots. Pigati et al. (10) noted similar dollar spot reductions for chlorothalonil (64 to 67%), propiconazole (50 to 54%), and iprodione (39 to 70%) in morning-mowed versus afternoon-mowed turf in which dew was not removed.

Reductions of dollar spot in fungicide treated plots resulting from daily dew removal in this study reflects findings of previous studies in which dollar spot was reduced when leaf surface moisture was displaced by various early morning dew removal methods (Ellram et al., 2007; Williams and Powell, 1995; Williams et al., 1996). Dew on fairway turf canopies is comprised of condensate and up to 33% plant-generated moisture (wound exudates and guttation fluid containing amino acids, sugars, potassium, and other compounds) that can enhance growth of certain fungal pathogens (Agrios, 2005; Goatley and Lewis, 1966; Williams et al., 1998). Dew on plant surfaces aids in hyphal growth, turgidity, and adherence to host surfaces; host penetration and infection; as well as pathogen dispersal (Agrios 2005; Jackson and Howard 1966). Presumably, interruption of leaf moisture duration via dew removal or mowing curtails important pathogen activities responsible for the increase in dollar spot severity.

Although increased mowing frequency on fairway turf has been shown to reduce dollar spot incidence, its role on fungicide efficacy is not well understood (Ellram et al., 2007; Putnam 2008). In a recent study on the impact of mowing frequency on fungicide efficacy, Putnam (2008) found that mowing frequency on dry turf with clippings collected did not influence seasonal fungicide use. The author suggested that removing
fungicide-protected leaf tissue had minimal impact on dollar spot control due to the short
duration of fungicide residual in turfgrass.

In the current study, as mowing frequency increased from 2 to 6 d wk\(^{-1}\), dollar
spot incidence decreased when both daily dew removal and no dew removal treatments
were included in the late summer 2009 and 2010 data analysis. However, when mowing
frequency data were analyzed only for treatments in which dew was removed every day,
differences were not detected according to Tukey’s Honestly Significant Difference Test.
Thus, when data from dew-covered turf was removed from the analysis, mowing
frequency had little impact on length of control from each fungicide. These results agree
with Putman’s finding that fungicide control is not associated with mowing frequency
when leaf wetness is not a factor (Putnam 2008). Results also suggest that the positive
influence of increased mowing frequency on reductions in dollar spot on fungicide-
treated turf is primarily related to dew removal. Pigati et al. (2010) suggested that
reduced leaf wetness and physical disruption or removal of \(S.\ homoeocarpa\) mycelia
associated with morning mowing are responsible for the improved efficacy of fungicides
for dollar spot control.

Golf course managers would benefit from knowing how long fungicides would
last when combined with dew removal practices or increasing mowing frequency. In the
current study, the additional days needed to reach the 15-IC threshold level for a
fungicide treatment subjected to dew removal varied with mowing frequency, fungicide,
and season. Using a mowing frequency of 4 d wk\(^{-1}\) in late summer of 2009, iprodione
treated plots receiving daily dew removal provided 10 additional days to reach the 15-IC
threshold when compared to iprodione treated plots not receiving daily dew removal. During the same period, iprodione treatments receiving daily dew removal provided six additional days to reach the threshold with the 2 d wk\(^{-1}\) mowing frequency. By comparison, propiconazole provided nine additional days to reach the threshold under the 4 d wk\(^{-1}\) mowing frequency treatment, but only one additional day under the 2 d wk\(^{-1}\) mowing frequency treatment in late summer 2009. The 2009 chlorothalonil 2 d wk\(^{-1}\) and 4 d wk\(^{-1}\) mowing frequency treatments provided very few additional days of acceptable dollar spot suppression, perhaps due to the short duration of control with this contact-type fungicide.

The 2009 and 2010 late summer test periods produced different dollar spot epidemics; thus, the number of days needed to reach the 15-IC threshold varied between the two test periods. During late summer of 2009, propiconazole plots subjected to daily dew removal and mowing 2 d wk\(^{-1}\) provided one additional day to reach the 15-IC threshold. However, in 2010, the same propiconazole treatment provided five additional days to reach the threshold. The discrepancy in results between 2009 and 2010 may have been due to an increased rate of dollar spot development early in the 2009 test, limiting the beneficial effects of repeated dew removal episodes. During late summer of 2009, chlorothalonil-treated plots that were subjected to daily dew removal and mowing 6 d wk\(^{-1}\) provided 10 additional days to reach the 15-IC threshold; whereas the same treatment provided only five additional days to reach the threshold in late summer 2010. In this case, a rapid increase in disease incidence late in the 2010 test may have overwhelmed some of the benefits of mowing and dew removal. Also, by the time the increase in
incidence occurred, the effects of chlorothalonil likely diminished. Determination of the number of days efficacy could be extended was complicated by the fact that threshold levels were not reached by the end of each study for all treatments, especially in 2010.

The threshold level used in the current study was for the purpose of comparing selected treatments. A higher threshold would have shown a longer reductions in dollar spot symptoms when dew was removed daily for some fungicides and mowing frequency treatments. If lower thresholds were used, the number of days until dollar spot became unacceptable would have been shorter for some treatments. Golf course managers establish different threshold levels for unacceptable dollar spot damage for a variety of reasons, and no universally accepted threshold is applicable to all golf courses. Although a high threshold level for dollar spot damage may result in an increase in days between fungicide applications, damage may be unacceptable to golfers. Additionally, higher thresholds likely would result in the increase in *S. homoeocarpa* inoculum and may necessitate higher fungicide rates to achieve acceptable control with subsequent applications. Lower threshold levels would likely provide fewer days of dollar spot suppression when fungicides were used in conjunction with dew removal. However, disease epidemics may be less damaging, and subsequent fungicide applications may require lower rates because of a more frequent reduction of inoculum.

