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Influence of simulated rainfall on efficacy of fluazinam, chlorothalonil and iprodione for dollar spot control in creeping bentgrass

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ABSTRACT

Efficacy of foliar applied fungicides following simulated rainfall for the control of dollar spot (caused by *Sclerotinia homoeocarpa* F.T. Bennett) was assessed in a two-year field study on creeping bentgrass (*Agrostis stolonifera* L.) turf maintained as a golf course fairway. The study was conducted as a randomized complete block design with a factorial arrangement. Fluazinam (0.8 kg a.i. ha^{-1}), chlorothalonil (3.79 kg a.i. ha^{-1}) or iprodione (1.5 kg a.i. ha^{-1}) were applied, then subjected to simulated rainfall (2.54-mm) at intervals of 15-, 30-, 60-min post-application, or no simulated rain. In most cases, simulated rainfall occurring ≤60 min post-application had greater disease than no rain plots; however, few differences occurred among rainfall intervals ≤60 min. Fluazinam provided the greatest dollar spot reduction regardless of simulated rainfall interval throughout the study. Chlorothalonil was most susceptible to losses in efficacy due to simulated rainfall, resulting in the greatest disease incidence of those fungicides evaluated. Iprodione was comparable to chlorothalonil during high disease pressure, although during moderate disease pressure it controlled dollar spot for approximately 7 days before disease increased in plots receiving simulated rain compared to those without simulated rain. These data demonstrate that efficacy of fungicides applied for dollar spot control are affected by rain, and differ in their ability to control disease following post-application rain events. Fluazinam, a recently introduced contact fungicide for use on turfgrass, can provide improved control compared to chlorothalonil or iprodione when rain is eminent.

1. Introduction

Fungicides are an essential component of integrated disease management programs for high maintenance turfgrass areas such as golf course greens, tees and fairways. Fungal diseases including dollar spot, caused by *Sclerotinia homoeocarpa* F.T. Bennett, routinely affect the quality and performance of turfgrasses from May to October throughout much of the northern United States, Canada, and Europe (Smith et al., 1989). During this period, fungicides may be applied every 7- to 28-d depending on disease pressure, selected active ingredient, budget, and tolerance for disease damage. Given the frequency of fungicide applications it is probable that following one or more treatments in a season, an unexpected rain event may occur during or shortly after a fungicide application. This may be particularly evident on golf courses where abundant play or scheduled events limit flexibility in application timing, or where prior notification of pesticide application is required.

Previous research has demonstrated that rainfall or irrigation can reduce the efficacy of contact fungicides applied to turf (Couch, 1985; Pigati et al., 2010) and other crops (Schepers, 1996; Töfoli et al., 2014). Contact fungicides are susceptible to wash off by rain and irrigation since the active ingredient exists as deposits or films on the external surface of plant tissues. The degree of fungicide wash-off can be affected by several factors including: interval between application and rain event, rain intensity, rain quantity, fungicide formulation, solubility of the fungicide, dose, and the foliar characteristics of the target crop (Cabras et al., 2001).

Chlorothalonil, iprodione, and recently fluazinam are fungicides commonly used alone or mixed with others to manage dollar spot epidemics. Chlorothalonil is a broad-spectrum, contact fungicide first registered in the United States for use on turfgrass in 1966 (Environmental Protection Agency, 1999). It remains an important turfgrass fungicide due to its broad spectrum of activity, multi-site

Abbreviations: Days after treatment, DAT; Dollar spot infection centers, DSIC.

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mode of action and role in managing fungicide resistance (Latin, 2011). However, efficacy of chlorothalonil is known to be reduced when rainfall or irrigation is applied shortly after application. An equivalent of 3.2 mm of irrigation applied before an application of chlorothalonil had completely dried on the canopy reduced dollar spot control compared to irrigating immediately after the canopy had dried on a creeping bentgrass (*Agrostis stolonifera* L.) putting green turf (Couch, 1985). Similarly, 30 mm of simulated rainfall 30 min after chlorothalonil was applied increased the area under disease progress curve (AUDPC) for dollar spot compared to fungicide treated plots where rain was withheld several days following application (Pigati et al.,2010).

Iprodione also has a broad spectrum of activity against turfgrass diseases, although it is considered to be a localized penetrant rather than a contact fungicide. Localized penetrants adhere strongly to the cuticle, and may diffuse from one side of a leaf to the other through apoplastic spaces (Latin, 2011). The high affinity of this fungicide for plant cuticle should reduce its susceptibility to wash-off following post-application rain or irrigation events. However, data from studies of this fungicide conducted on turfgrass provide inconsistent results. Irrigating a creeping bentgrass putting green that had not completely dried following an iprodione treatment eliminated dollar spot control; whereas non-irrigated turf treated with iprodione reduced the disease (Couch, 1985). Conversely, Pigati et al. (2010) found that dollar spot was unaffected by simulated rainfall occurring 30 min after iprodione application in fairway turf (Pigati et al., 2010).

