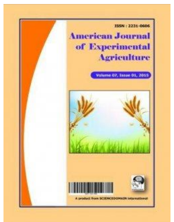

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Managing Sclerotinia Blight in Peanut: Evaluation of a Weather-based Forecasting Model to Time Fungicide Applications in Texas

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Authors' contributions

This work was carried out in collaboration between both authors. Author JEW designed the study, wrote the protocol, performed the statistical analysis and wrote the first draft of the manuscript. Author SAR reviewed the experimental design, performed the field work and reviewed all drafts of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate fungicide regimes were applications were made according a weather-based disease advisory compared to current application timings.
Study Design: Randomized complete block with four replications.
Place and Duration of Study: Studies were conducted during the 2008, 2009 and 2010 growing seasons on a producer farm located near Seminole Texas, Gaines County in fields with a history of Sclerotinia blight.
Methodology: Fungicide applications were made using a weather-based spray advisory model with varying Five-day risk index (FDI) thresholds that were calculated from daily average soil temperature, rainfall/irrigation and growth development. Five FDI treatments, a calendar-based and symptom-based (positive controls), as well as a non-treated (negative control) were evaluated. The cultivars Flavor Runner 458, Tamrun OL 02 and/or Tamrun OL07 were utilized in this study based

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on their differing reactions to Sclerotinia blight. Disease control, yield and quality for these timings were compared to the calendar-based and symptom-based programs, as well as the non-treated control.

Results: Appreciable levels of Sclerotinia blight were observed in 2008 and 2010. The application of fungicides led to a decrease in disease incidence compared to the non-treated control; however, few differences were observed among fungicide treatments. Overall, higher yields were achieved when fungicides were applied according to the calendar-based program. Similar yields were generally achieved for the lowest of the FDI thresholds evaluated and yields were generally lower when applications were delayed due to higher FDI thresholds. Grades were not affected by fungicide treatment; however, differences between cultivars were observed. Flavor Runner 458 consistently had higher grades than Tamrun OL07; however, Tamrun OL07 has improved resistance to *S. minor.*

Conclusion: Results from these studies suggest that the weather-based spray advisory model evaluated herein was not effective at improving upon the efficacy of fungicides for control of Sclerotinia blight in peanut. Moreover, applications for control of the disease in Texas should be made approximately 70 to 75 days after planting with a sequential application being made 28 to 30 days later.

Keywords: Weather advisories; disease forecasting; groundnut; fungicide timing.

1. INTRODUCTION

Sclerotinia blight of peanut (*Arachis hypogaea* L.) is caused by the soilborne fungus *Sclerotinia minor* (Jagger) [1]. The disease was initially identified in Virginia and North Carolina and subsequently reported in Oklahoma and Texas [2,3]. While *S. minor* is the predominant causal agent, *S. sclerotiorum* (Lib.) De Bary, has also been shown to incite the disease [4-6]. Crop losses due to *S. minor* from 17 to 33% have been reported [7]. More recently, Woodward et al. [8] reported yield losses as high as 41% in susceptible cultivars.

Current disease management strategies are comprised of using partially resistant varieties in conjunction with fungicides. Several cultivars including Tamrun OL07 and Tamrun OL11 have improved resistance to Sclerotinia blight and are commercially available in Texas [9,10]. In addition, fungicides such as fluazinam and boscalid have been labeled for use in peanut since the early to mid-2000s [11-13]. While these fungicides are effective at controlling the disease, they are expensive and generally comprise a large portion of production budgets in fields severely infested with *S. minor*. Furthermore, application timing is critical when using fungicides to manage Sclerotinia blight. Preventative applications of boscalid and fluazinam made prior to infections occurring have been shown to provide optimum disease control [12,13].