The benefits of reduced dollar spot severity and improved fungicide performance associated with dew removal may also depend on the thoroughness of the dew removal method. The reduction in dollar spot from dew removal in the current study may have been partially influenced by the removal method. Use of reel mower units with reels
disengaged provided extremely effective removal of leaf moisture, and would probably be more effective at suppressing dollar spot than more common methods such as dragging a hose over dew covered turf. Although a direct comparison of mower units with reels disengaged and other dew removal methods was not performed in the current study, Williams and Powell (1995) found that removal of dew by rolling or mowing was significantly better at displacing leaf moisture compared to a surfactant, dragging a hose, or syringing. However, all methods used by Williams and Powell (1995) dramatically reduced dollar spot severity compared to the no-dew removed control.

Whether the cost of dew removal programs can offset savings associated with fewer fungicide applications would depend on many factors, including the fungicide, mowing frequency, nature of the epidemic, threshold level, and possibly the dew removal method. Although results of this study do not provide enough information to establish a definite economic benefit from dew removal practices, they do suggest that dollar spot severity may be reduced when daily dew removal is practiced on fungicide treated turf. Results also confirm findings of previous studies that no detrimental effects on fungicide efficacy are associated with increasing mowing frequency.
LITERATURE CITED


APPENDIX
Reduced Sensitivity Experiment

Isolate Collection

Dollar spot samples were collected from Kentucky bluegrass lawns with no history of fungicide applications in Park Forest and at the Hintz Alumni Center in University Park, PA during June to September 2009. Samples of creeping bentgrass turf exhibiting dollar spot symptoms were also collected in the summer of 2009 from the Joseph Valentine Turfgrass Research Center, University Park, PA. Samples from the Joseph Valentine Turfgrass Research Center were from areas thought to contain *Sclerotinia homoeocarpa* isolates with reduced sensitivity to propiconazole fungicide.

Media used for isolation of *S. homoeocarpa* was created by placing 10 g of granulated potato dextrose agar (PDA) (Difco Laboratories, Detroit, MI) into a 1 L Erlenmeyer flask. Next, 500 ml of de-ionized water was added to the flask and the solution was stirred to dissolve the PDA. Cotton was used as a stopper in the mouth of the flask, and aluminum foil was placed over the top and sealed to prevent contamination after autoclaving. The flask containing the PDA suspension was then autoclaved at a temperature of 121 °C for 30 minutes. The suspension was cooled to a temperature of approximately 60 °C before removing from the autoclave. Once the molten PDA reached a temperature of approximately 40 °C, it was poured into 100 ml sterile Petri dishes. Each dish received approximately 25 ml of molten PDA. Dishes were allowed to cool overnight.

*Sclerotinia homoeocarpa* was isolated from sections of leaf tissue exhibiting typical dollar spot symptoms. Symptomatic leaf tissues were disinfested for 3 minutes in
a 10% sodium hypochlorite solution, then washed with sterile de-ionized water, and air-dried on sterile absorbent paper. Four pieces of tissue from each sample were placed on a Petri dish containing the aforementioned PDA. Plates were then sealed with Parafilm (Pechiney Plastic Packaging, Chicago, IL) and incubated for 1 to 3 d at approximately 25 °C.

Fungal colonies exhibiting typical growth characteristics of *S. homoeocarpa* were identified and transferred to fresh dishes of PDA. Growth of *S. homoeocarpa* was observed for approximately 3 days, and once the colony approached the edge of the Petri plate, 10 5-mm circular plugs were taken and placed into glass vials containing 10 ml of sterile de-ionized water and was stored at 4 °C (Putman, 2008).

**In Vitro Sensitivity**

To determine the sensitivity of isolates to propiconazole fungicide, baseline sensitivity was determined using isolates obtained from the Park Forest and University Park lawns. Two isolates from Park Forest and the Hintz Alumni Center were used as the baseline isolates for this assay.
Fungicide-Amended PDA Preparation

A serial dilution is necessary to prepare fungicide-amended PDA. In order to accomplish this, the following steps were taken:

The fungicide used in this screening procedure was propiconazole (ProPensity 1.3 ME, Sipcam Agro USA, Inc. Roswell, GA). The active ingredient (a.i.) of the formulated product was 155774.5 µg ml⁻¹.

\[
\begin{align*}
1.3 \text{ lbs ai} \times 1 \text{ gal} \times 128 \text{ fl oz} \times 453.59 \text{ g} \times 1000000 \text{ µg} &= 155774.5 \text{ µg ml}^{-1} \\
1 \text{ gal} & = 128 \text{ fl oz} & 29.57 \text{ ml} & = 1 \text{ lb} & = 1 \text{ g}
\end{align*}
\]

* Note: µg ml⁻¹ = mg L⁻¹ = parts per million (ppm)

A stock solution of 500 µg ml⁻¹ propiconazole was created for serial dilution using the following calculation:

\[
(155774.5 \text{ µg ml}^{-1}) (1 \text{ ml}) = (500 \text{ µg ml}^{-1}) (X) \\
X = 311.55 \text{ ml}
\]

Since 311.55 ml of the stock solution was needed for the screening experiment, 1 ml ProPensity was added to 310.55 ml of sterile de-ionized water to yield a total of 311.55 ml to make a 500 µg ml⁻¹ propiconazole solution.

Propiconazole concentrations of 1, 0.1, 0.01, 0.001, and 0.0001 µg ml⁻¹ were desired for this resistance screening. Five different flasks containing 499 ml of de-ionized water and 10 g PDA were prepared, autoclaved, and allowed to cool to approximately 40 °C. Each of these flasks would be amended with each concentration of propiconazole. (One 500 ml flask yields approximately 20 Petri plates with 25 ml of fungicide-amended PDA.)

