Evaluation of Weather-Based Spray Advisories for Improved Control of Peanut Stem Rot

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ABSTRACT

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Stem rot of peanut, caused by the soilborne fungus *Sclerotium rolfsii*, is greatly influenced by environmental conditions. Disease management programs rely heavily on fungicides, which are applied on a calendar-based program. To determine whether improved control of stem rot could result from weather-based spray advisories, models were constructed using what is currently known about the biology of *S. rolfsii* and etiology of stem rot epidemics in peanut. Spray advisories based on soil temperature, precipitation, and host parameters were tested, along with advisories focusing on soil temperature and precipitation or precipitation alone. The advisories were evaluated and compared with the currently used calendar-based program over four locations annually for 3 years. Fungicide application timing had a significant effect on both stem rot control and resulting pod yields. In general, stem rot control following the advisories considering soil temperature, precipitation, and canopy growth was similar or better than that offered by the calendar-based program, but yields generally were comparable. The AU-Pnut advisory for foliar diseases also was effective for scheduling azoxystrobin applications for stem rot.

Additional keywords: *Arachis hypogaea*

Stem rot, caused by the soilborne fungus *Sclerotium rolfsii* Sacc., is one of the most serious diseases of peanut (*Arachis hypogaea* L.) in Georgia. Costs incurred by Georgia peanut producers over the last decade due to stem rot have averaged \$43.7 million annually in crop loss and pesticide expenditures (University of Georgia Cooperative Extension Service estimation, 1996–2005; unpublished data). *S. rolfsii* can infect many parts of the peanut plant, including crowns, lateral branches, pegs, and pods (18). Tebuconazole, azoxystrobin, and flutolanil are labeled and used for stem rot control in peanut (2,8,18). These fungicides typically are applied according to calendar-based schedules, with initial sprays being applied approximately 60 days after planting (DAP). Although this management practice is effective in most growing seasons, disease control can be erratic during years in which stem rot onset is earlier or later than usual. Unfortunately, the climatic conditions that favor stem rot development in peanut have not been specifically defined.

Relative humidity, temperature, soil

moisture, and soil pH have been reported to influence infection and subsequent damage caused by *S. rolfsii* on many hosts (23). The optimal soil temperature for *S. rolfsii* infection has been cited as 30°C for most cropping systems (1). Optimal temperatures for stem rot damage in peanut have been determined to be between 27 and 35°C (18,25).

Soil moisture also plays an important role in stem rot development, and much research has been conducted examining this relationship. Severe outbreaks of stem rot in peanut have been noted during growing seasons of above-average humidity or rainfall (23). Shew and Beute (25) observed that moisture levels had a greater impact on disease incidence than inoculum levels, and that plots receiving low inoculum levels had considerable disease develop when compensated with high moisture levels. In separate studies, Brenneman (7) and Bowen (4) found incidence of stem rot to be higher in irrigated versus nonirrigated plots. Davis et al. (13) found greater differences in levels of disease severity between irrigated versus nonirrigated plots in years with low rainfall. Similarly, Black et al. (3) observed less stem rot developing in nonirrigated plots versus plots receiving the highest levels of irrigation.

The peanut canopy and resulting microclimate at the soil surface also have been shown to influence stem rot of peanut. The disease is usually first observed in peanut fields between 60 and 90 DAP, although

this date varies among seasons (2). Coinciding with stem rot outbreaks is row closure by the peanut canopy and fruit initiation (23). As the peanut foliage develops, relative humidity and soil moisture increase within the canopy (11).

Research is needed to determine whether our current knowledge of *S. rolfsii* and stem rot epidemics can be used to improve stem rot management through the development of spray advisories. Disease advisories use environmental parameters to identify periods that are favorable for pathogen and disease development (9), thus optimizing timing for fungicide applications. Spray advisories have been developed and successfully implemented for some pathogens of peanut. A spray advisory developed by Cu and Phipps (10) in Virginia has been successful in reducing the number of fungicide applications to control early leaf spot (caused by *Cercospora arachidicola* Hori) and has been widely accepted by growers (20). The Virginia leaf spot advisory was adapted from research conducted by Jensen and Boyle (15) and Phipps and Powell (22). Spray advisories for late leaf spot caused by *C. personata* (Berk. & M. A. Curtis) Ellis have been evaluated in other peanut-producing states, including Georgia (19) and Alabama (12). The leaf spot advisory currently recommended in Georgia is AU-Pnut, but grower acceptance has been low. AU-Pnut bases fungicide applications on the number of precipitation events since the last fungicide application and the 5-day probability of precipitation (POP; 12). Brenneman and Culbreath (8) examined the possibility of incorporating fungicides for stem rot control into the current AU-Pnut advisory at various times during the season; however, results were erratic. More recent research in Alabama found similar inconsistencies (5). Adapting AU-Pnut to successfully manage both leaf spot and stem rot could be highly beneficial and increase grower acceptance of this advisory.

The environmental conditions that stimulate outbreaks of Sclerotinia blight on peanut (caused by *Sclerotinia minor* Jagger) in Virginia were determined (21). Spray advisories were developed that provided superior control compared with calendar and scouting-based fungicide applications (16,17). Advisories were based on air and soil temperatures, moisture (precipitation and relative humidity), canopy

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width, and plant canopy density (17). A similar approach could be used to develop an advisory for stem rot, which would enable producers to apply fungicides at the initial stages of disease development, thus improving fungicide performance through better application timing. The purpose of this research was to evaluate the performance of various spray advisories compared with calendar-based programs for control of stem rot on peanut.