Environmental factors including soil temperature, rainfall and relative humidity are known to affect fungal growth and influence Sclerotinia blight development [14-17]. As a result, several disease-forecasting models to predict disease outbreaks and properly time fungicide applications have been created [15,18,19]. Langston et al. [19] developed a series of algorithms to compute disease risk and trigger fungicide applications in Virginia and North Carolina. Iterations of those algorithms were later used to predict the onset of Southern blight epidemics, caused by *Sclerotium rolfsii*, in Georgia [20]. These and other disease forecasting systems are currently being used in the management of Sclerotinia blight in the Southeastern United States; however, such an approach has not been used to time fungicide applications under the arid conditions experienced in the Southwestern production area of the country. Therefore, the objective of this research was to evaluate a weather-based model to time fungicide applications for the management of Sclerotinia blight of peanut.

2. MATERIALS AND METHODS

2.1 Evaluation of a Weather-based Model to Time Fungicides

A total of eight field trials were conducted from 2008 through 2010 at a producer farm in western Gaines Co. Texas (32°50'8.55"N, 103° 2'22.80"W). The field had a history of Sclerotinia blight. Soil type was a Brownfield or Patricia fine sand. Plots consisted of two 101.6-cm rows, 15.2 m long, with 1.5-m alleys between plots. The experimental design was a randomized complete block with four replications. The peanut cultivars Flavor Runner 458 [21], Tamrun OL 02 [22] and/or Tamrun OL07 [9], were selected because of their differing reaction to Sclerotinia blight. Plots were planted on 20-Apr, 23-Apr and 28-Apr of 2008, 2009 and 2010, respectively at a rate of 6 seeds per 30.5 cm. All production practices, other than disease control, were in accordance with extension recommendations [23].

Treatments consisted of applications of the fungicides fluazinam (Omega, Syngenta Crop Protection, Greensboro, NC) at 0.84 kg a.i. ha^{-1} or boscalid (Endura, BASF Corporation, Research Triangle Park, NC) at 0.44 kg a.i. ha^{-1} made preventatively, curatively, or according to a weather-based system utilizing various thresholds. Preventative applications were made 70 to 75 days after planting (DAP), whereas, curative applications were made following the onset of disease development (i.e. the first observation of symptoms of the disease or signs of the pathogen). Environmental factors monitored for forecasting models included soil temperature at a depth of 10-cm, rainfall or irrigation and relative humidity within the canopy, which were monitored with HOBO data loggers (Onset Computer Corporation, Bourne, MA). Host plant growth factors including vine growth and canopy density were also measured bi-weekly. Threshold treatments were derived by weighing values on the aforementioned factors as they relate to Sclerotinia blight development as described by Langston et al. [19]. If the value of the factor had little impact on disease development, it was assigned a value of zero. The greater the factors impact the higher the value assigned. These values were multiplied to provide a daily risk index and this value was summed over five days to calculate a “Five Day Risk Index” (FDI). Five FDI thresholds (16, 24, 32, 40 and 48) were utilized to trigger initial fungicide applications. All applications were made in a 38.1-cm band over the center of the row using a CO_2-pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} with one 8003 flat fan nozzle (TeeJet Technologies, Springfield, IL) per row.

2.2 Data Collection and Analysis

Disease incidence was assessed midseason and prior to plots being dug and inverted by counting the number of disease foci per plot, which consisted of 30.5-cm segments of row exhibiting symptoms of the disease or signs of the pathogen [24]. Percent disease incidence was calculated by dividing the number of affected 30.5-cm segments by the total number of 30.5-cm segments in the plot and multiplying by 100. Crop maturity was estimated by collecting pods from border plots within each trial and subjecting them to the hull scrape method [25]. Plots were mechanically dug and inverted using a KMC digger/shaker (Kelly Manufacturing Co., Tifton, GA) and allowed to dry in windrows for approximately 7 days. Windrows were harvested using a two-row combine (Lilliston Corporation, Albany, GA) equipped with a sacking attachment.

Pod yields were calculated after the moisture of pods was adjusted to 10% (wt:wt) and foreign matter was removed. Sub-samples of pods (500 g) were then collected from each plot, shelled, sorted and subjected to federal inspection procedures to determine grades [26]. The sum of total sound mature kernels (TSMK) and sound splits (SS) were used to determine peanut grades (%TSMK+SS). Final disease incidence, pod yield, grade and damaged kernel values were subjected to analysis of variance [27]. Means were separated using Fisher’s Protected LSD at P = .05 [28].