The PDA was amended with 1, 0.1, 0.01, 0.001, and 0.0001 µg ml⁻¹ propiconazole by performing the following steps:

Using the stock solution: 311.55 ml solution (at 500 µg ml⁻¹ propiconazole):
a. **Make up the 1 µg ml⁻¹ propiconazole concentration**: 1 ml of the stock solution was pipetted into one of the aforementioned prepared molten PDA flasks (500 ml PDA) at 40 °C. This yielded 1 µg ml⁻¹ propiconazole

\[
(500 \, \mu g \, ml^{-1})(1 \, ml) = (X \, \mu g \, ml^{-1})(500 \, ml)
\]

\[
X = 1 \, \mu g \, ml^{-1}
\]

b. Four glass vials with 9 ml of de-ionized water were autoclaved for 30 min. These were used for the serial dilution and were labeled as Vial A, B, C, and D.

c. 1 ml of the stock solution (500 µg ml⁻¹ propiconazole) was placed into the first glass vial with 9 ml of sterile de-ionized water. This yielded a 10 ml solution with a propiconazole concentration of 50 µg ml⁻¹. Vial A was then gently shaken to mix thoroughly.

\[
(500 \, \mu g \, ml^{-1})(1 \, ml) = (X \, \mu g \, ml^{-1})(10 \, ml)
\]

\[
X = 50 \, \mu g \, ml^{-1} \text{ (Vial A)}
\]

d. 1 ml from Vial A (50 µg ml⁻¹) was placed into Vial B. This yielded a propiconazole concentration one-tenth of Vial A. The concentration of Vial B was then 5 µg ml⁻¹. Vial B was then gently shaken to mix thoroughly.

\[
(50 \, \mu g \, ml^{-1})(1 \, ml) = (X \, \mu g \, ml^{-1})(10 \, ml)
\]

\[
X = 5 \, \mu g \, ml^{-1} \text{ (Vial B)}
\]

e. 1 ml from Vial B (5 µg ml⁻¹) was placed into Vial C. This yielded a propiconazole concentration one-tenth of Vial B. The concentration of Vial C was then 0.5 µg ml⁻¹. Vial C was then gently shaken to mix thoroughly.

\[
(5 \, \mu g \, ml^{-1})(1 \, ml) = (X \, \mu g \, ml^{-1})(10 \, ml)
\]

\[
X = 0.5 \, \mu g \, ml^{-1} \text{ (Vial C)}
\]
f. One ml from Vial C (0.5 µg ml$^{-1}$) was placed into Vial D. This yielded a propiconazole concentration one-tenth of Vial C. The concentration of vial D was then 0.05 µg ml$^{-1}$. Vial D was then gently shaken to mix thoroughly.

\[
(0.5 \text{ µg ml}^{-1})(1 \text{ ml}) = (X \text{ µg ml}^{-1})(10 \text{ ml})
\]

\[
X = 0.05 \text{ µg ml}^{-1} \text{ (Vial D)}
\]

The 0.1, 0.01, 0.001, and 0.0001 fungicide-amended PDA were created by the following steps:

a. 1 ml from the 50 µg ml$^{-1}$ solution (Vial A) was placed into a flask containing 499 ml of molten PDA. This yielded a concentration of 0.1 µg ml$^{-1}$ propiconazole.

\[
(50 \text{ µg ml}^{-1})(1 \text{ ml}) = (X \text{ µg ml}^{-1})(500 \text{ ml})
\]

\[
X = 0.1 \text{ µg ml}^{-1}
\]

b. One ml from the 5 µg ml$^{-1}$ solution (Vial B) was placed into a flask containing 499 ml of molten PDA. This yielded a concentration of 0.01 µg ml$^{-1}$ propiconazole.

\[
(5 \text{ µg ml}^{-1})(1 \text{ ml}) = (X \text{ µg ml}^{-1})(500 \text{ ml})
\]

\[
X = .01 \text{ µg ml}^{-1}
\]

c. One ml from the 0.5 µg ml$^{-1}$ solution (Vial C) was placed into a flask containing 499 ml of molten PDA. This yielded a concentration of 0.001 µg ml$^{-1}$ propiconazole.

\[
(0.5 \text{ µg ml}^{-1})(1 \text{ ml}) = (X \text{ µg ml}^{-1})(500 \text{ ml})
\]

\[
X = .001 \text{ µg ml}^{-1}
\]

d. One ml from the 0.05 µg ml$^{-1}$ solution (Vial D) was placed into a flask containing 499 ml of molten PDA. This yielded a concentration of 0.0001 µg ml$^{-1}$ propiconazole.
\[(0.05 \, \mu g \, ml^{-1})(1 \, ml) = (X \, \mu g \, ml^{-1})(500 \, ml)\]

\[X = 0.0001 \, \mu g \, ml^{-1}\]

* All fungicide-amended PDA was poured into Petri dishes immediately after adding solution from vials, as solidification occurs rapidly at cooler temperatures. Fungicide-amended Petri dishes were allowed to cool for at least one day prior to further disposition.

Once fungicide-amended PDA was prepared, isolates were removed from cold storage at 4 °C and three 5-mm plugs of each isolate were placed onto non-amended PDA. When growth of *S. homoeocarpa* was observed, a 5-mm circular plug was taken from the edge of the actively growing colony of each isolate, and placed onto a separate PDA Petri dish. After 2 to 3 days, several 5-mm circular plugs of actively growing mycelia were transferred to the fungicide-amended PDA (three reps for each concentration/isolate combination). The Petri dishes were then placed into an incubator for the duration of the experiment at a temperature of 25 °C. Plates were removed after 48 and 72 hours of incubation. At these times, the growth of the colony was measured. Two perpendicular measurements were taken on each plate by measuring the distance of colony growth from the edge of the 5-mm plug to the outermost edge of fungal growth. The average of these distances was deemed as the amount of radial growth per unit time period (48 hour and/or 72 hour growth) (Jo et. al., 2006).
**Statistical Analysis**

Radial growth was multiplied by two in order to determine diameter growth (DG). Relative growth for each isolate was determined by the following: \( RG = \left[ \frac{\text{the mean adjusted colony diameter on propiconazole-amended medium}}{\text{the mean adjusted colony diameter on non-amended medium}} \right] \times 100\% \). The 50% effective concentration (EC\(_{50}\)) value for each isolate was estimated by linear regression of relative inhibition (RI) value (RI = 1 – RG) on log\(_{10}\)-transformed fungicide concentration. Each replication was utilized for the determination of the regression equation, as the mean of all three replications was not used. This allowed for a better line-of-fit for each regression. Calculations for the aforementioned values were performed in Microsoft Excel 2007, while regression was performed using PROC REG in SAS 9.1 (SAS Institute, Cary, NC). Regression equations were obtained from data analysis and can be found in Table 3. In order to determine the EC\(_{50}\) value with units consisting of µg a.i. ml\(^{-1}\), the regression equation was utilized. A value of -50 was inserted for (x) to represent a 50 percent inhibition by propiconazole. This yielded a log\(_{10}\) transformed concentration of propiconazole. This value was then converted back to a non-log\(_{10}\) transformed value of concentration. This approximation was performed by taking the log\(_{10}\) value of positive numerical values, until the value from the regression equation was reached. This allowed for a concentration of propiconazole which had the desirable units (µg a.i. ml\(^{-1}\)). These values are found in Table 1A. The EC\(_{50}\) value listed is the concentration of propiconazole (µg a.i. ml\(^{-1}\)) which will inhibit 50 percent of mycelial growth. The mean EC\(_{50}\) value of
all isolates taken from the Valentine Research Center was determined by taking the mean of all nine Valentine Research Center isolate EC$_{50}$ values (Miller et. al., 2002).