MATERIALS AND METHODS

Several spray advisories were evaluated in four trials annually at the Coastal Plain Experiment Station (CPES) in Tift County, GA. In each year, one trial was conducted at the CPES Lang Farm, one at the CPES Blackshank Farm (Pond Field), and two more at the CPES Blackshank Farm (Irrigated or Nonirrigated Field), where replicated blocks of the field were irrigated or nonirrigated. Soil types for each location

are as follows: Lang Farm, Tifton loamy sand; Pond Field, Fuquay sand; and Irrigated or Nonirrigated Field, Tifton loamy sand. All soils in this study were of the classification Fine-loamy, kaolinitic, thermic Plinthic Kandudults. The peanut cv. Georgia Green was planted in all trials (23 seeds/m of row, 0.92-m row spacing) in fields infested with *S. rolfii* where peanut had been grown the previous year. Planting dates for the trials were 13 May (all trials) in 1999, 9 May (Lang Farm) and 10 May (all other trials) for 2000, and 10 May (Lang Farm) and 8 May (all other trials) for 2001. Individual plots consisted of one bed containing two rows and were either 6.2 or 7.6 m in length. All plots were over-sprayed with chlorothalonil (Bravo Ultrex; Syngenta Crop Protection, Greensboro, NC) at 1.3 kg a.i./ha on a 2-week schedule to control foliar diseases. All trials, except for the nonirrigated portion of the Irrigated or Nonirrigated Field, were irrigated as needed and other production practices were followed according to University of Georgia recommendations. Peanut plants were inverted at maturity and combine harvested, then dried to 10% moisture prior to determining yield and grading.

Fungicide applications. Azoxystrobin (Abound 2.08F; Syngenta Crop Protection) was used in this study at a rate of 0.34 kg

Table 1. Comparison of daily index value (DIV) assignments for two models used to advise sprays for stem rot control on peanut

Environmental and host variables	DIV	
	Model 1	Model 2
Precipitation (rainfall + irrigation)		
Precipitation ≥ 1.27 cm over previous 5 days	1	1
Precipitation ≥ 2.54 cm over previous 10 days	1	1
Precipitation ≥ 3.81 cm over previous 5 days	1	2
Otherwise	0	0
Soil temperature ^y		
22 $\leq$ soil temperature $< 25^{\circ}\text{C}$	1	1
25 $\leq$ soil temperature $< 28^{\circ}\text{C}$	2	2
28 $\leq$ soil temperature $< 35^{\circ}\text{C}$	3	3
Otherwise	0	0
Distance between adjacent rows ^z		
Rows overlapping	3	3
Rows ≤ 15 cm apart	2	2
Rows ≥ 15 cm apart	1	1

^y Mean daily soil temperatures from a 5-cm depth.

^z Rows were planted 0.92 m apart in a single row pattern.

Fig. 1. Daily average soil temperatures (5-cm depth) and precipitation (irrigation plus rainfall) from 35 to 110 days after planting from four trials conducted in 1999. **A** = Lang Farm, **B** = Pond Field, **C** = Irrigated Field, and **D** = Nonirrigated Field.

a.i./ha to control stem rot. Azoxystrobin was applied in accordance with label restrictions, such that all applications were made between 35 and 110 DAP and no plot received more than two applications per season. The fungicide was applied using a CO₂-pressurized backpack sprayer with three TX-6 nozzles (TeeJet Technologies, Springfield, IL) per row at an output of 188 liters/ha.

Three-variable advisories. Spray advisories based on soil temperature, precipitation (rainfall and irrigation), and peanut canopy, as measured by distance between adjacent rows, were developed using a framework similar to the Virginia Sclerotinia Blight Advisory (VSBA) (16,21). Because warmer conditions favor *S. rolfsii* compared with *S. minor*, adjustments were made to the VSBA to better reflect conditions that favor stem rot development (Table 1). Soil temperature was recorded at a 5-cm depth, where most sclerotia germinate (23), every 30 min using HOBO Pro Series 8 sensors (Onset Computer Corporation, Bourne, MA) and daily means were calculated for each trial location. Daily total precipitation (in 0.025-cm increments), either rainfall or irrigation, was recorded with a digital rain gauge (Spectrum Technologies, Inc., Plainfield, IL). For each trial, one temperature sensor and

rainfall gauge was placed within the peanut canopy. The distance between peanut canopies in adjacent rows was measured with a ruler at 10 flagged locations within nontreated plots.

Fungicides were applied according to estimates of how favorable conditions had been over the past 5 days for stem rot development. Daily index values (DIVs) were assigned for each parameter based on daily means for soil temperature, daily total precipitation, and host growth (Table 1). The DIVs for each individual variable were multiplied to calculate a daily risk value (DRV = soil temperature DIV × rainfall DIV × canopy DIV). DRVs were summed over the previous 5 days to derive a 5-day risk values (FDRV). Fungicide applications were made if the calculated FDRV exceeded a predetermined threshold value and azoxystrobin had not been applied within the past 21 days. Two three-variable models were tested (Table 1). Model 2 assigned an index value of 2 when rainfall ≥3.81 cm was recorded in the previous 5 days; an index value of 1 was used in model 1. Otherwise, the models were identical. For model 1, four threshold FDRVs were tested: 15, 20, 25, and 30. For model 2, only an FDRV of 20 was tested.