3. RESULTS AND DISCUSSION

3.1 Field Trials in 2008

In-season rainfall was 18% above the long-term average with the majority of rainfall occurring in mid-September (Table 1). Soil temperatures were well above the two other years in the study between 45 to 65 DAP and well below later in the growing season, but similar from the middle of the season (Fig. 1). Plant development was similar in all trials with canopy closure occurring on approximately 31-Jul (data not shown).

Calendar-based applications of fluazinam were made on 10-Jul and 7-Aug, while curative applications were made on 22-Jul and 20-Aug. Applications for the FDI threshold of 16 triggered at the same time as the curative application. The initial application for the FDI = 24 was delayed a single day, whereas, FDI thresholds of 32, 40 and 48 triggered simultaneously on 26-Jul. All subsequent applications were made on a 28-day interval. Moderate temperatures in conjunction with abundant rainfall triggered each model (Fig. 1). Label restrictions did not permit a third application of fluazinam; therefore, a final application of boscalid was made 5-Sept for the calendar-base regime, 17-Set for the curative treatment and 16 and 24 FDI thresholds, and 19-

Sept for the 32, 40 and 48 threshold values. Ideally, two applications of fungicide with Sclerotinia blight activity are made in season to control the disease [23]. The additional application of boscalid did not improve disease control over the calendar-based or symptom-based treatments. Similarly, additional applications of fungicides have not been effective at increasing disease control [12].

A significant treatment × trial interaction was observed for disease incidence; therefore, data are presented for each trial independently. In the two trials planted to the susceptible Flavor Runner 458, the application of fungicides reduced disease incidence compared to the non-treated control; whereas, no differences were observed among treatments in the trial planted to the partially resistant Tamrun OL07 (Table 2). Disease pressure was low in two of the trials and moderate in the third trial. Overall, applications made via the calendar provided the best level of control; however, the FDI thresholds of 16 and 24 were similar.

Lack of a treatment × trial interaction allowed for yield data to be combined (Table 3). When averaged across treatments, yields were similar for Tamrun OL07 and the Flavor Runner trial with the lowest level of disease were similar

Table 1. In-season rainfall accumulation for Gaines County Texas for 2008-2010 compared to the 15 year average[a]

Year	June	July	August	September	October	Sum
2008	40	12	39	120	47	258
2009	71	68	16	13	15	183
2010	65	149	9	9	7	239
15 year average	41	43	26	68	41	219

[a] *Data from 2008, 2009 and 2010 were collected from weather sensors deployed in the field, whereas, the long term rainfall amounts were collected from the West Texas Mesonet [29]*

