Comparison of Weather-Based Advisory Programs for Managing Early Leaf Spot on Runner and Spanish Peanut Cultivars

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ABSTRACT

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Weather-based advisory programs for scheduling applications of chlorothalonil to control early leaf spot of peanut were evaluated for two runner cultivars (Florunner and Okrun) and one Spanish cultivar (Spanco). Advisory programs included the following: (i) the Parvin, Smith, and Crosby program that utilizes daily infection indices based on the favorableness of relative humidity (RH) and temperature (T) for infection over a 2-day period (PSC); (ii) the modified PSC program for cultivars with partial resistance that reduces daily infection indices by 0.85 (0.85*PSC); (iii) the Virginia program that accumulates hours of T and RH favorable for infection with spray thresholds of 36 to 96 h (VA-36 to VA-96); and (iv) the AU-Pnuts program based on precipitation events and/or probability forecasts. Using the standard 14-day program, 6.7 sprays per year were applied to Spanco and 7 sprays per year were applied to the runner cultivars. Disease control, the reduction in area under the disease progress curve compared with the unsprayed treatment, was greater than 90% with the 14-day program for all cultivars. The PSC and 0.85*PSC programs failed to recommend needed sprays for all cultivars in 1992 and 1993 when disease incidence for these programs did not differ from the unsprayed control. For Spanco, the VA-36 (3.3 sprays/year) and AU-Pnuts (4.5 sprays/year) were the most effective advisory programs, providing 53 to 78% disease control. Except for the VA-48 and VA-60 programs in 1992, disease control on Spanco for VA programs was reduced with increasing spray thresholds of 48 to 96 h. The VA and AU-Pnuts programs provided better disease control on the runner cultivars than on Spanco. Disease control for the VA-36 (3.3 sprays/year), VA-48 (2.3 sprays/year), and AU-Pnuts (4.5 sprays/year) programs ranged from 62 to 95%, and was 80% or greater in 1992 and 1993, when levels of leaf spot were highest. The VA-60 and VA-72 programs also reduced disease incidence and area under the disease progress curve (AUDPC) for the runner cultivars each year compared with the control. In 1992 and 1993, when leaf spot reduced yields of Spanco, the VA-36, VA-48 (2.3 sprays/year), VA-60 (2.5 sprays/year), and AU-Pnuts programs were the only advisory programs that had yields equal to the 14-day program. Yields of the runner cultivars were not reduced by leaf spot in any year. The VA program was the most efficient advisory program tested. The optimum spray threshold for the VA program depended on the cultivar grown and the level of control desired. Spray thresholds of 36 h for Spanish and 48 h for runner cultivars have been implemented commercially in Oklahoma.

Early leaf spot, caused by the fungus *Cercospora arachidicola* S. Hori, is currently the most common and damaging foliar disease of peanut (*Arachis hypogaea* L.) in Oklahoma. Agronomic practices such as crop rotation and deep plowing of infested peanut residue are only effective in reducing primary inoculum and delaying disease onset (17,25). Some commercially acceptable cultivars have partial resistance (14,15), but levels of resistance are not sufficient to preclude the need for repeated fungicide applications (14,18).

Decision-support systems for improving the efficiency of leaf spot control with fungicides have relied largely on the observed association of disease incidence and weather (12). A model to forecast the increase of leaf spot was developed using the period of relative humidity (RH) ≥95% and the minimum temperature (T) during the period (13). The Jensen and Boyle model was later adapted and computerized by Parvin et al. (19) to issue advisories on the need for fungicide sprays. The Parvin, Smith, and Crosby (PSC) program was used commercially in Virginia from 1981 to 1988. In Virginia from 1979 to 1982 an average of 4.25 fewer sprays per season was reported with no reduction in yield (21). The PSC program was simplified to make it easier to use in North Carolina, where it has been deployed since 1984 (3). Subsequently, the PSC advisory was modified to further reduce sprays for peanut cultivars with partial resistance (18).