Two-variable advisories. Three additional spray advisories, based solely on

soil temperature and precipitation (irrigation + rainfall) but not canopy closure, were evaluated. The two-variable models evaluated were (i) daily mean soil temperature ≥26°C for 3 of 5 days and total precipitation over the past 5 days ≥2.54 cm, (ii) daily mean soil temperature ≥28°C for 3 of 5 days and total precipitation over past 5 days ≥2.54 cm, and (iii) daily mean soil temperature ≥28°C for 3 of 5 days and total precipitation over past 5 days ≥1.27 cm. Azoxystrobin was applied when thresholds for soil temperature and precipitation were exceeded.

AU-Pnut. Azoxystrobin was applied for stem rot control according to the AU-Pnut leaf spot advisory. Daily precipitation was recorded as previously described and the regional 5-day POP was obtained daily from the Agricultural Weather Information Service website (www.awis.com). The initial application of azoxystrobin was made at the first advisory spray recommendation subsequent to 50 DAP, which generally was either the second or third time during the season that AU-Pnut recommended a fungicide application for leaf spot control. After the first azoxystrobin application, the second spray was applied at the first AU-Pnut spray recommendation following the expiration of the 21-day protection interval.

Fig. 2. Daily average soil temperatures (5-cm depth) and precipitation (irrigation plus rainfall) from 35 to 110 days after planting from four trials conducted in 2000. **A** = Lang Farm, **B** = Pond Field, **C** = Irrigated Field, and **D** = Nonirrigated Field.

Experimental design and statistical analyses. Treatments for each trial were arranged in randomized complete block designs with four or five replications per treatment. In addition to treatments applied according to the nine spray advisories, treatments included a nontreated control (chlorothalonil) and the calendar-based spray program (azoxystrobin applied at 60 and 90 DAP). Incidence of stem rot was assessed after peanut inversion by determining the percentage of infected 30.5-cm segments of each row (24). Pod yields and disease incidence values for stem rot were analyzed by analysis of variance using SAS software (SAS Institute, Cary, NC). Statistical differences among treatment means were determined using Waller-Duncan mean separation tests (k ratio = 100).

RESULTS

Field trials in 1999. Cumulative precipitation was higher for all four locations and mean daily soil temperatures generally were greater in 1999 than observed in the other 2 years. Higher soil temperatures coupled with ample moisture created a favorable environment for stem rot development, and disease incidence was greater in 1999 than in 2000 or 2001 (Figs. 1–3). Canopy closure occurred at the Irrigated

trial on 59 DAP, Nonirrigated trial at 60 DAP, and Lang and Pond trials at 72 DAP.

There were no significant treatment–location interactions from the trials in 1999. However, there were significant treatment–location interactions in both 2000 and 2001. To remain consistent across the 3 years of this study, trial data from 1999 is presented separately.

At the Lang Farm, all treatments receiving applications of azoxystrobin showed significantly better stem rot control than the nontreated control (Table 2). Spraying according to any of the advisories did not produce disease control significantly different from the calendar program. Only the calendar program and the model 1, FDRV 20 advisory produced pod yields greater than the nontreated control. The model 1, FDRV 20 advisory provided better disease control and produced higher pod yields than the calendar program at the Pond trial as well. Application dates according to advisory were the same for these two trials.

At the Irrigated trial, the model 1, FDRV 15 and 20 advisories recommended fungicide applications that offered enhanced stem rot control compared with the calendar program, but yields were not significantly higher than in the calendar program. The two-variable advisories (variations 2 and 3)

recommended only one application of azoxystrobin. Resulting disease control from these advisories was not significantly better than the nontreated control. Performance of the two-variable advisories was similarly poor in the Nonirrigated trial.

Field trials in 2000. This growing season was characterized by lower stem rot incidence and more variable pod yields than in the previous year (Table 3). Several of the two-variable advisories in certain locations failed to call for a single application of azoxystrobin.

Stem rot control and pod yields from plots treated with three-variable advisories were more variable in 2000 than in 1999. Advisories based on model 1 using threshold FDRVs of 15 and 20 generally produced spray dates slightly earlier than the calendar-based program. Stem rot levels and pod yields were not significantly different from the calendar program except for the model 1, FDRV 20 treatment, which provided significantly better disease control than the calendar program at the Lang farm. Canopy closure was noted at 54 DAP for the Lang trial, 66 DAP for the Pond trial, 57 DAP for the Irrigated trial, and 67 DAP for the Nonirrigated trial. Therefore, the model 1, FDRV 25 and FDRV 30 spray advisories produced initial application dates later than the calendar-

Fig. 3. Daily average soil temperatures (5-cm depth) and precipitation (irrigation plus rainfall) from 35 to 110 days after planting from four trials conducted in 2001. **A** = Lang Farm, **B** = Pond Field, **C** = Irrigated Field, and **D** = Nonirrigated Field.

based program. Disease control and yields produced by these advisories were not different in three of the four trials. In the Nonirrigated trial, azoxystrobin was applied only once at 81 DAP for both advisories; however, little difference in disease control and yield was noted when compared with the calendar program. The model 2 advisory produced a wide range of initial (40 to 68 DAP) and subsequent (62 to 90 DAP) spray dates across the four locations; however, stem rot control and pod yields were not different from the calendar-based regime. In three of the four trials, yield was not significantly greater than the nontreated control using either the

model 1 spray advisories or the calendar program.

As observed in the previous year, the two-variable advisory, variation 1, produced very early initial (37 to 38 DAP) and secondary (59 to 70 DAP) spray dates, although no significant differences were observed in stem rot levels or pod yields when compared with the calendar-based program. For the two-variable advisories, variations 2 and 3, no sprays were called for at the Lang farm and Irrigated trials. In the Pond trial, variations 2 and 3 called for single azoxystrobin applications at 97 and 75 DAP, respectively, resulting in disease control and pod yields that did not differ

significantly from the calendar-based treatment. At the Nonirrigated trial, variation 2 called for a single application of azoxystrobin at 65 DAP and stem rot control was significantly lower than in plots receiving the calendar-based program, although no differences in yields were noted. Variation 3 advised applications at 65 and 110 DAP and resulted in disease control and yields similar to those in the calendar-based treated plots.

