AU-Pnuts Advisory II: Modification of the Rule-Based Leaf Spot Advisory System for a Partially Resistant Peanut Cultivar

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ABSTRACT

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The AU-Pnuts advisory was originally developed for peanut cultivars that are highly susceptible to early (*Cercospora arachidicola*) and late leaf spot (*Cercosporidium personatum*). The system uses a combination of recorded daily precipitation and National Weather Service precipitation probabilities to provide warnings for the need to apply fungicides. Field studies were conducted from 1989 through 1992 to evaluate modifications of the advisory for use on the late leaf spot resistant cultivar Southern Runner. The advisory system was modified by increasing the thresholds for both the initial and subsequent fungicide applications. Each modified advisory treatment was evaluated along with three other treatments: nonsprayed control, 14-day schedule, and 21-day schedule. Averaged over 1991 and 1992, the final version of the AU-Pnuts advisory saved 0.5 and 2.5 sprays compared with the 21-day and 14-day schedules, respectively. These timed fungicide applications controlled leaf spot as effectively as did the 21-day schedule. Yields were not significantly different between the advisory and either the 14-day or 21-day schedule. AU-Pnuts advisory can be used to schedule fungicide applications for control of early and late leaf spot on Southern Runner peanut.

Early and late leaf spot of peanut (*Arachis hypogaea* L.), caused by *Cercospora arachidicola* S. Hori and *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, respectively, can cause major yield losses if not managed appropriately (1). These diseases are currently controlled by a combination of fungicides and cultural practices including deep plowing and use of resistant cultivars (23). In the peanut production area of the Southeast (Alabama, Georgia, and Florida), early and late leaf spots are controlled primarily by application of the protectant fungicide chlorothalonil applied on a 10- to 14-day calendar schedule beginning 30 to 40 days after planting (DAP) (25). Southern Runner was the first runner-type cultivar to be released exhibiting moderate levels of rate-reducing resistance to *C. personatum* (11). This cultivar requires fewer fungicide applications than susceptible cultivars such as Florunner due to a combination of rate-reducing resistance and tolerance to late leaf spot (5,11,21). Tolerance of Southern Runner to this disease may be due to continual leaf production throughout the growing season, thereby replacing leaves defoliated by leaf spot (21). The combination of resistance and tolerance also affects the strategy used to control peanut leaf spot. Gorbet et al. (12) reported that the number of fungicide applications could be reduced on Southern Runner by increasing the interval between applications from 10- to 14-days to 20- to 28-days beginning 40 DAP. The 28-day schedule had higher leaf spot severity than the 14-day schedule without a yield reduction in Southern Runner (12). We also found that by increasing the interval between sprays from 14 to 28 days, fungicide use on Southern Runner could be reduced without sacrificing yield (13). The ability of Southern Runner to tolerate leaf spot induced defoliation without yield loss permits the use of control strategies that are less effective than those used for susceptible cultivars. To maximize economic return, higher levels of disease in this cultivar can be tolerated without yield or quality losses. Presently, there are no guidelines for scheduling fungicide applications to maximize the economic returns using Southern Runner peanut.

Fixed interval or calendar-based spray applications, whether applied on a 10- to 14-day or a 20- to 28-day interval, may schedule fungicide applications during periods when environmental conditions are unfavorable for infection by the pathogens. Conversely, during periods favorable for pathogen development, fixed schedules may recommend fungicide applications too infrequently. Calendar-based systems do not account for variable environments. Forecasting systems have been developed that reduce fungicide use by applying fungicide only during periods favorable for pathogen development (4,14,15,16,19, 20). These systems not only reduce unnecessary fungicide applications but improve timeliness by scheduling fungicide applications only when needed. All of these systems were developed for cultivars susceptible to one or both leaf spot pathogens. Matyac and Bailey (17) modified Jensen and Boyle's model to account for the partial resistance of selected peanut cultivars. Fry (9,10) modified the BLITECAST system, which schedules fungicide applications for the control of late blight of potato, for use with resistant potato cultivars. The system was modified by allowing larger numbers of severity units to accumulate on resistant cultivars than on susceptible cultivars. These modifications reduced fungicide applications, with similar levels of disease control, compared with the unmodified schedule on susceptible cultivars.