Concern over the higher levels of leaf spot that frequently develop when the PSC program is used compared with the levels under a 14-day program (5,18,21) has resulted in efforts to improve advisory programs. A new advisory program was developed and released in Virginia in 1989 to replace the PSC program (5). The Virginia program (VA) is based largely on the response of conidial germination, germ tube elongation, and stomatal penetration to T and RH (1,2). The VA program accumulates hourly periods of favorable T and RH. Using a spray threshold of 48 h for Virginia cultivars, the VA program has enabled growers to reduce sprays by an average of 2.25 per season while maintaining disease control equal to that of the 14-day program and better than that of the PSC program (20). Increasing the spray threshold has been proposed for cultivars with partial resistance (5). This has been evaluated for some Virginia cultivars (6), but not for runner and Spanish cultivars.

Rainfall is another weather variable that has been used to predict leaf spot epidemics (8,16). The AU-Pnuts program was developed primarily for control of late leaf spot caused by *Cercosporidium personatum* (Berk. & M. A. Curtis), but it is also useful for early leaf spot (11). The program uses daily rainfall or irrigation events and/or precipitation probability to schedule sprays. AU-Pnuts has reduced sprays by an average of 1.25 per season in Alabama, where it has been released commercially for the cultivar Florunner (11).

Except for AU-Pnuts, advisory programs for early leaf spot have been developed and used primarily on Virginia cultivars. In Oklahoma, about 70% of the peanut production is planted to Spanish and 30% to runner cultivars. Runner cultivars, including Florunner and Okrun, appear to be less susceptible to early leaf spot than are Spanish cultivars. Less sporulation and fewer lesions per leaf were observed on Florunner than on some Spanish cultivars (9). On runner cultivars in the field, epidemics were delayed and disease incidence and area under the disease progress curve (AUDPC) were reduced compared with Spanish cultivars (7). These traits are consistent with components of partial resistance described for Virginia cultivars (14,15).

The effectiveness of the PSC advisory in maintaining yields of runner and Spanish cultivars in a reduced spray program was demonstrated in Oklahoma (7). However, disease control on Spanish cultivars was often poor, as the percentage of sympto-

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matic leaflets reached 75% and that of defoliation 50% in several trials. The VA, modified PSC, and AU-Pnuts programs provide alternatives to the PSC advisory as decision-support systems for control of early leaf spot. These advisories have not been evaluated in Oklahoma and have not been critically compared elsewhere. Therefore, the objective of this study was to compare the performance of leaf spot advisory programs on Spanish and runner cultivars.

MATERIALS AND METHODS

Spray programs were compared in a field previously cropped to peanut at the Oklahoma State University Agronomy Research Station in Perkins. The Spanish cultivar Spanco and the runner cultivar Florunner were used from 1991 to 1993. Spanco is susceptible to early leaf spot while Florunner is partially resistant. The runner cultivar Okrun was added in 1992 and 1993. Okrun has appeared to be slightly more resistant to early leaf spot than is Florunner. Planting dates for all cultivars were 17 May in 1991 and 1992 and 27 May in 1993. Separate but adjacent plantings of each cultivar were made to facilitate harvest at the different maturity dates.

Treatments (spray programs) were applied to plots randomized within four complete blocks of each cultivar. Plots consisted of four 7.6-m rows spaced 0.92 m apart. Chlorothalonil at 1.26 kg/ha (Bravo 720, ISK Biosciences Corp., Mentor, OH) was used to control early leaf spot for all spray programs. Sprays were applied to all four rows of a plot with a wheelbarrow sprayer equipped with three TX-10, hollow-cone nozzles per row. The sprayer was calibrated to deliver 302 liters per ha at 275 kPa. Except for spray programs to control leaf spot, practices recommended for crop management in Oklahoma were followed (24). The field also received sprinkler irrigation as necessary to prevent moisture stress.

The PSC program as simplified by Bailey et al. (3) and evaluated previously (7) was tested from 1991 to 1993. Daily infection indices from 0 to 3 (with 0 = unfavorable and 3 = very favorable) were obtained from the PSC nomogram (3): the period of RH ≥95% and the minimum T during the period were used as input variables. A 2-day sum of infection indices ≥3.5 was used as the spray threshold. The PSC program modified for cultivars with partial resistance (18) was tested in 1992 and 1993. Daily infection indices were reduced with a multiplier of 0.85 while the spray threshold of 3.5 was retained (0.85* PSC).