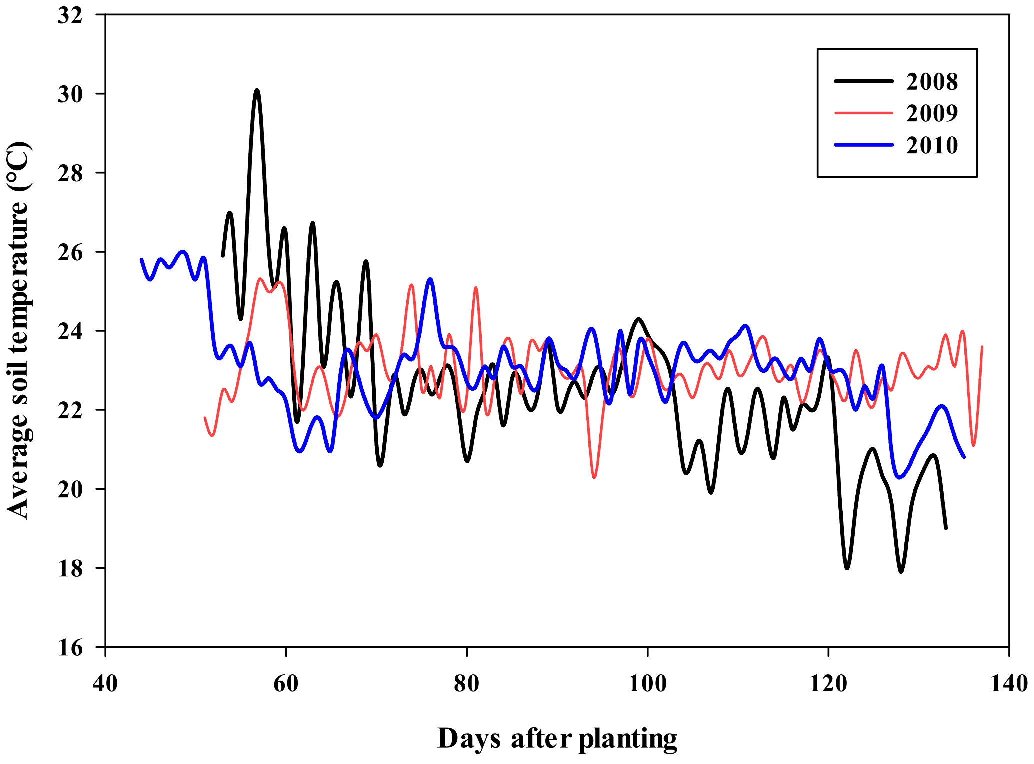

Fig. 1. Daily average soil temperatures (10-cm depth) from approximately 45 to 140 days after planting from field trials conducted during the 2008, 2009 and 2010 growing seasons

Table 2. Effect of preventative and curative fungicide regimes compared to weather-based forecasting models with five different thresholds on the incidence of Sclerotinia blight[a]

Treatment (Application timing)	Disease incidence (%)				
	2008			2010	
	FR 458a	FR 458b	TR OL07	FR 458	TR OL07
Non-treated control	3.0a	17.5a	2.0a	21.0a	20.0a
Calendar-based	0.5c	4.0b	0.5a	7.0ab	11.0b
Symptom-based	1.5abc	7.5b	2.0a	7.0ab	11.0b
FDI = 16	0.5c	6.0b	1.0a	5.0b	15.0b
FDI = 24	1.0bc	7.0b	1.0a	9.0ab	16.0b
FDI = 32	2.5ab	9.0b	1.0a	9.0ab	16.0b
FDI = 40	2.0abc	8.5b	1.0a	11.0ab	13.0b
FDI = 48	3.0a	8.5b	0.5a	14.0ab	16.0b

[a]Values within a column followed by the same letter are not different according to Fishers Protected LSD (P = .05)

averaging 5377 and 5915 kg ha^{-1}, respectively (data not shown). When combined across all trials, yields were lowest for the non-treated control averaging 5092 kg ha^{-1}. Yields were highest for plots, which received applications on the calendar-based timing followed by the symptom-based or curative application timing. None of the threshold-based treatments increased yields compared to the non-treated control. These results support previous research in that preventative fungicide applications provide superior control of Sclerotinia blight, compared to curative or post-infection applications [12,13].

Due to the lack of a treatment × trial interaction, grade factors were combined across cultivars. No differences in grades were observed between treatments with TSMK+SS ranging from 69.2 to 71.4% (Table 4). Differences were observed among cultivars with grades being higher for Flavor Runner 458 than Tamrun OL07, which supports previous findings [6,9].

3.2 Field Trials in 2009

Despite the previous history of disease in this field and adjacent fields no appreciable levels of Sclerotinia blight were observed during the 2009 growing season (data not shown). Cumulative rainfall within the season was 16% below the 15-year average (Table 1). Rainfall in the early part of the season was 58 to 73% above average, whereas, precipitation later during August, September and October was well below average. Dailey average soil temperatures were intermediate throughout much of the season and above average towards the end of the season compared to 2008 and 2010 (Fig. 1). Peanut growth was similar to the other years of the study with canopy closure occurring approximately 70 DAP. Calendar-based applications were made 6-Jul and 7-Aug. Initial applications for the 16 and 24-point FDI threshold treatments were made on 22-Jul. The first applications for the symptom-based treatment and 32 point FDI threshold were made on 24-Jul. Initial applications for the two highest threshold treatments were made eight and 10 days later. All sequential applications were made between 20 and 22-Aug, except for the calendar-based treatment, which was made on 7-Aug.