The timing of fungicide applications made according to the AU-Pnut advisory was very similar to the calendar-based program. However, the AU-Pnut advisory showed significantly better stem rot con-

Table 2. Effect of spray advisories and fungicide application timing on control of stem rot and pod yields in peanut for four trials conducted in 1999^v

	Azoxystrobin application (DAP) ^w			
Trial, spray advisory ^x	1st	2nd	FDI (%) ^y	HPY (kg/ha) ^z
Lang Farm				
Calendar program	60	90	35.5 b–e	3,550.1 a
Model 1, FDRV 15	60	82	28.5 de	3,470.3 ab
Model 1, FDRV 20	60	82	26.5 e	3,615.5 a
Model 1, FDRV 25	70	96	41.0 bc	3,150.8 ab
Model 1, FDRV 30	71	96	43.5 b	2,831.4 ab
Model 2, FDRV 20	53	96	31.5 c–e	3,165.4 ab
Two-variable, Var. 1	36	74	34.0 b–e	3,506.6 ab
Two-variable, Var. 2	74	96	37.0 b–e	2,845.9 ab
Two-variable, Var. 3	74	96	44.0 b	2,693.5 ab
AU-Pnut	57	86	37.5 b–d	3,521.1 ab
Nontreated control	None	None	71.0 a	2,599.1 b
Blackshank Farm (Pond Field)				
Calendar program	60	90	61.0 bc	3,296.0 bc
Model 1, FDRV 15 ^z	60	82	62.5 bc	3,513.9 bc
Model 1, FDRV 20	60	82	45.0 d	4,327.0 a
Model 1, FDRV 25	70	95	52.5 cd	3,833.3 ab
Model 1, FDRV 30	72	95	66.5 bc	3,760.7 ab
Model 2, FDRV 20	51	74	60.0 bc	3,245.2 bc
Two-variable, Var. 1	36	72	52.0 cd	3,267.0 bc
Two-variable, Var. 2	79	104	72.5 ab	3,071.0 bc
Two-variable, Var. 3	79	104	67.5 b	3,143.6 bc
AU-Pnut	57	86	59.5 b–d	3,811.5 ab
Nontreated control	None	None	83.5 a	2,875.0 c
Blackshank Farm (Irrigated Field)				
Calendar program	60	90	70.5 bc	4,145.5 a–d
Model 1, FDRV 15 ^z	50	72	59.5 d	3,593.7 b–e
Model 1, FDRV 20	53	75	58.0 d	4,268.9 ab
Model 1, FDRV 25	60	82	72.0 bc	4,218.1 a–c
Model 1, FDRV 30	60	82	66.5 cd	3,898.6 a–e
Model 2, FDRV 20	49	71	62.5 cd	4,534.0 a
Two-variable, Var. 1	36	60	67.5 b–d	3,492.1 de
Two-variable, Var. 2	78	None	77.0 ab	3,622.7 b–e
Two-variable, Var. 3	78	None	82.5 a	3,542.9 c–e
AU-Pnut	57	86	65.5 cd	4,297.9 ab
Nontreated control	None	None	85.0 a	3,274.3 e
Blackshank Farm (Nonirrigated Field)				
Calendar program	60	90	55.5 c–e	3,956.7 a
Model 1, FDRV 15 ^z	51	74	52.5 de	3,724.4 ab
Model 1, FDRV 20	60	104	55.5 c–e	3,564.7 a–c
Model 1, FDRV 25	60	104	62.5 b–d	3,492.1 a–c
Model 1, FDRV 30	60	106	63.0 b–d	3,630.0 ab
Model 2, FDRV 20	50	74	46.5 e	3,818.8 a
Two-variable, Var. 1	36	74	69.0 a–c	2,787.8 d
Two-variable, Var. 2	78	None	71.5 ab	2,787.8 d
Two-variable, Var. 3	78	104	68.0 a–c	3,136.3 b–d
AU-Pnut	57	91	60.5 b–e	3,535.6 a–c
Nontreated control	None	None	78.0 a	2,918.5 cd

^v Means within a column followed by the same letters are not significantly different according to the Waller-Duncan *t* test (*k* ratio = 100).

^w DAP = days after planting. Azoxystrobin was applied at 0.34 kg a.i./ha per application.

^x FDRV = 5-day risk value.

^y FDI = final disease incidence. Stem rot incidence assessed immediately following peanut inversion prior to harvest, based upon the percentage of 30.5-cm row segments showing signs or symptoms of *Sclerotium rolfsii* infection.

^z HPY = harvested pod yields, based on weight of peanuts having 10% moisture (wt/wt).

trol at the Lang Farm and Pond field trial when compared with the calendar program. Disease incidence at the other two trials and pod yields in all trials from plots receiving the AU-Pnut-based treatment did not differ from the calendar program.

Field trials in 2001. Pod yields observed in 2001 were higher than in the two previous growing seasons. Excellent growing conditions and timely rainfall throughout the growing season produced near record yields across the state. Canopy closure was delayed in 2001 compared with the two previous growing seasons. Closure was observed at the Lang trial at 62 DAP, 95 DAP for the Pond trial, 81

DAP for the Irrigated trial, and 94 DAP for the Nonirrigated trial. Spray dates produced by specific advisories were highly variable across trials; however, in general, fungicides were applied later in the growing season when compared with the previous two seasons.