Both Park Forest (PF 3-2) and Hintz Alumni Center (Hintz 4) isolates were determined to be sensitive isolates. In this experiment, the isolate taken from the Hintz Alumni Center lawn was used as the baseline. The resistance factor was determined for each isolate by dividing the EC$_{50}$ value of each resistant isolate by the EC$_{50}$ value of the baseline population (Hintz 4). This demonstrates how much more resistant a particular isolate is to propiconazole in comparison to the most sensitive population. These values can also be found in Table 3.
Table 3. In vitro sensitivities of various *Sclerotinia homoeocarpa* isolates to propiconazole collected near University Park, Pennsylvania 2009.

<table>
<thead>
<tr>
<th>Isolate no.</th>
<th>Location</th>
<th>Host Species</th>
<th>$EC_{50}$ value (µg a.i. ml$^{-1}$)†</th>
<th>Resistance Factor‡</th>
<th>Regression Equation§</th>
<th>Phenotype ¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF 3-2</td>
<td>Park Forest Village</td>
<td>Kentucky Bluegrass</td>
<td>0.004</td>
<td>1.7</td>
<td>y = -0.2968 + 0.0415x</td>
<td>Sensitive</td>
</tr>
<tr>
<td>Hintz 4</td>
<td>Hintz Alumni Center</td>
<td>Kentucky Bluegrass</td>
<td>0.003</td>
<td>1.0</td>
<td>y = -0.2698 + 0.0465x</td>
<td>Sensitive</td>
</tr>
<tr>
<td>Val 2-2</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.871</td>
<td>348.2</td>
<td>y = 2.5798 + 0.0465x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 3-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.171</td>
<td>68.4</td>
<td>y = 1.5224 + 0.0458x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 4-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.154</td>
<td>61.6</td>
<td>y = 1.6765 + 0.0498x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 5-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.701</td>
<td>280.4</td>
<td>y = 2.4058 + 0.0512x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 5-2-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>1.143</td>
<td>457.2</td>
<td>y = 2.8131 + 0.0551x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 6-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>1.036</td>
<td>414.4</td>
<td>y = 2.805 + 0.0558x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 7-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.775</td>
<td>310.0</td>
<td>y = 2.6945 + 0.0561x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 2-1</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.535</td>
<td>214.0</td>
<td>y = 2.2983 + 0.0514x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val 6-2</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.358</td>
<td>143.2</td>
<td>y = 1.8799 + 0.0465x</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Val Mean&quot;</td>
<td>Valentine Research Center</td>
<td>Creeping Bentgrass</td>
<td>0.638</td>
<td>255.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Fifty percent effective concentration value based upon log$_{10}$-transformed $EC_{50}$ values obtained from three replicates.

‡ Resistance factor was determined by dividing the $EC_{50}$ value of isolates for the resistant population by the $EC_{50}$ value of isolates from the baseline population (Hintz 4).

§ Equation based on regressing relative inhibition (RI) values on log10-transformed $EC_{50}$ values for propiconazole. Value inserted for (x) was -50, representing a 50 percent inhibition by propiconazole.

¶ Reaction to propiconazole.

# The mean of all nine (Val) values from Valentine Research Center.
Table 4. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>11 DAT ‡</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC §</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mowing Frequency (Mow) ¶</td>
<td>NS #</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Dew Removal (Dew) ††</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Fungicide ‡‡</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>***</td>
<td>*</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Contrast §§</td>
<td>Mow</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
</tr>
<tr>
<td>Dew</td>
<td>NS</td>
<td>**</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Fungicide</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot was visually counted. Data were log₁₀ transformed prior to analysis.
‡ DAT = Days after treatments were applied.
§ AUDPC = Area under disease progress curve.
¶ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
# *, **, and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
†† Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
‡‡ Fungicides included chlorothalonil (8.18 kg a.i. ha⁻¹), iprodione (2.13 kg a.i. ha⁻¹), propiconazole (0.65 kg a.i. ha⁻¹), and a non-treated control. Fungicide treatments were applied on 21 Aug.
§§ Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
Table 5. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009.

<table>
<thead>
<tr>
<th>Mowing Frequency‡</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>20</td>
<td>50</td>
<td>95 a⁺</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>18</td>
<td>37</td>
<td>79 ab</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>11</td>
<td>20</td>
<td>49 b</td>
</tr>
</tbody>
</table>

ANOVA#

Mowing Frequency

NS    NS    *

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log_{10} transformed prior to analysis, but actual means are shown.
# *, **, *** and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 6. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>11 DAT</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>12</td>
<td>37</td>
<td>81 a</td>
<td>630 a</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>11</td>
<td>27</td>
<td>69 ab</td>
<td>509 ab</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>6</td>
<td>12</td>
<td>41 b</td>
<td>261 b</td>
</tr>
</tbody>
</table>

Contrast††

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>ANOVA†‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log_{10} transformed prior to analysis, but actual means are shown.
†† Contrasts that evaluated mowing frequency excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
‡‡ *, **, *** , and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 7. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots receiving dew removal on days not mowed were not included.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>24</td>
<td>68</td>
<td>126 a⁻¹</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>23</td>
<td>52</td>
<td>114 a</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>14</td>
<td>29</td>
<td>70  b</td>
</tr>
<tr>
<td>Contrast#</td>
<td></td>
<td>ANOVA++</td>
<td></td>
</tr>
<tr>
<td>Mowing Frequency</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant ( P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
# Contrasts that evaluated mowing frequency excluding plots receiving dew removal on days not mowed were included.
++ *, **, ***, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 8. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots in which dew was not removed on days not mowed and non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>10</td>
<td>22</td>
<td>53 a</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>8</td>
<td>15</td>
<td>38 ab</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>4</td>
<td>4</td>
<td>19 b</td>
</tr>
</tbody>
</table>

Contrast# ANOVA††
Mowing Frequency NS NS **

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
# Contrasts evaluated mowing frequency excluding plots with no dew removal on days not mowed and non-fungicide treated plots.
†† *, **, *** and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 9. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Plots in which dew was not removed on days not mowed were excluded.