The majority of these systems (4,16,18–20) use a combination of relative humidity or leaf wetness and temperature to forecast conditions favorable for pathogen development and thereby schedule fungicide applications. In contrast, the AU-Pnuts advisory used a combination of recorded rainfall and precipitation probabilities to predict conditions favorable for leaf spot development (14). Davis et al. (7) found that the number of days with rainfall ≥2.5 mm was the single best daily rainfall amount to predict leaf spot disease progress. A variable for temperature was not included in the advisory model because temperatures are generally favorable for pathogen development during the peanut growing season in Alabama, Georgia, and Florida.

The AU-Pnuts advisory was developed for leaf spot susceptible peanut cultivars (14). Due to the simplicity of the AU-Pnuts advisory, management strategies for new cultivars with different leaf spot susceptibility can be made by modifying rules or adding new ones. The successful implementation of these modifications should reduce fungicide usage without loss of production when compared with 14-day and 21-day fungicide schedules. The objectives of this study were to determine the efficacy of various modifications of the AU-Pnuts advisory for use with the late leaf spot resistant peanut cultivar Southern Runner.

MATERIALS AND METHODS

Field trials. Field experiments were conducted at the Wiregrass Substation of the Alabama Agricultural Experiment Station near Headland, Ala., from 1989 through 1992. Experiments were conducted in a Dothan sandy loam soil with an organic matter content of <1.0% and

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pH = 6.5. The 1989 field site had been under cultivated summer fallow the previous year, while the field sites in 1990 through 1992 had been planted to peanut the previous year. Southern Runner peanut were planted at a rate of 112 kg per ha on the following dates: 8 May 1989, 15 May 1990, 8 May 1991, and 15 May 1992. Peanut plots were maintained using standard cultural practices including local recommendations for weed, insect, and nematode control (8). All trials were irrigated as needed to maintain optimal plant growth.

The experimental design in all trials was a randomized complete block design with six replications per fungicide schedule. Each plot was six rows wide by 11 m long with 0.9 m between rows. In 1989, the plot size was eight rows by 12 m. The fungicide used for all treatment schedules was chlorothalonil (Bravo 720, ISK Biosciences Corp., Mentor, Ohio) at 1.26 kg a.i. per ha. Fungicide applications were made with a tractor-mounted boom sprayer with three Teejet TX8 nozzles (Spraying Systems Co., Wheaton, Ill.) per row delivering 140 liters per ha at 410 kPa.

The incidence of peanut leaf spot was monitored four to six times during each experiment. Estimates of leaf spot incidence (percent leaflets with lesions) were made by removing the main stem of five selected plants from each plot. We counted the numbers of nodes with expanded leaves, defoliated leaflets, and leaflets with lesions on each stem. Percentages of infected and defoliated leaflets were calculated as previously described (7). The area under the disease progress curve for percent infected (AUINFC) and defoliated leaflets (AUDEFC) were calculated for each plot (24).

Yield data were collected from the second and third rows of each plot. Peanuts were mechanically inverted at maturity and air dried for 3 to 4 days, then pods were harvested and dried to approximately 10% moisture before weighing.

Percent infected and defoliated leaflets, AUINFC, AUDEFC, and pod yields were compared for the different fungicide schedules. Each experiment was analyzed separately using analysis of variance. Fisher's protected least significant difference (LSD) ($P \leq 0.05$) was used to separate treatment means (3,26).

Initial rules. The prototype version of the AU-Pnuts advisory was developed for susceptible cultivars and tested beginning in 1989. Modified versions of the advisory were tested thereafter. In all versions of the AU-Pnuts advisory, the first number refers to action threshold for the initial fungicide application and the second number is the threshold for subsequent sprays (Table 1). For example, the first fungicide application of the AU-Pnuts advisory 7/3 was made after recording seven rain events following plant emergence. A rain event was defined as a 24-h period (beginning at 0700 h CST) with rainfall ≥2.5 mm of rainfall or irrigation, or a ground fog before 2000 h CST occurring on the previous evening (7). The decision to apply subsequent fungicide was based on the combination of recorded rainfall and average National Weather Service precipitation probability for the next 5 days. For all AU-Pnuts advisory treatments, chlorothalonil fungicide applications were assumed to provide at least 10 days protection from infection by *C. arachidicola* and *C. personatum*, so that no treatment was applied until at least 10 days had elapsed since the last application, regardless of rainfall or forecast conditions. Daily precipitation data were collected using a wedge-shaped Tru-Check rain gauge (Edwards Manufacturing Co., Albert Lea, Minn.) on the edge of the experimental site. Fungicide applications were not made within 14 days of digging.