The only three-variable advisory that recommended two fungicide applications in all trials was the model 1, FDRV 15 treatment, and stem rot control and pod yields resulting from this treatment were not significantly different from the calendar-based program (Table 4). The model 1, FDRV 20 advisory called for two fungicide applications in three of the four trials

and only one application (81 DAP) in the Nonirrigated trial. No differences in disease control or pod yields were noted between this treatment and the calendar regime for any trial. The model 1, FDRV 25 and 30 advisories produced similar levels of disease control when two fungicide applications were recommended. In several instances, only one or no applications were recommended and, in most of these cases, disease control and pod yields were inferior to the calendar-based program. The model 2, FDRV 20 advisory produced stem rot control and pod yields similar to the calendar program except in the Nonirrigated trial, where only one fungicide

Table 3. Effect of spray advisories and fungicide application timing on control of stem rot and pod yields in peanut for four trials conducted in 2000^v

	Azoxystrobin application (DAP) ^w			
Trial, spray advisory ^x	1st	2nd	FDI (%) ^y	HPY (kg/ha) ^z
Lang Farm				
Calendar program	60	90	36.4 d	5,084.0 a
Model 1, FDRV 15	49	76	40.0 cd	4,738.8 ab
Model 1, FDRV 20	52	76	23.2 e	5,084.0 a
Model 1, FDRV 25	63	90	30.0 de	5,149.0 a
Model 1, FDRV 30	69	104	34.4 de	4,673.8 ab
Model 2, FDRV 20	52	76	30.0 de	5,350.7 a
Two-variable, Var. 1	38	61	33.6 de	5,188.2 a
Two-variable, Var. 2	None	None	61.6 a	4,094.3 b
Two-variable, Var. 3	None	None	49.0 bc	4,809.4 ab
AU-Pnut	63	85	23.0 e	5,053.7 a
Nontreated control	None	None	60.8 ab	4,497.8 ab
Blackshank Farm (Pond Field)				
Calendar program	60	90	25.0 bcd	3,759.2 a
Model 1, FDRV 15	61	83	17.5 de	4,003.5 a
Model 1, FDRV 20	62	87	20.0 cde	3,913.9 a
Model 1, FDRV 25	75	97	29.5 bc	4,166.0 a
Model 1, FDRV 30	76	102	21.5 cde	3,921.7 a
Model 2, FDRV 20	62	84	20.5 cde	4,101.0 a
Two-variable, Var. 1	37	59	25.0 bcd	3,596.7 a
Two-variable, Var. 2	97	None	34.0 b	3,247.0 ab
Two-variable, Var. 3	75	None	17.5 de	3,995.7 a
AU-Pnut	58	83	13.5 e	4,076.4 a
Nontreated control	None	None	52.5 a	2,425.4 b
Blackshank Farm (Irrigated Field)				
Calendar program	60	90	12.5 bc	3,279.5 a
Model 1, FDRV 15	53	75	14.5 bc	3,214.5 a
Model 1, FDRV 20	54	76	11.5 bc	3,238.0 a
Model 1, FDRV 25	62	87	10.5 c	3,360.2 a
Model 1, FDRV 30	65	94	17.0 bc	2,660.8 a
Model 2, FDRV 20	40	62	21.5 b	3,043.0 a
Two-variable, Var. 1	37	60	17.5 bc	3,352.3 a
Two-variable, Var. 2	None	None	32.0 a	2,725.8 a
Two-variable, Var. 3	None	None	32.5 a	2,628.3 a
AU-Pnut	67	91	21.5 b	3,434.1 a
Nontreated control	None	None	37.5 a	3,059.8 a
Blackshank Farm (Nonirrigated Field)				
Calendar program	60	90	9.5 de	2,204.6 ab
Model 1, FDRV 15	55	78	12.0 cde	2,383.9 a
Model 1, FDRV 20	68	110	8.5 de	2,204.6 ab
Model 1, FDRV 25	81	None	13.0 bcde	1,741.7 b
Model 1, FDRV 30	81	None	21.0 b	2,107.1 ab
Model 2, FDRV 20	68	90	13.0 bcde	2,116.1 ab
Two-variable, Var. 1	37	70	8.0 e	2,311.1 a
Two-variable, Var. 2	65	None	18.5 bc	2,335.7 a
Two-variable, Var. 3	65	110	9.5 de	2,156.4 ab
AU-Pnut	68	91	13.0 bcde	2,391.8 a
Nontreated control	None	None	41.0 a	2,237.1 ab

^v Means within a column followed by the same letters are not significantly different according to the Waller-Duncan *t* test (*k* ratio = 100).

^w DAP = days after planting. Azoxystrobin was applied at 0.34 kg a.i./ha per application.

^x FDRV = 5-day risk value.

^y FDI = final disease incidence. Stem rot incidence assessed immediately following peanut inversion prior to harvest, based upon the percentage of 30.5-cm row segments showing signs or symptoms of *Sclerotium rolfsii* infection.

^z HPY = harvested pod yields, based on weight of peanuts having 10% moisture (wt/wt).

application was made and disease control was less than using the calendar-based program.

Fungicides applied according to the two-variable advisory, variation 1, were sprayed later than in 1999 and 2000 using the same model. Pod yields were not significantly different from the calendar program in all trials, and disease control was significantly less than the calendar program in only one trial (Irrigated trial). With variation 2, three trials received no sprays and only one application at 78 DAP was made in the Nonirrigated trial. A single fungicide application was called for in three of the four trials by variation 3 and

no applications were advised in the other trial. In these three trials, where fungicides were applied, disease control generally less was than observed in the calendar-treated plots but yields were not significantly different. In all trials, plots treated according to the AU-Pnut advisory did not significantly differ in stem rot control or yield from the plots treated according to the calendar schedule.