Dollar spot
----- Mean No. of infection centers

<table>
<thead>
<tr>
<th>Mowing Frequency (^{‡})</th>
<th>11 DAT(^{§})</th>
<th>20 DAT</th>
<th>27 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week(^{−1})</td>
<td>17</td>
<td>32</td>
<td>65</td>
</tr>
<tr>
<td>4 days week(^{−1})</td>
<td>14</td>
<td>24</td>
<td>46</td>
</tr>
<tr>
<td>6 days week(^{−1})</td>
<td>9</td>
<td>12</td>
<td>28</td>
</tr>
</tbody>
</table>

Contrast\(^{#}\)
Mowing Frequency

<table>
<thead>
<tr>
<th></th>
<th>11 DAT(^{§})</th>
<th>20 DAT</th>
<th>27 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ANOVA(^{††})</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

\(^{†}\) The number of dollar spot infection centers plot\(^{−1}\) was visually counted.

\(^{‡}\) Mowing treatments were performed by mowing plots two, four, or six times week\(^{−1}\) using a Toro 5400 fairway reel mower set to a height of 1.3 cm.

\(^{§}\) DAT = Days after treatments were applied.

\(^{§}\) Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log\(_{10}\) transformed prior to analysis, but actual means are shown.

\(^{#}\) Contrasts evaluated mowing frequency excluding plots with no dew removal on days not mowed.

\(^{††}\) *, **, and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 10. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009.

<table>
<thead>
<tr>
<th>Dew Removal†</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew not removed</td>
<td>20 a#</td>
<td>49 a</td>
<td>103 a</td>
<td>843 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>13 b</td>
<td>22 b</td>
<td>46 b</td>
<td>400 b</td>
</tr>
</tbody>
</table>

ANOVA††

| Dew Removal | * | *** | *** | *** |

† The number of dollar spot infection centers plot† was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log10 transformed prior to analysis, but actual means are shown.
†† *, **, ***, and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 11. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009. Non-fungicide-treated plots were excluded.

Dollar spot

<table>
<thead>
<tr>
<th>Dew Removal†</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew not removed</td>
<td>12</td>
<td>37 a</td>
<td>90 a</td>
<td>663 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>7</td>
<td>14 b</td>
<td>37 b</td>
<td>271 b</td>
</tr>
</tbody>
</table>

Contrast††

Dew Removal

NS ** *** ***

ANOVA‡‡

† The number of dollar spot infection centers plot† was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log_{10} transformed prior to analysis, but actual means are shown.
†† Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
‡‡ *, **, ***, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 12. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>11 DAT§</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>14 b</td>
<td>37 b</td>
<td>76 b</td>
<td>627 b</td>
</tr>
<tr>
<td>Iprodione</td>
<td>4 c</td>
<td>12 c</td>
<td>46 c</td>
<td>275 c</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>11 b</td>
<td>26 b</td>
<td>68 b</td>
<td>498 b</td>
</tr>
<tr>
<td>Non-Treated Control</td>
<td>38 a</td>
<td>67 a</td>
<td>108 a</td>
<td>1085 a</td>
</tr>
</tbody>
</table>

ANOVA††

| Fungicide | *** | *** | *** | *** |

† The number of dollar spot infection centers plot† was visually counted.
‡ Fungicides included chlorothalonil (8.18 kg a.i. ha⁻¹), iprodione (2.13 kg a.i. ha⁻¹), propiconazole (0.65 kg a.i. ha⁻¹), and a non-treated control. Fungicide treatments were applied on 21 Aug.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
†† *, **, *** means refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 13. Influence of the interaction between dew removal and various fungicides on the number of dollar spot infection centers on Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2009.

<table>
<thead>
<tr>
<th>Dew x Fungicide</th>
<th>11 DAT</th>
<th>20 DAT</th>
<th>27 DAT</th>
<th>AUDPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>17</td>
<td>54</td>
<td>105 a</td>
<td>872 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>10</td>
<td>21</td>
<td>48 b</td>
<td>383 b</td>
</tr>
<tr>
<td>Iprodione</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>5</td>
<td>19</td>
<td>72 a</td>
<td>430 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>3</td>
<td>5</td>
<td>20 b</td>
<td>120 b</td>
</tr>
<tr>
<td>Propiconazole</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>13</td>
<td>37</td>
<td>94 a</td>
<td>686 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>9</td>
<td>15</td>
<td>42 b</td>
<td>310 b</td>
</tr>
<tr>
<td>Non-treated control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>46</td>
<td>85</td>
<td>141 a</td>
<td>1383 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>30</td>
<td>48</td>
<td>76 b</td>
<td>787 b</td>
</tr>
</tbody>
</table>

Dew x Fungicide ANOVA

All fungicides NS NS *** *
Contrast NS NS ** NS

† The number of dollar spot infection centers plot\(^{-1}\) was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ Fungicides included chlorothalonil (8.18 kg a.i. ha\(^{-1}\)), iprodione (2.13 kg a.i. ha\(^{-1}\)), propiconazole (0.65 kg a.i. ha\(^{-1}\)), and a non-treated control. Fungicide treatments were applied on 21 Aug.
¶ DAT = Days after treatments were applied.
# AUDPC = Area under disease progress curve.
†† Dew was not removed on days plots were not mowed.
‡‡ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (\(P \leq 0.05\)) difference test. Data were log\(_{10}\) transformed prior to analysis, but actual means are shown.
‡§ Dew was removed on days plots were not mowed.
¶¶ *, **, ***, and NS refer to significance at \(P \leq 0.05, 0.01, 0.001\), and not significant, respectively.
## Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to lack of dollar spot suppression in control plots.
Table 14. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>10 DAT $^\dagger$</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
<th>AUDPC $^\ddagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mowing Frequency (Mow)$^\dagger$</td>
<td>NS $^#$</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
</tr>
<tr>
<td>Dew Removal (Dew)$^\ddagger$</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Fungicide $^\ddagger$</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>*</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Contrast $^\S$:

- Mow
- Dew
- Fungicide
- Mow x Dew
- Mow x Fungicide
- Dew x Fungicide
- Mow x Dew x Fungicide

$^\dagger$ The number of dollar spot infection centers plot$^1$ was visually counted. Data were log$_{10}$ transformed prior to analysis.