Table 1. Treatment schedules for chlorothalonil fungicide evaluated on Southern Runner peanut for control of peanut leaf spots from 1989 to 1992 in Headland, Ala.

	Subsequent sprays[b]			
	Rain event threshold for each precipitation percentile mean			
AU-Pnuts treatment schedule[a]	60 to 100%	40 to 59%	20 to 39%	<20%[c]
6/3	0	1	2	3
9/3	0	1	2	3
9/4	1	2	3	4
9/5	2	3	4	5
12/3	0	1	2	3
12/4	1	2	3	4
12/5	2	3	4	5
15/3	0	1	2	3
15/4	1	2	3	4
15/5	2	3	4	5

[a] Each treatment schedule was not tested in all years. The first number refers to the number of recorded rain events before the initial spray and the second number refers to the number of predicted or recorded rain events before all subsequent sprays. A rain event is a 24-h period in which ≥2.5 mm of rainfall or irrigation water is recorded, or a ground fog occurs before 2000 h CST the previous evening.

[b] Threshold number of recorded rain events required for each 5-day average precipitation probability range before triggering subsequent fungicide applications are applied. After each fungicide application, a 10-day period was observed before monitoring rain events and precipitation probabilities.

[c] Subsequent fungicide applications are applied immediately after recording this number of rain events regardless of 5-day precipitation probability.

Table 2. Effect of fungicide schedule on peanut leaf spot development and yield of Southern Runner peanut at Headland, Ala. in 1989 and 1990

Year/fungicide schedule[a]	No. of sprays[b]	Final incidence (%)[c]	AUINFC[d] % infection	AUDEFC[e] % defoliation	Pod yield (kg per ha)
1989					
Nonsprayed Control	0	82.4	4,209.8	3,489.7	3,351
14-Day	7	51.5	2,641.0	2,234.2	4,099
AU-Pnuts advisory 7/3	6	41.9	2,181.9	1,868.9	4,059
LSD ($P \leq 0.05$)		8.6	279.6	227.5	654
1990					
Nonsprayed Control	0	74.5	3,927.4	3,448.1	1,944
14-Day	7	24.2	1,898.2	1,755.2	2,203
21-Day	5	38.7	2,798.3	2,388.8	2,199
AU-Pnuts advisory 12/3	4	35.9	3,056.0	2,700.4	2,188
AU-Pnuts advisory 12/4	3	40.9	3,155.4	2,742.2	2,207
AU-Pnuts advisory 12/5	2	47.2	3,474.6	3,056.1	1,342
AU-Pnuts advisory 15/3	3	47.6	3,523.9	3,134.3	2,250
AU-Pnuts advisory 15/4	2	46.4	3,573.9	3,138.0	2,157
AU-Pnuts advisory 15/5	2	53.2	3,622.4	3,180.6	2,102
LSD ($P \leq 0.05$)		5.9	295.5	256.1	NS[f]

[a] Fungicide schedule. For all AU-Pnuts advisory treatments, the first number refers to the number of recorded rain events before the initial spray and the second number refers to the number of predicted or recorded rain events before all subsequent sprays. A rain event is a 24-h period in which ≥2.5 mm of rainfall or irrigation water is recorded, or a ground fog occurs before 2000 h CST the previous evening.

[b] Number of applications of the fungicide chlorothalonil (1.26 kg per ha).

[c] Final leaf spot incidence (percent leaflets with lesions) assessed on 20 September 1989 and 18 September 1990, for respective years.

[d] Area under the season-long disease progress curve for percent infected leaflets.

[e] Area under the season-long disease progress curve for percent defoliated leaflets.

[f] NS = not significant ($P \leq 0.05$).