The VA program accumulated hourly periods of favorable weather for infection, herein called infection hours, that consisted of RH ≥95% while T is 16 to 32°C (5). Spray thresholds of 36, 48, 72, and 96 h (VA 36-96) were tested in 1991 to 1993 while a 60-h threshold was added in 1992 and 1993. Infection hours were reset to zero when weather became lethal to germinating conidia. Lethal conditions were five consecutive hours of T ≥37°C or eight consecutive hours of RH <40% (5).

The AU-Pnuts program was based on rain events that consisted of a day with >2.5 mm rain and/or irrigation (11). Counts of rain events began at emergence and the first spray was applied after seven rain events. Thereafter, the occurrence of two rain events was used as the spray threshold in 1991 (AU-Pnuts-7/2) while the occurrence of three was used in 1993 (AU-Pnuts-7/3). No rain events were required if the 5-day average precipitation forecast was ≥50%. Rain event thresholds were reduced by two if the 5-day average forecast was ≥40%, and by one for a 5-day average forecast of ≥20% (11).

Advisory programs were compared with a standard 14-day program and an unsprayed control each year. Except for the AU-Pnuts program as described above, the first spray for all spray programs was applied 45 days after planting (DAP) in 1991. Thereafter, advisory sprays were applied when indicated by the respective programs. A 10-day protection period followed spray dates for all advisory programs (3,5,11). During this period, VA infection hours and AU-Pnuts rain events were reset to zero and remained at zero, and PSC infection indices were not considered. In 1992 and 1993, sprays for the 14-day program and calculation of VA infection hours and PSC infection indices began 30 DAP for Spanco and 45 DAP for the runner cultivars. The first sprays for all advisory programs were then made when respective spray thresholds were exceeded. Sprays for advisory programs were made as soon as possible after thresholds were exceeded, usually within 3 days. All spray programs were maintained until 14 days before anticipated harvest.

T, RH, and rainfall were monitored continuously from late June through harvest with a CR21X datalogger (Campbell Scientific, Logan, UT) equipped with a ventilated psychrometer and a tipping bucket rain gauge. The psychrometer was set at a height of 1.2 m over peanut plants and was under the influence of irrigation. Point readings of T and RH data were taken every 15 min and a 30-min mean value was output. Weather data were processed with a basic program that provided advisory program outputs for a 24-h period beginning at 1100 CST. Program output was total daily rainfall, daily PSC infection indices, and VA infection hours and lethal periods. Five-day precipitation forecasts were obtained daily from the National Weather Service in Oklahoma City.

Plots were evaluated for incidence of early leaf spot at 14-day intervals beginning approximately 45 DAP. Leaf spot incidence, expressed as the percentage of symptomatic leaflets, was assessed visually in three 1-m row segments selected arbitrarily in each of the two center rows. Leaflets with lesions and defoliated leaflets were considered symptomatic. Final assessments of leaf spot incidence and a separate assessment of defoliation alone were made within a week of harvest.

Yields were taken from the center two rows of each plot. Plots were dug and inverted, dried in the field for 2 days, and threshed with a peanut combine. Digging dates were 30 September (136 DAP) for Spanco and 21 October (157 DAP) for Florunner in 1991; 12 October (138 DAP) for Spanco and 23 October (149 DAP) for Florunner and Okrun in 1992; and 11 October (147 DAP) for Spanco and 25 October (161 DAP) for Florunner and Okrun in 1993. Pods were dried to approximately 10% moisture and cleaned to remove foreign material prior to weighing.

Analysis of disease incidence data was performed on the mean of the six subsamples per plot. AUDPC was calculated as a measure of disease progress according to Shaner's formula (23). Disease incidence and yield data were subjected to analysis of variance (ANOVA) as a split-plot design using the GLM procedure of SAS (22). The whole-plot effects of year and cultivar, and the year × cultivar interaction were tested with block(year × cultivar) as the whole-plot error term. The split-plot effects of treatment and treatment interactions with year, cultivar, and year × cultivar were tested with the residual error that contained the block interactions. Where year × cultivar × treatment interactions were significant ($P \leq 0.05$), the ANOVA was performed by cultivar. Where year × treatment interactions were significant in the reduced model, the ANOVA was performed by year and cultivar. Treatment means were separated using Duncan's multiple range test (26) as indicated by significant effects in the ANOVA. Simple correlation analysis was used to assess the association of disease incidence and AUDPC with yield in plots (26). Unless otherwise indicated, only significant ($P \leq 0.05$) differences between treatment means are described below.