Trial summary. Results according to spray advisory across the 12 trials in this study are summarized in Table 5. Fungicides applied according to the calendar program; AU-Pnut; and the advisories model 1, FDRV 15 and 20; and model 2,

FDRV 20 produced significantly lower stem rot levels than the nontreated control in all 12 trials in this study. The two variable advisories, variations 2 and 3, performed poorly in this study, offering improved stem rot control when compared with the nontreated control in only four and seven trials, respectively.

Only three advisories produced stem rot control levels significantly better than the calendar program. The model 1, FDRV 20 advisory bested the calendar program in three trials. Fungicide applications made according to the AU-Pnut advisory suppressed levels of stem rot significantly better than the calendar program in 2 of 12

Table 4. Effect of spray advisories and fungicide application timing on control of stem rot and pod yields in peanut for four trials conducted in 2001^v

	Azoxystrobin application (DAP) ^w			
Trial, spray advisory ^x	1st	2nd	FDI (%) ^y	HPY (kg/ha) ^z
Lang Farm				
Calendar program	60	90	18.0 c	6,946.7 a
Model 1, FDRV 15	61	84	23.2 bc	6,426.7 a
Model 1, FDRV 20	62	84	17.2 c	6,779.7 a
Model 1, FDRV 25	67	102	19.6 c	6,500.6 a
Model 1, FDRV 30	102	None	31.6 b	5,725.0 b
Model 2, FDRV 20	52	76	19.6 c	6,723.7 a
Two-variable, Var. 1	62	84	14.8 c	6,604.9 a
Two-variable, Var. 2	None	None	50.4 a	5,035.8 c
Two-variable, Var. 3	None	None	48.0 a	5,212.8 bc
AU-Pnut	61	86	17.6 c	6,452.4 a
Nontreated control	None	None	51.2 a	5,064.9 bc
Blackshank Farm (Pond Field)				
Calendar program	60	90	21.0 de	4,003.5 a
Model 1, FDRV 15	86	108	36.0 cd	3,718.8 a
Model 1, FDRV 20	86	110	31.0 cde	3,539.5 a
Model 1, FDRV 25	102	None	39.0 c	3,930.6 a
Model 1, FDRV 30	102	None	44.0 bc	3,767.0 a
Model 2, FDRV 20	86	108	30.5 cde	3,711.0 a
Two-variable, Var. 1	78	100	29.0 cde	4,182.8 a
Two-variable, Var. 2	None	None	56.0 ab	2,408.6 b
Two-variable, Var. 3	63	None	36.5 c	3,783.8 a
AU-Pnut	63	88	17.5 e	3,808.5 a
Nontreated control	None	None	66.5 a	2,294.3 b
Blackshank Farm (Irrigated Field)				
Calendar program	60	90	26.0 c	5,252.1 ab
Model 1, FDRV 15	63	86	24.0 c	5,383.2 ab
Model 1, FDRV 20	64	86	23.5 cd	5,401.1 ab
Model 1, FDRV 25	65	88	25.5 c	4,987.6 ab
Model 1, FDRV 30	86	108	26.5 c	4,943.8 b
Model 2, FDRV 20	64	86	23.0 cd	5,666.8 a
Two-variable, Var. 1	78	102	12.5 d	5,284.6 ab
Two-variable, Var. 2	None	None	59.5 a	3,731.1 c
Two-variable, Var. 3	63	None	42.0 b	4,820.6 b
AU-Pnut	63	88	17.0 cd	5,230.8 ab
Nontreated control	None	None	57.5 a	3,841.0 c
Blackshank Farm (Nonirrigated Field)				
Calendar program	60	90	11.0 d	3,960.9 ab
Model 1, FDRV 15	69	95	9.0 d	4,158.2 a
Model 1, FDRV 20	81	None	11.0 d	4,447.3 a
Model 1, FDRV 25	None	None	46.5 a	2,952.2 c
Model 1, FDRV 30	None	None	39.5 a	3,362.4 bc
Model 2, FDRV 20	81	None	24.0 b	4,129.0 a
Two-variable, Var. 1	78	None	15.5 bcd	4,224.3 a
Two-variable, Var. 2	78	None	17.5 bcd	4,342.0 a
Two-variable, Var. 3	69	None	22.0 bc	4,305.0 a
AU-Pnut	69	94	9.5 d	4,467.5 a
Nontreated control	None	None	42.5 a	3,417.3 bc

^v Means within a column followed by the same letters are not significantly different according to the Waller-Duncan *t* test (*k* ratio = 100).

^w DAP = days after planting. Azoxystrobin was applied at 0.34 kg a.i./ha per application.

^x FDRV = 5-day risk value.

^y FDI = final disease incidence. Stem rot incidence assessed immediately following peanut inversion prior to harvest, based upon the percentage of 30.5-cm row segments showing signs or symptoms of *Sclerotium rolfsii* infection.

^z HPY = harvested pod yields, based on weight of peanuts having 10% moisture (wt/wt).

trials. The model 1, FDRV 15 advisory offered significantly better stem rot control than the calendar program in one trial. Model 1, FDRV 20 and the two variable (variation 1) advisories did not produce stem rot control levels significantly worse than the best treatment in 11 of 12 trials.