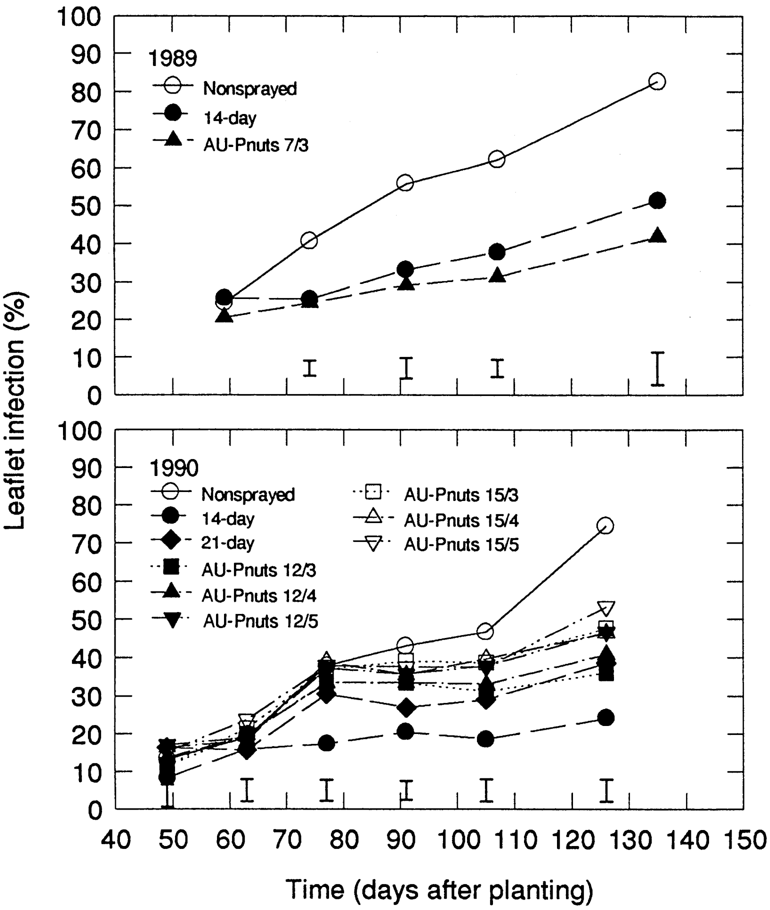

Fig. 1. Leaf spot disease progress curves for Southern Runner peanut to which chlorothalonil (1.26 kg per ha) was applied according to several fungicide schedules at Headland, Ala., in 1989 and 1990. Vertical bars indicate Fisher's protected least significant difference ($P \leq 0.05$) for treatment mean comparisons at each sampling date.

Table 3. Effect of fungicide schedule on peanut leaf spot development and yield of Southern Runner peanut at Headland, Ala., in 1991 and 1992

Year/fungicide schedule[a]	No. of sprays[b]	Final incidence (%)[c]	AUINFC[d] % infection	AUDEFC[e] % defoliation	Pod yield (kg per ha)
1991					
Nonsprayed control	0	92.3	4,866.5	3,335.3	3,120
14-Day	7	43.3	2,042.6	1,593.8	3,229
21-Day	5	75.2	3,743.6	2,860.1	2,958
AU-Pnuts advisory 9/3	5	72.4	3,115.6	2,300.2	3,385
AU-Pnuts advisory 9/4	4	87.9	3,321.8	2,424.0	3,385
AU-Pnuts advisory 9/5	4	87.0	2,996.1	2,160.1	3,531
AU-Pnuts advisory 12/3	4	59.1	2,506.4	1,908.8	3,407
AU-Pnuts advisory 12/4	3	87.9	3,730.6	2,815.1	3,539
AU-Pnuts advisory 12/5	3	91.9	4,107.3	3,201.8	3,662
LSD ($P \leq 0.05$)		6.3	278.4	226.4	476
1992					
Nonsprayed Control	0	93.0	3,790.1	2,733.0	3,167
14-Day	7	44.4	1,808.9	1,237.2	3,616
21-Day	5	61.3	2,458.2	1,664.9	3,531
AU-Pnuts advisory 6/3	7	39.7	1,393.7	1,053.2	3,508
AU-Pnuts advisory 9/4	5	58.2	1,824.3	1,270.6	3,555
AU-Pnuts advisory 12/4	5	61.8	1,893.5	1,293.5	3,686
LSD ($P \leq 0.05$)		10.7	306.1	226.3	457

[a] Fungicide schedule. For all AU-Pnuts advisory treatments, the first number refers to the number of recorded rain events before the initial spray and the second number refers to the number of predicted or recorded rain events before all subsequent sprays. A rain event is a 24-h period in which ≥2.5 mm of rainfall or irrigation water is recorded, or a ground fog occurs before 2000 h CST the previous evening.