$^\ddagger$ AUDPC = Area under disease progress curve.

$^\dagger$ DAT = Days after treatments were applied.

$^\#: Mowing treatments were performed by mowing plots two, four, or six times week$^1$ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.

$^\#$ *, **, and NS refer to significance at $P \leq 0.05$, 0.01, 0.001, and not significant, respectively.

$^\ddagger$ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.

$^\ddagger$ Fungicides included chlorothalonil (8.18 kg a.i. ha$^{-1}$), iprodione (2.13 kg a.i. ha$^{-1}$), propiconazole (0.65 kg a.i. ha$^{-1}$), and a non-treated control. Fungicide treatments were applied on 28 May.

$^\S$ Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
Table 15. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>10 DAT</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>10</td>
<td>15</td>
<td>22</td>
<td>29</td>
<td>36</td>
<td>38</td>
<td>43 a⁻⁵</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>5</td>
<td>7</td>
<td>11</td>
<td>14</td>
<td>17</td>
<td>18</td>
<td>20 b</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>8</td>
<td>12</td>
<td>13</td>
<td>17</td>
<td>21</td>
<td>22</td>
<td>24 ab</td>
</tr>
</tbody>
</table>

ANOVA

| Mowing Frequency | NS | NS | NS | NS | NS | NS | *    |

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
* *, **, ***, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 16. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010. Non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>10 DAT§</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
<th>Mean No. of infection centers†</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>3</td>
<td>7</td>
<td>14</td>
<td>21</td>
<td>28</td>
<td>30</td>
<td>36 a§</td>
<td></td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>15 b</td>
<td></td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>11</td>
<td>16</td>
<td>16</td>
<td>19 b</td>
<td></td>
</tr>
</tbody>
</table>

Contrast# ANOVA††

| Mowing Frequency | NS   | NS   | NS   | NS   | NS   | NS   | NS   | *               |

† The number of dollar spot infection centers plot was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
# Contrasts that evaluated mowing frequency excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
†† *, **, ***, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 17. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Dew Removal†</th>
<th>Dollar spot - Mean No. of infection centers‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 DAT§</td>
</tr>
<tr>
<td>Dew not removed</td>
<td>9</td>
</tr>
<tr>
<td>Dew removed</td>
<td>6</td>
</tr>
</tbody>
</table>

ANOVA#

| Dew Removal | NS | NS | * | NS | NS | NS | NS | NS |

† The number of dollar spot infection centers plot was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log10 transformed prior to analysis, but actual means are shown.
# *, **, ***,…, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 18. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010. Non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Dew Removal†</th>
<th>10 DAT§</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew not removed</td>
<td>2</td>
<td>6</td>
<td>12 a¶</td>
<td>18</td>
<td>25</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>Dew removed</td>
<td>2</td>
<td>3</td>
<td>6 b</td>
<td>9</td>
<td>12</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

Contrast#

<table>
<thead>
<tr>
<th>Dew Removal</th>
<th>ANOVA††</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot† was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log10 transformed prior to analysis, but actual means are shown.
# Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
†† *, **, *** and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 19. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>10 DAT§</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
<th>AUDPC$^|$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>5 b$^#$</td>
<td>12 b</td>
<td>20 b</td>
<td>27 b</td>
<td>32 a</td>
<td>34 a</td>
<td>35 b</td>
<td>517 b</td>
</tr>
<tr>
<td>Iprodione</td>
<td>0 c</td>
<td>1 d</td>
<td>2 d</td>
<td>5 d</td>
<td>9 c</td>
<td>10 c</td>
<td>15 d</td>
<td>127 c</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>1 c</td>
<td>2 c</td>
<td>5 c</td>
<td>10 c</td>
<td>14 b</td>
<td>15 b</td>
<td>19 c</td>
<td>198 c</td>
</tr>
<tr>
<td>Non-Treated Control</td>
<td>24 a</td>
<td>31 a</td>
<td>33 a</td>
<td>38 a</td>
<td>43 a</td>
<td>45 a</td>
<td>47 a</td>
<td>796 a</td>
</tr>
</tbody>
</table>

**ANOVA**$^\|\|$

| Fungicide      | *** | *** | *** | *** | *** | *** | *** |

$^\dagger$ The number of dollar spot infection centers plot$^\dagger$ was visually counted.

$^\ddagger$ Fungicides included chlorothalonil (8.18 kg a.i. ha$^{-1}$), iprodione (2.13 kg a.i. ha$^{-1}$), propiconazole (0.65 kg a.i. ha$^{-1}$), and a non-treated control. Fungicide treatments were applied on 28 May.

$^\S$ DAT = Days after treatments were applied.

$^\|$ AUDPC = Area under disease progress curve.

$^\|$ Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log$_{10}$ transformed prior to analysis, but actual means are shown.