Fluazinam is a contact fungicide first registered for use in the United States on potatoes (*Solanum tuberosum* L.) and peanuts (*Arachis hypogaea* L.) in 2001 (EPA, 2001), and recently registered for use on turfgrass. Efficacy of this fungicide in studies on potato following simulated rain has been greater than other contact fungicides. Fluazinam provided better control of potato late blight [caused by *Phytopthora infestans* (Mont.) de Bary] compared to maneb-fentinacetate following simulated rainfall in the greenhouse and naturally occurring rain in the field (Schepers, 1996). A comprehensive study of 20 and 18 active ingredients for late blight and early blight (caused by *Alternaria solani*) control on potato, respectively, evaluated disease in plants treated with fungicides followed by simulated rain at intervals of 0.5, 1.0, 2.0, or 4.0 h post application (Töfoli et al., 2014). Simulated rain reduced the efficacy of all fungicides compared to plants not subjected to simulated rain; although contact fungicides were affected by simulated rainfall to a greater extent than acropetal penetrant fungicides in the study. However, fluazinam was statistically intermediate between penetrant fungicides and contact fungicides such as chlorothalonil and mancozeb when followed by simulated rainfall.

Data from studies on potato suggest that fluazinam may have improved rainfastness compared to other contact fungicides routinely used in managing dollar spot and other diseases in turfgrass. The objective of this study was to compare the efficacy of fluazinam, chlorothalonil, and iprodione for dollar spot control on creeping bentgrass fairway turf subjected to simulated rainfall.

2. Materials and methods

2.1. Site description

The two-year field study was initiated in 2013 on a 'Crenshaw' creeping bentgrass turf grown on a Woodbridge sandy loam (coarse-loamy, mixed, active, mesic Aquic Dystrudepts) with a pH of 5.4 at the University of Connecticut Plant Science Research and Education Facility in Storrs, CT. The turf was established from seed in September 2006, and the field was inoculated with *S. homoeocarpa* in 2007, as described by Putman and Kaminski (2011); after which disease developed each year as a natural infestation.

Mowing was performed three times wk^{-1} with a triplex mower equipped with a grooved front roller at a bench setting of 1.3 cm with clippings removed. Nitrogen was applied once in April, May, and June at 12.3–24.5 kg ha^{-1} as a solution of 21-0-0 or 46-0-0 with a total of 49.0 or 36.8 kg N ha^{-1} applied prior to and during the evaluation period in 2013 and 2014, respectively. Irrigation was applied only when wilt stress was evident and to wash fertilizer off of leaf tissue. Chlorothalonil (3.79 kg a.i. ha^{-1}) and fluazinam (0.8 kg a.i. ha^{-1}) were applied to the entire study area on 22 and 29 May 2013, respectively and chlorothalonil was applied at 9.77 kg a.i. ha^{-1} on 17 May 2014 to prevent dollar spot development prior to initiation of treatments. Chlorantraniliprole (0.21 kg a.i. ha^{-1}) was applied on 22 Jun for control of white grubs (*Anomala orientalis* Waterhouse, *Popillia japonica* Newman, and *Rhizotrogus majalis* Razoumowsky).

2.1.1. Experimental design and treatments

The experimental design was a completely randomized block containing 1 × 2 m plots with four replicated blocks arranged in a 3 × 4 factorial. Main effects were fungicide and simulated rainfall timing post-application. Fungicides evaluated were fluazinam (Secure; Syngenta Professional Products, Greensboro, NC; 0.8 kg a.i. ha^{-1}), chlorothalonil (Daconil Weather Stik; Syngenta Professional Products, Greensboro, NC; 4.6 kg a.i. ha^{-1}), and iprodione (26 GT; Bayer Environmental Science, Research Triangle Park, NC; 1.5 kg a.i. ha^{-1}) applied every 14 days during the study. Rates and intervals were selected based on manufacturer label recommendations for dollar spot control on golf course fairways. Fungicides were applied using a hand-held CO^2 powered sprayer with a single AI9504E flat fan nozzle (TeeJet Technologies; Glendale Heights, IL) calibrated to deliver 407 L ha^{-1} at 276 kPa. Fungicides were applied before sunrise between 0430 and 0500 h when relative humidity was between 70 and 90%. Dew was removed with a hand roller prior to application, however the canopy remained wet and some dew reformed on the canopy following removal. These application conditions were selected to simulate the environment which may exist prior to a rain event which would be unsuitable for rapid drying of fungicides on the turf canopy. Simulated rainfall was applied 15-, 30-, or 60-min following application of each of the fungicides. A no simulated rainfall treatment was also included for each fungicide. At each specified time interval, four people applied the simulated rainfall to each plot using watering cans (model B5L; DRAMM; Manitowoc, WI) containing the equivalent of 2.54 mm of precipitation at a rate of 300 mm h^{-1}. A simulated rainfall control (i.e., no fungicide applied) was not included in the study due to the expectation that 2.54 mm of simulated rainfall applied every 14-d, in addition to naturally occurring rainfall, would have little effect on dollar spot epiphytotics. No rainfall or irrigation was applied to the study area for at least 24 h after fungicide treatment. Initial treatments were applied preventively on 6 Jun 2013 and 29 May 2014 with subsequent applications every 14-d through 4 Jul 2013 and 24 Jul 2014, respectively.

2.1.2. Data collection and statistical analysis

Naturally occurring precipitation was recorded throughout the duration of the study by an onsite weather station (U-30; Onset Computer Corporation; Bourne, MA). Dollar spot incidence was assessed as a count of individual disease foci within each plot every 3-, 7-, and 14-d after treatment. Each 14-d period following a treatment application during the disease epidemic is presented as an observation period for clarity of interpretation of treatment effects relative to applications. However, data were not analyzed by observation period. There were two observation periods during the