[b] Number of applications of the fungicide chlorothalonil (1.26 kg per ha).

[c] Final leaf spot incidence (percent leaflets with lesions) assessed on 4 October 1991 and 1 October 1992, for respective years.

[d] Area under the season-long disease progress curve for percent infected leaflets.

[e] Area under the season-long disease progress curve for percent defoliated leaflets.

1989 field trial. A field experiment was conducted in 1989 in which three treatment schedules were evaluated. Three treatments were tested: nonsprayed control, 14-day schedule beginning 37 DAP, and the prototype AU-Pnuts advisory (AU-Pnuts 7/3).

1990 field trial. The AU-Pnuts advisory was modified for the partial resistance of the cultivar Southern Runner by increasing action thresholds for the initial and subsequent fungicide applications. A final modification of the AU-Pnuts advisory for use with resistant cultivars was to increase the preharvest interval during which no fungicide applications were made from 14 to 21 days before harvest. Six versions of the AU-Pnuts advisory (AU-Pnuts 12/3, 12/4, 12/5, 15/3,15/4, 15/5) were tested along with the following treatments: nonsprayed control, 14-day schedule beginning 42 DAP, and 21-day schedule beginning 42 DAP (Table 1).

1991 field trial. Data from the 1990 experiment showed that scheduling the initial fungicide application after recording 15 rain events after plant emergence produced excessively high disease levels and these treatments (AU-Pnuts 15/3, 15/4, and 15/5) were discontinued. In addition to the AU-Pnuts 12/3, 12/4, and 12/5 versions of the advisory, three additional versions were added in 1991: AU-Pnuts 9/3, 9/4, and 9/5 (Table 1). All six modified versions of the advisory were tested along with the following treatments: nonsprayed control, 14-day schedule, and 21-day schedule, with the latter two schedules beginning 36 DAP.

1992 field trial. Efficacious treatments were further reduced to 9/4 and 12/4 during the 1992 season. Four additional treatments were evaluated in 1992: nonsprayed control, 14-day schedule, 21-day schedule, and AU-Pnuts 6/3 (Table 1). The initial fungicide application for both the 14-day and 21-day schedules was 39 DAP. The AU-Pnuts 6/3 is the version of the advisory for cultivars highly susceptible to peanut leaf spots (14).

RESULTS

1989 field trial. Frequent early season rainfall produced high incidence of late leaf spot on nonsprayed plots of both cultivars by the end of the season (Table 2). The AU-Pnuts treatment had lower final disease incidence, AUINFC, and AUDEFC than did the 14-day schedule treatment (Table 2 and Fig. 1). Higher levels of disease control by the AU-Pnuts 7/3 treatment were obtained with one less fungicide application than in the 14-day schedule. Both fungicide schedules increased yields over the nonsprayed control.

1990 field trial. A severe drought late in the growing season produced low yields and only moderate leaf spot incidence. Rainfall for May to September was 47% of the 30-year normal. Irrigation was used frequently during July and August, but yields were less than half those of 1989. No differences occurred between yields of fungicide-treated and nonsprayed plots. All modified versions of the AU-Pnuts advisory reduced numbers of fungicide applications when compared with both the 14-day and 21-day schedules (Table 2). However, several advisory treatments, including the AU-Pnuts versions 12/5, 15/3, 15/4, and 15/5, had significantly greater final leaf spot incidence, AUINFC, and AUDEFC than the 21-day schedule (Table 2). The AU-Pnuts 12/3 and 12/4 versions of the advisory provided disease control equivalent to that of the 21-day schedule (Table 2).