No appreciable levels of disease were observed in the three trials conducted in 2009 (data not shown). As a result, no differences in yield were observed among treatments (Table 3). When averaged across all fungicide treatments, pod yields of 6311, 6159 and 6477 kg ha^{-1} were observed for Flavor Runner 458, Tamrun OL02, and Tamrun OL07, respectively (data not shown). Differences in previous agronomic practices may have contributed to differences in disease pressure in this field, as longer durations of crop rotations with cotton (*Gossypium hirsutum* L.) and deep tillage were both employed. Each of these practices is known to affect Sclerotinia blight development [30]. Although statistical comparisons could not be made, field observations indicate that differences in pod rot incidence (caused by *Rhizoctonia solani* and *Pythium* spp.) may exist between the cultivars evaluated. Mean pod rot incidence was 8.1, 1.5, and 1.3% for the respective cultivars (data not shown). No differences in grades were observed among treatments (Table 4). When averaged across treatments, grades averaged 72.2% TSMK+SS. Differences in grade were observed among cultivars with Tamrun OL07 having lower TSMK values than both Flavor Runner 458 and Tamrun OL 02.

3.3 Field Trials in 2010

When considering rainfall totals, a trend similar to 2009 where above average amounts fell early in the growing season with a more than three-fold increase falling in July (Table 1). Although the later part of the season was dry, such large rains occurring in July resulted in a 9% surplus of precipitation for the season. Soil temperatures through 60 were generally lower than what was observed in the other two seasons, but moderated as the season progressed (Fig. 1). The overlapping of plant rows occurred 80 DAP.

The lowest FDI threshold called for an application to be made 10-Jul, which again coincided with the calendar-based application. The curative treatment was made 14 days later with applications for the 24, 32, 40 and 48 FDI thresholds occurring on a daily basis afterwards. As was the case in previous years, a second application of fluazinam was made on a 28-day interval following initial applications for all treatments.

Appreciable levels of disease were observed at this location with 21 and 20% of the non-treated controls exhibiting symptoms of Sclerotinia blight or signs of *S. minor* in Flavor Runner 458 and Tamrun OL07, respectively (Table 2). Disease incidence for Tamrun OL07 was higher than expected; however, development was much less severe than that observed in Flavor Runner 458 (data not shown). Differences were not observed among treatments when fungicides were applied to Tamrun OL 07; however, disease incidence was generally lower when applications were made according to the 16-point FDI value. Disease incidence for all other treatments including the calendar-based curative programs was intermediate.

Table 3. Effect of preventative and curative fungicide regimes compared to weather-based forecasting models with five different thresholds on peanut yield[a]

Treatment (Application timing)	Pod yield (kg ha^{-1})			
	2008	2009	2010	
	Combined	Combined	FR 458	TR OL07
Non-treated control	5092c	6340a	3091c	4123ab
Calendar-based	6054a	6288a	5348a	4928a
Symptom-based	5659ab	6300a	5117ab	4358ab
FDI = 16	5156c	6608a	4893ab	3424b
FDI = 24	5124c	6169a	4760ab	3413b
FDI = 32	5210bc	6390a	4463abc	4483ab
FDI = 40	5297bc	6336a	3866bc	4996a
FDI = 48	5313bc	6092a	5023ab	4155ab

[a] *Data from 2008 and 2009 were combined across trials and cultivars due to the lack of a significant interaction. Values within a column followed by the same letter are not different according to Fishers Protected LSD (P = .05)*

Table 4. Effect of preventative and curative fungicide regimes compared to weather-based forecasting models with five different thresholds on peanut grade[a]