RESULTS

Weather conditions that favored the development of early leaf spot, the only foliar disease encountered in this study, were recorded each year. Rainfall from emergence to harvest each year totaled 38 cm in 1991, 68 cm in 1992, and 34 cm in 1993. The trials received six 1-inch irrigations in 1991, four in 1992, and eight in 1993. AU-Pnuts rain events resulting from ambient rainfall and irrigation totaled 29 in 1991, 39 in 1992, and 33 in 1993. VA infection hours from 21 June to 1 October each year totaled 299 in 1991, 336 in 1992, and 234 in 1993. Lethal conditions as defined by the VA program were met three times in

August 1991, but were not met in either 1992 or 1993. PSC infection indices from 21 June to 30 September totaled 30.5 in 1991, 11.0 in 1992, and 5.5 in 1993.

The number of sprays for the 14-day program averaged 6.7 for Spanco and 7.0 for Florunner. All advisory programs reduced the number of sprays per year over a 3-year period compared with the 14-day program. The PSC program averaged 1.3 sprays per year for both cultivars, while no sprays were applied according to the 0.85*PSC program in 1992 or in 1993. The number of sprays applied to Spanco for the VA programs averaged 3.3 for VA-36, 2.3 for VA-48, 2.3 for VA-72, and 1.7 for VA-96. The number of sprays applied to Florunner for the VA programs averaged 3.3 for VA-36, 2.3 for VA-48, 2.0 for VA-72, and 1.7 for VA-96. From 1992 to 1993, the VA-60 program reduced the number of sprays from 7 to 2.5 for Spanco, and from 7 to 2.0 for Florunner.

In the ANOVA over years and cultivars for final leaf spot incidence, defoliation, and AUDPC, the year × cultivar × treatment interactions were significant ($P \leq 0.01$). Treatment × year interactions also were significant ($P \leq 0.01$) for each cultivar. Therefore, means were separated by year and cultivar.

For Spanco, the 14-day program had the lowest disease incidence, defoliation, and AUDPC (Table 1). Disease control, the reduction in AUDPC compared with the unsprayed control, exceeded 90% for the 14-day program each year. The VA-36 program was the most effective advisory program tested from 1991 to 1993, with disease control ranging from 53 to 78%. While leaf spot incidence and AUDPC were greater for the VA-36 program than for the 14-day program each year, defoliation levels did not differ from those for the 14-day program in 1991 and 1992. Leaf spot incidence and defoliation for the AU-Pnuts program did not differ from those for the VA-36 program in 1991 or 1993, but AUDPC for the AU-Pnuts program was higher in 1993. While disease control was similar for the AU-Pnuts and VA-36 programs, one more spray was applied each year with the AU-Pnuts program. In 1991, none of the other VA programs reduced disease incidence or AUDPC compared with the control. In 1992 and 1993, when leaf spot levels were higher, disease control ranged from 47% to 79% for the VA-48 program and from 34 to 68% for the VA-60 program. The VA-72 and VA-96 programs provided little or no disease control in 1992 and 1993, as leaf spot incidence exceeded 80% and defoliation 50%. The PSC program provided little or no disease control in 1991 or 1993, and did not recommend any sprays in 1992 when disease incidence and AUDPC did not differ from the unsprayed control.

Advisory programs provided better disease control for Florunner (Table 2) than for Spanco. Leaf spot incidence and defoliation were minimal for the 14-day program, and disease control exceed 90% each year. All advisory programs except the PSC program reduced final incidence of

Table 1. Comparison of spray programs with chlorothalonil (1.26 kg/ha) for control of early leaf spot on the spanish peanut cultivar Spanco in 1991 to 1993