1991 field trial. Leaf spot incidence was higher than in 1990 due to above normal early season rainfall (Tables 2 and 3). Also, incidence of early leaf spot was greater than observed during experiments conducted in 1989 and 1990. A late-season increase in leaf spot incidence occurred with several AU-Pnuts advisory treatments (Fig. 2). However, season-long disease control was better as indicated by significantly lower AUINFC and AUDEFC compared with the 21-day schedule. No yield differences were detected between AU-Pnuts advisory treatments and the 14-day schedule. However, the 21-day schedule had lower yields when compared with AU-Pnuts 9/5, 12/4, and 12/5 treatments (Table 3).

1992 field trial. July and August were two of the wettest months in the past 10 years (131% of the 31-year normal), initiating a severe leaf spot epidemic and reducing opportunities to save fungicide applications. The AU-Pnuts version 6/3 significantly reduced AUINFC as compared with the 14-day schedule with the same number of fungicide applications (Table 3). Both the AU-Pnuts 9/4 and 12/4 versions of the advisory saved two sprays compared with the 14-day schedule, but did not reduce numbers of fungicide applications compared with the 21-day schedule. No differences in AUINFC or AUDEFC occurred with either the 9/4 or 12/4 versions of the AU-Pnuts advisory compared with the 14-day schedule (Table 3). Leaf spot incidence with the AU-Pnuts 9/4 and 12/4 schedules was not different than with the 14-day schedule at each observation date except the last one (Fig. 2). Both versions improved leaf spot control compared with the 21-day schedule with the same number of fungicide applications (Table 3). Yields with all fungicide schedules were greater than with the nonsprayed control but were not different from each other (Table 3).

DISCUSSION

The AU-Pnuts advisory was modified to take advantage of the partial leaf spot resistance of the cultivar Southern Runner. Of the modified versions of the advisory evaluated, both the AU-Pnuts 9/4 and 12/4 treatment schedules reduced the number of fungicide applications while maintaining adequate control of peanut leaf spot to prevent economical yield loss, compared with the 14-day schedule. Mean pod yields for both the modified AU-Pnuts advisory treatments were equal to or better than the 14-day and 21-day schedules. The version of the AU-Pnuts advisory for Southern Runner peanut has also been tested in Florida with excellent success (F. M. Shokes, *personal communication*).

The AU-Pnuts 9/4 treatment reduced the total number of fungicide applications per season by 36% compared with the conventional 14-day calendar schedule. This reduction in fungicide use represents significant potential economic and environmental benefits in reduced leaf spot disease control costs and reduced use of organic fungicides. Fixed interval schedules (20- to 28-day) also reduce the number of fungicide applications with no loss in pod yield, compared with the 14-day schedule (5,11,12). However, Southern Runner is only partially resistant to late leaf spot and is susceptible to early leaf spot, making it potentially vulnerable to yield losses due to leaf spots (11). In some cases a 21-day schedule may not prevent yield losses during favorable conditions for severe leaf spot development (2).

In 1992, above normal rainfall during July and August resulted in a high incidence of early leaf spot. The AU-Pnuts 9/4 treatment had significantly lower AUINFC and AUDEFC than the 21-day schedule with the same number of fungicide applications. The ability of the AU-Pnuts advisory to provide better season-long disease control than the 21-day schedule suggests that advisory fungicide applications were more appropriately scheduled. The longer fixed interval schedules (20 to 28 days) are not responsive to changing environmental conditions and are probably missing important infection periods in the development of early and late leaf spot.

Yields were not different between the fixed and advisory fungicide schedules even with large differences in level of dis-