Pod yields according to spray advisories for the 12 trials are summarized in Table 6. Only one advisory, model 1, FDRV 20, produced a pod yield significantly greater than the calendar program. This was observed in only one trial. The model 1, FDRV 20 advisory produced pod yields significantly greater than the nontreated control in 8 of 12 trials (the highest amount of any advisory). The model 1, FDRV 20 and AU-Pnut advisories produced pod yields that were not significantly worse than the best treatment in all 12 trials.

DISCUSSION

Although there was remarkable flexibility in the timing of azoxystrobin sprays, application timing had an effect on stem rot control and, to a lesser extent, pod yields. Stem rot severity varied greatly across the three seasons examined in this study. Because trials were conducted in the same locations each year, variation in stem rot severity across years more than likely resulted from differences in microclimatic conditions and peanut canopy growth, resulting in differences in canopy closure. Of the environmental variables examined in this study, precipitation varied across trials and growing seasons more than average daily soil temperatures. Closure of the peanut canopy varied between seasons due to the difference in environmental conditions. Variability in these factors is known to influence stem rot epidemics and may be responsible for the differences in disease onset and severity observed across years (6,13,25).

Over the three growing seasons, the calendar program calling for applications at 60 and 90 DAP performed well. The epidemics in this study were not problematic compared with years. Performance of the calendar program in such seasons may be less than satisfactory, which is a concern due to the potential crop losses associated with program failure. Although the calendar program has proved reliable in most years and performed well in this study, the need still exists for a spray advisory for stem rot in peanut to safeguard against such instances.

The spray advisories evaluated in this study did not perform consistently better than the calendar program. Of these advisories, the three-variable models (particularly FDRV 20) generally offered better stem rot control than the two-variable types, suggesting the need to include a host canopy factor in a successful advisory. The addition of the canopy variable prevents sprays from being applied too far ahead of

disease onset. Soil temperatures were relatively uniform throughout the growing season in the 3 years of this study. Shading effects by the canopy later in the growing season were compensated for by warmer temperatures that increased soil temperatures to similar levels seen earlier in the growing season. Of the thresholds tested using the three-variable advisories, the lower FDRVs (15 and 20) performed the best. Disease control was always equal to or better than the calendar program. FDRV thresholds of 25 or 30 produced variable spray dates and, in many cases, recommended either only one or no fungicide applications. In most cases, advisories calling for one fungicide application resulted in reductions in disease control and yield; however, the success of a single spray in some cases raises the probability

of reducing fungicide inputs if this can be shown to be consistently effective.

The efficacy of stem rot control when using AU-Pnut to time sprays for managing peanut leaf spot was encouraging. The guidelines examined in this study offered a reasonable and effective method of incorporating azoxystrobin into AU-Pnut for stem rot management. This scheme performed adequately in all trials and seasons, offering stem rot suppression equal to or significantly better than the calendar program. This validates previous research showing that AU-Pnut provides equivalent stem rot control (compared with calendar programs) when tebuconazole or azoxystrobin is substituted for chlorothalonil for midseason applications (5,8). AU-Pnut offers producers a successful management tool for stem rot and leaf spot, and may

Table 5. Summary of stem rot control offered by various spray advisories in 12 trials conducted over a 3-year period (1999–2001)

Spray advisory ^x	No. of trials out of 12 in which an advisory offered stem rot control ^w		
	Better than the nontreated control ^y	Better than the calendar-based program ^y	Not worse than the best treatment ^z
Calendar program	12	...	7
Model 1, FDRV 15	12	1	8
Model 1, FDRV 20	12	3	11
Model 1, FDRV 25	11	0	5
Model 1, FDRV 30	11	0	3
Model 2, FDRV 20	12	0	9
Two-variable, Var. 1	11	0	11
Two-variable, Var. 2	4	0	2
Two-variable, Var. 3	7	0	2
AU-Pnut	12	2	10
Nontreated control	...	0	0

^w Stem rot incidence was assessed immediately following peanut inversion prior to harvest, based upon the percentage of 30.5-cm row segments showing signs or symptoms of *Sclerotium rolfsii* infection.

^x FDRV = 5-day risk value.

^y Number of trials in which the difference between treatments indicated was significant according to the Waller-Duncan *t* test (*k* ratio = 100).

^z Number of trials in which the difference between treatments indicated was not significant according to the Waller-Duncan *t* test (*k* ratio = 100).

Table 6. Summary of pod yields offered by various spray advisories in 12 trials conducted over a 3-year period (1999–2001)

Spray advisory ^x	Number of trials out of 12 in which an advisory offered pod yields ^w		
	Better than the nontreated control ^y	Better than the calendar-based program ^y	Not worse than the best treatment ^z
Calendar program	7	...	11
Model 1, FDRV 15	6	0	10
Model 1, FDRV 20	8	1	12
Model 1, FDRV 25	6	0	10
Model 1, FDRV 30	5	0	9
Model 2, FDRV 20	7	0	11
Two-variable, Var. 1	5	0	9
Two-variable, Var. 2	1	0	5
Two-variable, Var. 3	4	0	7
AU-Pnut	7	0	12
Nontreated control	...	0	3

^w Yields are based on weight of peanuts having 10% moisture (wt/wt).

^x FDRV = 5-day risk value.

^y Number of trials in which the difference between treatments indicated was significant according to the Waller-Duncan *t* test (*k* ratio = 100).

^z Number of trials in which the difference between treatments indicated was not significant according to the Waller-Duncan *t* test (*k* ratio = 100).

even reduce the number of fungicide applications (12).