	Sprays (no.)			Leaf spot (%)[w]			Defoliation (%)[x]			AUDPC[y]		
Spray program[v]	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**
14-day	6	7	7	2 d[z]	12 e	15 f	0 b	5 d	4 f	257 c	269 d	513 g
PSC	3	0	1	56 ab	100 a	84 bc	24 a	91 a	63 b	1,232 a	4,655 a	3,243 b
0.85*PSC	...	0	0	...	100 a	92 ab	...	90 a	69 b	...	4,456 a	3,777 a
AU-Pnuts	5	...	4	21 c	...	41 e	1 b	...	25 e	548 b	...	1,683 e
VA-36	3	4	3	18 c	24 d	40 e	3 b	9 d	24 e	705 b	994 c	1,349 f
VA-48	2	3	2	48 b	29 d	58 d	23 a	10 d	43 d	1,381 a	976 c	2,064 d
VA-60	...	3	2	...	47 c	78 c	...	27 c	53 c	...	1,475 c	2,537 c
VA-72	2	3	2	70 a	89 b	84 bc	29 a	67 b	67 b	1,464 a	3,583 b	3,063 b
VA-96	2	2	1	60 ab	88 b	80 c	22 a	66 b	69 b	1,327 a	3,496 b	2,727 c
Control	0	0	0	66 a	100 a	94 a	29 b	90 a	76 a	1,510 a	4,582 a	3,872 a

[v] PSC = Parvin, Smith, and Crosby program; 0.85*PSC = modified Parvin, Smith, and Crosby program in which the daily infection indices were reduced by 0.85 for cultivars with partial resistance; AU-Pnuts program with spray thresholds of 2 rain events in 1990 and 3 rain events in 1993; VA-*n* = Virginia program with spray thresholds of *n* cumulative infection hours.
[w] Final estimation of symptomatic or defoliated leaflets.
[x] Final estimation of defoliated leaflets.
[y] Area under the disease progress curve.
[z] Means within in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Table 2. Comparison of spray programs with chlorothalonil (1.26 kg/ha) for control of early leaf spot on the runner peanut cultivar Florunner in 1991 to 1993

	Sprays (no.)			Leaf spot (%)[w]			Defoliation (%)[x]			AUDPC[y]		
Spray program[v]	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**	**1991**	**1992**	**1993**
14-day	7	7	7	1 b[z]	1 d	6 f	0 b	0 d	1 g	33 c	62 d	241 g
PSC	3	0	1	14 b	76 a	74 a	3 b	14 ab	13 b	326 b	2,018 a	2,932 b
0.85*PSC	...	0	0	...	82 a	79 a	...	17 a	15 a	...	2,201 a	3,532 a
AU-Pnuts	5	...	4	1 b	...	15 ef	0 b	...	3 f	27 c	...	621 f
VA-36	3	4	3	2 b	2 d	15 ef	0 b	0 d	3 f	77 bc	85 d	588 f
VA-48	2	3	2	16 b	2 d	24 e	3 b	0 d	5 e	301 b	101 d	715 f
VA-60	...	2	2	...	16 c	37 d	...	3 cd	7 e	...	576 c	1,437 e
VA-72	2	2	2	12 b	21 c	47 c	1 b	3 cd	9 d	275 bc	711 c	2,040 d
VA-96	2	2	1	13 b	61 b	64 b	2 b	8 bc	11 c	255 bc	1,225 b	2,376 c
Control	0	0	0	56 a	80 a	80 a	14 a	17 a	16 a	790 a	2,016 a	3,720 a

[v] PSC = Parvin, Smith, and Crosby program; 0.85*PSC = modified Parvin, Smith, and Crosby program in which the daily infection indices were reduced by 0.85 for cultivars with partial resistance; AU-Pnuts program with spray thresholds of 2 rain events in 1990 and 3 rain events in 1993; VA-*n* = Virginia program with spray thresholds of *n* cumulative infection hours.
[w] Final estimation of symptomatic or defoliated leaflets.
[x] Final estimation of defoliated leaflets.
[y] Area under the disease progress curve.
[z] Means within in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

leaf spot compared with the unsprayed control each year. The AU-Pnuts, VA-36, and VA-48 were the most effective advisory programs. Disease control for these programs ranged from 62 to 96% and disease incidence did not differ from the 14-day program in one or more years. However, the VA-48 program was most efficient, receiving one less spray each year than the VA-36 program, three less sprays than AU-Pnuts-7/2 in 1991, and two less sprays than AU-Pnuts-7/3 in 1993. The PSC program provided 59% disease control in 1991, was not effective in 1992 when no sprays were applied, and afforded only 21% disease control in 1993.