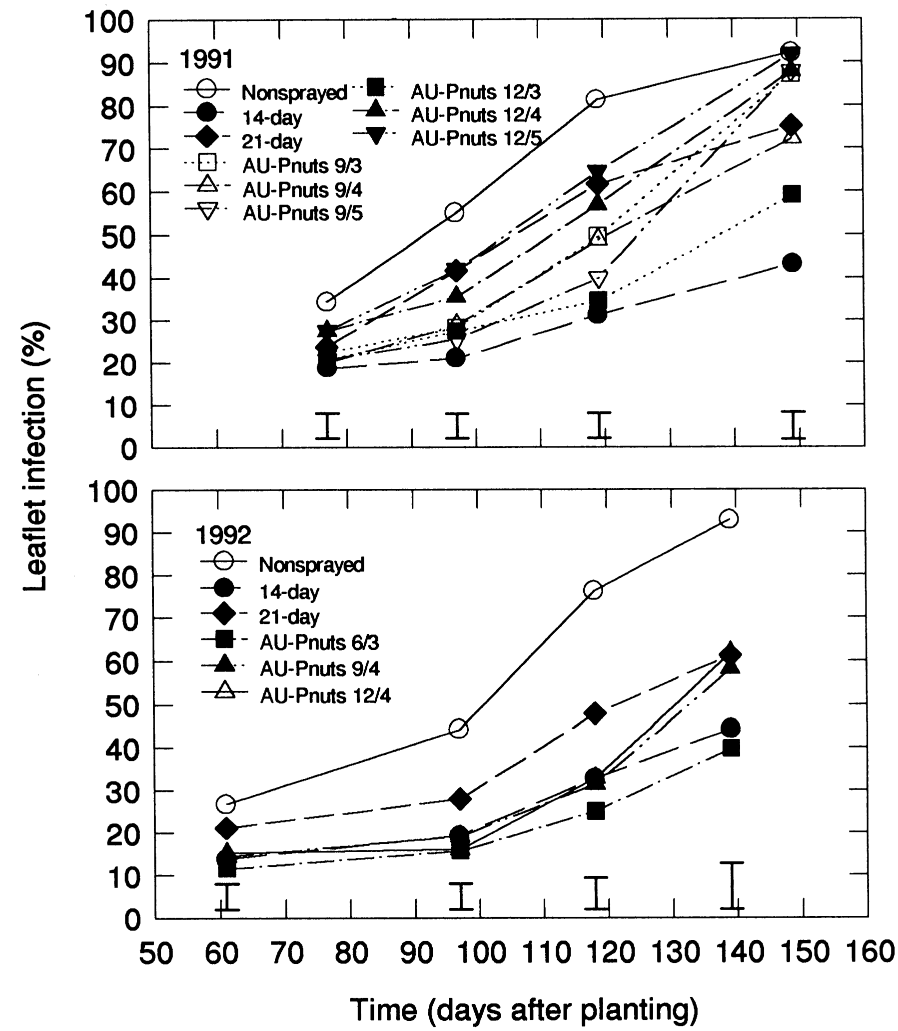

Fig. 2. Leaf spot disease progress curves for Southern Runner peanut to which chlorothalonil (1.26 kg a.i. per ha) had been applied according to several fungicide schedules at Headland, Ala., in 1991 and 1992. Vertical bars indicate Fisher's protected least significant difference ($P \leq 0.05$) for comparing fungicide schedules at each sampling date.

ease control. The lack of yield differences is probably due to the tolerance of Southern Runner. Several factors have been implicated in that tolerance. The cultivar loses fewer pods when peanut plants are inverted than does the susceptible cultivar Florunner (22). Southern Runner continues to produce new leaves throughout the growing season to compensate for leaves lost due to infection and defoliation by leaf spot pathogens (21); this allows Southern Runner to maintain a higher leaf area index during severe leaf spot epidemics than does Florunner (21). However, this continued leaf production reduces the photosynthate partitioning coefficient of Southern Runner (22). Southern Runner partitions 80% of its photosynthate to pods compared with 92% for Florunner. Another factor possibly involved in the tolerance of Southern Runner is that it develops fewer stem lesions caused by *C. personatum* than Florunner does under severe leaf spot pressure (6).

The AU-Pnuts advisory is a rule-based system. Beyond new and/or modified rules for new cultivars with disease resistance, such as Southern Runner, the system allows for the addition of new rules for new fungicides as they become available. The AU-Pnuts advisory could also be updated to include rules for the control of other diseases such as southern stem rot (*Sclerotium rolfsii* Sacc.) and Rhizoctonia limb rot (*Rhizoctonia solani* Kühn AG-4). Peanut growers are confronted with more than one disease problem in a growing season; incorporating rules for other important diseases of peanut increases the usefulness, acceptance, and adoption of the advisory system.

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