$^\|\|\|$ *, **, *** and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 20. Influence of the interaction between mowing frequency and various fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Mow x Fungicide</th>
<th>10 DAT</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days week</td>
<td>6</td>
<td>17</td>
<td>32 a</td>
<td>41</td>
<td>49</td>
<td>53 a</td>
<td>55</td>
</tr>
<tr>
<td>4 days week</td>
<td>2</td>
<td>6</td>
<td>11 b</td>
<td>15</td>
<td>17</td>
<td>18 b</td>
<td>19</td>
</tr>
<tr>
<td>6 days week</td>
<td>5</td>
<td>13</td>
<td>19 ab</td>
<td>24</td>
<td>31</td>
<td>32 ab</td>
<td>32</td>
</tr>
<tr>
<td>Iprodione</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days week</td>
<td>0</td>
<td>1</td>
<td>3 a</td>
<td>9</td>
<td>16</td>
<td>18 a</td>
<td>25</td>
</tr>
<tr>
<td>4 days week</td>
<td>1</td>
<td>1</td>
<td>2 a</td>
<td>4</td>
<td>7</td>
<td>8 ab</td>
<td>10</td>
</tr>
<tr>
<td>6 days week</td>
<td>0</td>
<td>0</td>
<td>1 a</td>
<td>2</td>
<td>5</td>
<td>5 b</td>
<td>9</td>
</tr>
<tr>
<td>Propiconazole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days week</td>
<td>1</td>
<td>3</td>
<td>7 a</td>
<td>14</td>
<td>20</td>
<td>20 a</td>
<td>27</td>
</tr>
<tr>
<td>4 days week</td>
<td>1</td>
<td>2</td>
<td>6 a</td>
<td>9</td>
<td>11</td>
<td>12 a</td>
<td>15</td>
</tr>
<tr>
<td>6 days week</td>
<td>1</td>
<td>1</td>
<td>2 b</td>
<td>6</td>
<td>11</td>
<td>12 a</td>
<td>15</td>
</tr>
<tr>
<td>Non-treated control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days week</td>
<td>31</td>
<td>40</td>
<td>45 a</td>
<td>52</td>
<td>59</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>4 days week</td>
<td>16</td>
<td>21</td>
<td>26 a</td>
<td>28</td>
<td>31</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>6 days week</td>
<td>25</td>
<td>32</td>
<td>29 a</td>
<td>35</td>
<td>38</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fungicides</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Contrast</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot was visually counted. Data were log<sub>10</sub> transformed prior to analysis.
‡ Mowing treatments were performed by mowing plots two, four, or six times week using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
Fungicides included chlorothalonil (8.18 kg a.i. ha⁻¹), iprodione (2.13 kg a.i. ha⁻¹), propiconazole (0.65 kg a.i. ha⁻¹), and a non-treated control.

Fungicide treatments were applied on 28 May.

DAT = Days after treatments were applied.

Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.

* , **, *** , and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.

Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
Table 21. Influence of the interaction between dew removal and various fungicides on the number of dollar spot infection centers on Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Spring 2010.

<table>
<thead>
<tr>
<th>Dew x Fungicide</th>
<th>10 DAT†</th>
<th>13 DAT</th>
<th>17 DAT</th>
<th>20 DAT</th>
<th>24 DAT</th>
<th>26 DAT</th>
<th>31 DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>5 a ‡‡</td>
<td>16 a</td>
<td>26</td>
<td>33</td>
<td>42</td>
<td>45</td>
<td>48</td>
</tr>
<tr>
<td>Dew removed</td>
<td>4 a</td>
<td>8 b</td>
<td>15</td>
<td>20</td>
<td>22</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Iprodione</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>0 a</td>
<td>0 a</td>
<td>3</td>
<td>7</td>
<td>14</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Dew removed</td>
<td>0 a</td>
<td>1 a</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Propiconazole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>1 a</td>
<td>2 a</td>
<td>7</td>
<td>14</td>
<td>20</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Dew removed</td>
<td>1 a</td>
<td>1 a</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Non-treated control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew not removed</td>
<td>29 a</td>
<td>39 a</td>
<td>42</td>
<td>50</td>
<td>56</td>
<td>58</td>
<td>62</td>
</tr>
<tr>
<td>Dew removed</td>
<td>18 b</td>
<td>23 b</td>
<td>24</td>
<td>27</td>
<td>30</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fungicides</td>
<td>*</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Contrast**</td>
<td>*</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ Fungicides included chlorothalonil (8.18 kg a.i. ha⁻¹), iprodione (2.13 kg a.i. ha⁻¹), propiconazole (0.65 kg a.i. ha⁻¹), and a non-treated control. Fungicide treatments were applied on 28 May.
¶ DAT = Days after treatments were applied.
# Dew was not removed on days plots were not mowed.
†† Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
‡‡ Dew was removed on days plots were not mowed.
§§ *, **, ***, and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
¶¶ Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of suppression in control plots.
Table 22. Dollar spot incidence as influenced by mowing frequency, dew removal, and various fungicides on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>11 DAT†</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mowing Frequency (Mow)¶</td>
<td>***#</td>
<td>*</td>
<td>NS</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>*</td>
<td>***</td>
</tr>
<tr>
<td>Dew Removal (Dew)††</td>
<td>***</td>
<td>**</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Fungicide‡‡</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>***</td>
<td>*</td>
<td>**</td>
<td>***</td>
<td>**</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Contrast§§</td>
<td>Mow</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Dew</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Fungicide</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Mow x Dew</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Dew x Fungicide</td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Mow x Dew x Fungicide</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot\(^{1}\) was visually counted. Data were log\(_{10}\) transformed prior to analysis.
‡ DAT = Days after treatments were applied.
§ AUDPC = Area under disease progress curve.
¶ Mowing treatments were performed by mowing plots two, four, or six times week\(^{-1}\) using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
# *, **, ***, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
†† Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
‡‡ Fungicides included chlorothalonil (8.18 kg a.i. ha\(^{-1}\)), iprodione (2.13 kg a.i. ha\(^{-1}\)), propiconazole (0.65 kg a.i. ha\(^{-1}\)), and a non-treated control. Fungicide treatments were applied on 24 Aug.