The performance of spray programs for Okrun in 1992 and 1993 (Table 3) was similar to their performance for Florunner. The VA-36 and VA-48 programs afforded better than 80% disease control each year. However, the VA-48 program received 0.5 fewer sprays per season than the VA-36 program. Disease incidence and AUDPC for the VA-60 program were equal to the VA-36 and VA-48 programs in 1993, but not in 1992. Disease incidence approached or exceeded 50% with higher thresholds of the VA program. Disease control for the AU-Pnuts-7/3 program was equal to that for the VA-36 and VA-48 programs in 1993, but the AU-Pnuts program required one more spray. The PSC program did not provide disease control in 1992 when no sprays were recommended and afforded only 11% control in 1993.

The 0.85*PSC program did not recommend any sprays in 1992 or 1993. Disease incidence and AUDPC for this program did not differ from the unsprayed control for all cultivars.

Sclerotinia blight, caused by *Sclerotinia minor* Jagger, was detected in all cultivars each year, but incidence was highest for Okrun. Disease incidence for spray programs over years ranged from 3 to 11% for Spanco and 5 to 17% for Florunner. However, treatment effects were not significant and disease incidence was not correlated with yields of these cultivars. Treatment effects were significant ($P \leq 0.05$) for Okrun. In 1992, disease incidence did not differ among the 14-day (63%), VA-36 (45%), and VA-72 (46%) programs. Levels of disease incidence for the other programs, which ranged from 25 to 38%, were less than those for the 14-day program. In 1993, disease incidence did not differ among the 14-day (25%) and VA-48 (21%) programs. Levels of disease incidence for the other programs, which ranged from 14 to 19%, were less than those for the 14-day program. Disease incidence was negatively correlated with yields of Okrun over years ($r = -0.44$, $P < 0.01$).

In the ANOVA over years and cultivars for yield, the year × cultivar × treatment interaction was significant ($P \leq 0.05$). Treatment × year interactions also were significant ($P \leq 0.05$) for Spanco, but not Florunner and Okrun. Therefore, means were separated by year for Spanco and over years for Florunner and Okrun.

Yields of Spanco were affected by spray programs in 2 of the 3 years (Table 4). In 1991, there was no correlation between leaf spot incidence or AUDPC and yield, and the treatment means did not differ. AUDPC was negatively correlated with yield in 1992 ($r = -0.89$, $P < 0.01$) and 1993 ($r = -0.79$, $P < 0.01$) when disease incidence was higher. In 1992 and 1993, yields for the VA-36, VA-48, and VA-60 programs were greater than the control and not less than the 14-day program. Yield for the AU-Pnuts program also did not differ from these programs in 1993. Leaf spot reduced yields of the other programs compared with the 14-day program by an average of 30% in 1992 and 17% in 1993.

Spray programs had less impact on yields of Florunner and Okrun than on those of Spanco (Table 4). AUDPC and yield were correlated for Florunner over years ($r = -0.39$, $P < 0.01$). However, yields of Florunner did not differ among spray programs, as the effect of treatment was not significant ($P > 0.05$). Yields of Okrun were not correlated with incidence

Table 3. Comparison of spray programs with chlorothalonil (1.26 kg/ha) on control of early leaf spot on the runner peanut cultivar Okrun in 1992 and 1993

	Sprays (no.)		Leaf spot (%)[w]		Defoliation (%)[x]		AUDPC[y]	
Spray program[v]	1992	1993	1992	1993	1992	1993	1992	1993
14-day	7	7	1 d[z]	3 d	0 d	1 e	44 d	156 e
PSC	0	1	81 a	69 a	19 a	12 b	2,284 a	3,064 b
0.85*PSC	0	0	85 a	74 a	21 a	15 a	2,583 a	3,357 a
AU-Pnuts	...	4	...	10 cd	...	2 e	...	425 d
VA-36	4	3	3 d	10 cd	0 d	2 e	151 d	479 d
VA-48	3	3	3 d	13 c	2 cd	5 d	187 d	512 d
VA-60	2	2	26 c	15 c	6 bc	7 c	1,364 bc	578 d
VA-72	2	1	19 c	47 b	5 bc	7 c	1,050 c	1,585 c
VA-96	2	1	73 b	54 b	9 b	12 b	1,568 b	1,755 c
Control	0	0	83 a	74 a	21 a	15 a	2,514 a	3,435 a