Treatment	Grade (% TSMK+SS)		
(Application timing)	2008	2009	2010
Non-treated control	69.8a	72.3a	72.8a
Calendar-based	69.8a	73.1a	73.8a
Symptom-based	70.2a	72.9a	72.4a
FDI = 16	71.4a	71.8a	72.5a
FDI = 24	70.7a	72.2a	73.0a
FDI = 32	69.2a	72.0a	72.3a
FDI = 40	71.0a	71.6a	73.1a
FDI = 48	71.3a	71.3a	72.7a
Cultivar			
Flavor Runner 458	70.9A	72.7A	73.5A
Tamrun OL 02	---	72.3A	---
Tamrun OL07	69.8B	71.3B	72.1B

[a] *Data within a column followed by the same letter are not different according to Fishers Protected LSD (P = .05). Data were combined across cultivars for each year with comparisons made between varieties within a year*

Yields were similar among treatments (data not shown); however, responses to fungicide treatments differed between the two cultivars (Table 3, above). Flavor Runner 458 responded to all fungicide treatments with the exception of the 32 and 40 FDI values. Yields were highest for the calendar-based program. Yield responses among treatments were less for Tamrun OL07 ranging from 3413 to 4996 kg ha^{-1}. As with previous studies, greater yield responses were observed for the calendar-based treatments, which, coincides with preventative applications [12]. Grade parameters were similar among treatments ranging from 72.4 to 73.8% SMK+SS and averaging 73.5 and 72.1% for Flavor Runner 458 and Tamrun OL07, respectively (Table 4, above).

4. CONCLUSIONS

Several disease-forecasting models have been developed to better time fungicide applications for a number of diseases in peanut [15,18,19]. While weather-based forecasting models similar to the one evaluated in this study have been used to manage Sclerotinia blight in in Virginia and later adapted to time applications for Southern blight in Georgia, there appears to be limited utility for this system in the arid peanut production regions in the Southwestern United States. Perhaps additional parameters need to be added to the model to adequately determine when infections by *S. minor* will occur. Smith et al. [17] reported that germination of sclerotia was greatest at a temperature of 30°C and a soil matric potential of -7.2 kPa. In addition, previous agronomic practices employed may need to be examined, as differences in tillage and crop rotation may have affects populations of the fungus in the soil.

The ability to use forecasting models should allow producers to maximize efficacy, as applications would be made only when conditions conducive for disease development occur. Ambient and soil conditions in the Southwestern United States differ greatly from those which occur in areas where this model have been used successfully. For example, west Texas is an arid environment, thus the rate of evaporation is much greater than other areas. This results in greater amounts of irrigation being applied within the season. Declining irrigation capacity has affected the speed at which irrigation can be applied, creating large variability in soil matric potential across a field. Furthermore, changes in matric potential resulting from the addition of irrigation does not impact soil or ambient temperature the same as a rainfall event.

Soil temperature and moisture in addition to canopy closure were the primary factors in the model evaluated. In addition to differences in rainfall, irrigation practices and the possible impact on soil matric potential, soil temperatures in the region where this study was conducted vary. This is a result of large temperature swings that occur between day and night. Daytime highs and nighttime lows during periods when fungicide applications were made can differ by as much as 16°C (data not show). This in turn greatly affects growth of the fungus, as disease development generally stops during the middle part of the day, only resuming later in the evening once following the return of cooler temperatures.

Fungicide applications in the Southwestern United States are typically made based on intensive scouting or days after planting. Fungicide applications are most efficacious when made preventatively; however, the cost associated with fungicides labeled for use in peanut does not justify more than two applications, as was seen in 2008. Results from these studies indicate that of the range of FDI risk-values evaluated, only FDI=16 consistently reduced disease incidence and somewhat increased yields. The majority of applications made following this threshold being breached were at the same time as applications made using the calendar-based approach. Without refining the weather-based model, producers should continue to budget for fungicides for control of Sclerotinia blight in peanut, making initial applications approximately 70 to 75 DAP with a sequential application being made 28 to 30 days later.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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