§§ Contrasts that evaluated main effects excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
Table 23. Influence of mowing frequency on the number of dollar spot infection centers on ‘Penneagle’ creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>11 DAT†</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>18 a#</td>
<td>19 a</td>
<td>16</td>
<td>18 a</td>
<td>25 a</td>
<td>34 a</td>
<td>84 a</td>
<td>546 a</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>14 b</td>
<td>16 ab</td>
<td>11</td>
<td>5 b</td>
<td>7 b</td>
<td>12 b</td>
<td>62 ab</td>
<td>300 b</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>10 b</td>
<td>11 b</td>
<td>5</td>
<td>3 b</td>
<td>4 b</td>
<td>8 b</td>
<td>36 b</td>
<td>183 b</td>
</tr>
</tbody>
</table>

ANOVA††

| Mowing Frequency | ** | * | NS | ** | *** | ** | * | *** |

† The number of dollar spot infection centers plot was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test.

Data were log₁₀ transformed prior to analysis, but actual means are shown.
†† *, **, *** and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 24. Influence of mowing frequency on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010. Non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>11 DAT§</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 days week⁻¹</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3 a</td>
<td>8 a</td>
<td>15 a</td>
<td>59 a</td>
<td>184 a</td>
</tr>
<tr>
<td>4 days week⁻¹</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1 b</td>
<td>1 b</td>
<td>3 b</td>
<td>37 ab</td>
<td>79 b</td>
</tr>
<tr>
<td>6 days week⁻¹</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1 b</td>
<td>1 b</td>
<td>3 b</td>
<td>22 b</td>
<td>54 b</td>
</tr>
</tbody>
</table>

Contrast††

<table>
<thead>
<tr>
<th>Mowing Frequency</th>
<th>ANOVA‡‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot⁻¹ was visually counted.
‡ Mowing treatments were performed by mowing plots two, four, or six times week⁻¹ using a Toro 5400 fairway reel mower set to a height of 1.3 cm.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey’s honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
†† Contrasts that evaluated mowing frequency excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
‡‡ *, **, and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 25. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010.

<table>
<thead>
<tr>
<th>Dew Removal</th>
<th>11 DAT§</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew not removed</td>
<td>21 a#</td>
<td>23 a</td>
<td>17 a</td>
<td>15 a</td>
<td>20 a</td>
<td>29 a</td>
<td>97 a</td>
<td>549 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>8 b</td>
<td>8 b</td>
<td>14 b</td>
<td>2 b</td>
<td>3 b</td>
<td>7 b</td>
<td>25 b</td>
<td>137 b</td>
</tr>
</tbody>
</table>

Dew Removal

|            | **      | **      | *       | ***     | ***     | ***     | ***     |

*† The number of dollar spot infection centers plot was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log10 transformed prior to analysis, but actual means are shown.
†† *, **, *** and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 26. Influence of dew removal on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010. Non-fungicide-treated plots were excluded.

<table>
<thead>
<tr>
<th>Dew Removal</th>
<th>11 DAT§</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew not removed</td>
<td>1</td>
<td>2 a#</td>
<td>1</td>
<td>3 a</td>
<td>5</td>
<td>12 a</td>
<td>63 a</td>
<td>172 a</td>
</tr>
<tr>
<td>Dew removed</td>
<td>0</td>
<td>0 b</td>
<td>0</td>
<td>0 b</td>
<td>1</td>
<td>3 b</td>
<td>15 b</td>
<td>39 b</td>
</tr>
</tbody>
</table>

Contrast††

<table>
<thead>
<tr>
<th>Dew Removal</th>
<th>ANOVA‡‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>*</td>
</tr>
<tr>
<td>NS</td>
<td>**</td>
</tr>
<tr>
<td>NS</td>
<td>***</td>
</tr>
<tr>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

† The number of dollar spot infection centers plot† was visually counted.
‡ Dew removal treatments were performed by using a Toro 5400 fairway reel mower with reels disengaged.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey's honestly significant (P ≤ 0.05) difference test. Data were log_{10} transformed prior to analysis, but actual means are shown.
†† Contrasts that evaluated mowing frequency excluding non-fungicide-treated plots were included due to the lack of dollar spot suppression in control plots.
‡‡ *, **, ***; and NS refer to significance at P≤ 0.05, 0.01, 0.001, and not significant, respectively.
Table 27. Influence of fungicides on the number of dollar spot infection centers on 'Penneagle' creeping bentgrass managed as a fairway, Pennsylvania State University, University Park, Pennsylvania, Late Summer 2010.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>11 DAT‡</th>
<th>15 DAT</th>
<th>18 DAT</th>
<th>23 DAT</th>
<th>25 DAT</th>
<th>29 DAT</th>
<th>32 DAT</th>
<th>AUDPC¶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorothalonil</td>
<td>0 b</td>
<td>2 b</td>
<td>1 b</td>
<td>3 b</td>
<td>7 b</td>
<td>15 b</td>
<td>68 b</td>
<td>194 b</td>
</tr>
<tr>
<td>Iprodione</td>
<td>0 b</td>
<td>0 c</td>
<td>0 b</td>
<td>0 c</td>
<td>1 c</td>
<td>2 d</td>
<td>16 d</td>
<td>34 d</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>0 b</td>
<td>2 bc</td>
<td>0 b</td>
<td>1 bc</td>
<td>3 c</td>
<td>5 c</td>
<td>34 c</td>
<td>89 c</td>
</tr>
<tr>
<td>Non-Treated Control</td>
<td>56 a</td>
<td>58 a</td>
<td>41 a</td>
<td>30 a</td>
<td>37 a</td>
<td>49 a</td>
<td>125 a</td>
<td>1056 a</td>
</tr>
</tbody>
</table>

ANOVA‡‡

| Fungicide       | *** | *** | *** | *** | *** | *** | *** |

† The number of dollar spot infection centers plot was visually counted.
‡ Fungicides included chlorothalonil (8.18 kg a.i. ha⁻¹), iprodione (2.13 kg a.i. ha⁻¹), propiconazole (0.65 kg a.i. ha⁻¹), and a non-treated control. Fungicide treatments were applied on 24 Aug.
§ DAT = Days after treatments were applied.
¶ AUDPC = Area under disease progress curve.
# Means in a column followed by the same letter are not significantly different according to Tukey’s honestly significant (P ≤ 0.05) difference test. Data were log₁₀ transformed prior to analysis, but actual means are shown.
‡‡ *, **, *** and NS refer to significance at P ≤ 0.05, 0.01, 0.001, and not significant, respectively.