The importance of fungicide application timing, as suggested in other research (5,8,14), was demonstrated in this study. Although calendar-based applications are usually effective and AU-Pnut offers site-specific recommendations, further research examining the environmental conditions promoting stem rot epidemics is needed. Special attention is advised when peanut rows overlap during hot and humid periods when precipitation has occurred or is forecasted. For the time being, peanut producers are encouraged to use AU-Pnut and substitute azoxystrobin or a comparable stem rot fungicide when fungicide applications are advised close to the calendar date recommendations of 60 and 90 DAP.

LITERATURE CITED

1. Aycock, R. 1966. Stem rot and other diseases caused by *Sclerotium rolfsii* or the status of Rolf's fungus after 70 years. N. C. Agric. Exp. Stn. Bull. 174.
2. Backman, P. A., and Brenneman, T. B. 1997. Stem rot. Pages 36-37 in: Compendium of Peanut Diseases, 2nd ed. N. Kokalis-Burelle, D. M. Porter, R. Rodriguez-Kabana, D. H. Smith, and P. Subrahmanyam, eds. American Phytopathological Society, St. Paul, MN.
3. Black, M. C., Tewolde, H., Fernandez, C. J., and Schubert, A. M. 2001. Seeding rate, irrigation, and cultivar effects on tomato spotted wilt, rust, and southern blight of peanut. Peanut Sci. 28:1-4.
4. Bowen, K. L. 1998. Development of southern stem rot in peanuts over three growing seasons. Proc. Am. Peanut Res. Educ. Soc. 30:26.
5. Bowen, K. L., Hagan, A. K., Campbell, H. L., and Wells, L. 2006. Comparison of calendar and AU-Pnut advisory programs with azoxystrobin for the control of leaf spot and southern stem rot on peanut. Peanut Sci. 33:76-82.
6. Bowen, K. L., Hagan, A. K., and Weeks, R. 1992. Seven years of *Sclerotium rolfsii* in peanut fields: yield losses and means of minimization. Plant Dis. 76:982-985.
7. Brenneman, T. B. 1998. Effects of ten years of peanut monoculture under irrigated and nonirrigated conditions on peanut yields, diseases and fungicide performance. Proc. Am. Peanut Res. Educ. Soc. 30:34.
8. Brenneman, T. B., and Culbreath, A. K. 1994. Utilizing a sterol demethylation inhibiting fungicide in an advisory program to manage foliar and soilborne pathogens of peanut. Plant Dis. 78:866-872.
9. Campbell, C. L., and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. John Wiley and Sons, Inc., New York.
10. Cu, R. M., and Phipps, P. M. 1993. Development of a pathogen growth response model for the Virginia peanut leafspot advisory program. Phytopathology 83:195-201.
11. Davidson, J. I., Blankenship, P. D., Henning, R. J., Guerke, W. R., Smith, R. D., and Cole, R. J. 1991. Geocarposphere temperature as it relates to Florunner peanut production. Peanut Sci. 18:79-85.
12. Davis, D. P., Jacobi, J. C., and Backman, P. A. 1993. Twenty-four-hour rainfall, a simple environmental variable for predicting peanut leafspot epidemics. Plant Dis. 77:722-725.
13. Davis, R. F., Smith, F. D., Brenneman, T. B., and McLean, H. 1996. Effect of irrigation on expression of stem rot of peanut and comparison of aboveground and belowground disease ratings. Plant Dis. 80:1155-1159.
14. Hagan, A. K., Weeks, J. R., and Bowen, K. 1991. Effects of application timing and method on control of southern stem rot of peanut with foliar-applied fungicides. Peanut Sci. 18:47-50.
15. Jensen, R. E., and Boyle, L. W. 1966. A technique for forecasting leaf spot on peanuts. Plant Dis. Rep. 50:810-814.
16. Langston, D. B., Jr. 1998. The role of host, environment, and fungicide use patterns in algorithms for improving control of Sclerotinia blight of peanut. Ph.D. dissertation, Virginia Polytechnic Institute and State University, Blacksburg.
17. Langston, D. B., Jr., Phipps, P. M., and Stipes, R. J. 2002. An algorithm for predicting outbreaks of Sclerotinia blight of peanut and improving the timing of fungicide sprays. Plant Dis. 86:118-126.
18. Mehan, V. K., Mayee, C. D., Brenneman, T. B., and McDonald, D. 1995. Stem and pod rots of groundnut. Int. Crops Res. Inst. Semi-Arid Trop. Inf. Bull. 44.
19. Nutter, F. W., Jr., and Brenneman, T. B. 1989. Development and validation of a weather-based late leafspot advisory. Proc. Am. Peanut Res. Educ. Soc. 21:24.
20. Phipps, P. M. 1993. IPM in peanuts: Developing and delivering working IPM systems. Plant Dis. 77:307-309.
21. Phipps, P. M. 1995. An assessment of environmental conditions preceding outbreaks of Sclerotinia blight of peanut in Virginia. Peanut Sci. 22:90-93.
22. Phipps, P. M., and Powell, N. L. 1984. Evaluation of criteria for the utilization of peanut leafspot advisories in Virginia. Phytopathology 74:1189-1193.
23. Punja, Z. K. 1985. The biology, ecology, and control of *Sclerotium rolfsii*. Annu. Rev. Phytopathol. 23:97-127.
24. Rideout, S. L., Brenneman, T. B., and Culbreath, A. K. 2002. A comparison of disease assessment methods for southern stem rot of peanut. Peanut Sci. 29:66-71.
25. Shew, B. B., and Beute, M. K. 1984. Effects of crop management on the epidemiology of southern stem rot of peanut. Phytopathology 74:530-535.