[v] PSC = Parvin, Smith, and Crosby program; 0.85*PSC = modified Parvin, Smith, and Crosby program where the daily infection indices were reduced by 0.85 for cultivars with partial resistance; AU-Pnuts program with a spray thresholds of 3 rain events; VA-*n* = Virginia program with spray thresholds of *n* cumulative infection hours.
[w] Final estimation of symptomatic or defoliated leaflets.
[x] Final estimation of defoliated leaflets.
[y] Area under the disease progress curve.
[z] Means within in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Table 4. Effects of spray programs with chlorothalonil (1.26 kg/ha) on yield of the spanish peanut cultivar Spanco and the runner cultivars Florunner and Okrun in 1991 to 1993

	Yield (kg/ha)[y]									
	Spanco			Florunner				Okrun		
Spray program[y]	1991	1992	1993	1991	1992	1993	Mean	1992	1993	Mean
14-day	4,679 a[z]	4,984 a	4,516 ab	4,699	4,373	3,946	4,340 a	3,204	3,169	3,187 c
PSC	4,130 a	3,312 b	3,869 cd	4,780	4,048	3,967	4,265 a	3,611	3,531	3,571 abc
0.85*PSC	...	3,356 b	3,544 d	...	4,140	4,093	4,116 a	3,662	3,653	3,658 ab
AU-Pnuts	4,882 a	...	4,589 a	4,598	...	4,292	4,445 a	...	3,381	3,381 bc
VA-36	4,271 a	4,536 a	4,496 ab	4,740	4,475	4,264	4,493 a	3,407	3,829	3,618 ab
VA-48	4,556 a	4,496 a	4,138 bc	4,597	4,353	4,191	4,380 a	3,601	3,499	3,550 abc
VA-60	...	4,638 a	4,138 bc	...	4,221	4,325	4,273 a	3,784	3,901	3,843 a
VA-72	4,475 a	3,580 b	3,828 cd	4,516	4,190	4,357	4,355 a	3,285	3,535	3,410 bc
VA-96	4,536 a	3,865 b	3,910 cd	4,739	4,261	3,853	4,285 a	3,641	4,044	3,843 a
Control	4,537 a	3,357 b	3,523 d	4,435	4,191	4,056	4,227 a	3,550	3,271	3,411 bc

[y] PSC = Parvin, Smith, and Crosby program; 0.85*PSC = modified Parvin, Smith, and Crosby program where the daily infection indices were reduced by 0.85 for cultivars with partial resistance; AU-Pnuts program with spray thresholds of 2 rain events in 1990 and 3 rain events in 1993; VA-*n* = Virginia program with spray thresholds of *n* cumulative infection hours.
[z] Means within in a column followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

of leaf spot or AUDPC in 1992 or 1993. The significant effect of spray programs on yields of Okrun resulted from Sclerotinia blight. Yield for the 14-day program, which had among the highest levels of Sclerotinia blight, was less than that for the VA-36, VA-60, VA-96, and 0.85*PSC programs. Yields for the VA-60 and VA-96 programs, which had among the lowest levels of Sclerotinia blight, were greater than those for the AU-Pnuts and VA-72 programs.

DISCUSSION

Several weather-based advisory programs have been developed for improving the efficiency of fungicide usage to control early leaf spot (3,5,11,18,19). In the development and testing of these programs, it has been apparent that the timing of sprays is more important than the number of applications (5,21). All of the advisory programs evaluated in this study reduced the number of sprays compared with a standard 14-day schedule, resulting in less inputs for leaf spot control. However, these programs differed in the level of spray savings, in disease control, and in maintaining yield.

The VA program provided the most consistent control of leaf spot over the 3 years and was superior to the PSC program. The most efficient spray thresholds of the VA program varied with cultivar. When the VA-36 program was used on the susceptible cultivar Spanco, the average final incidence of leaf spot over years (27%) was nearly within the range of 20 to 25% often cited as a safe level in commercial production (3,24). The average incidence of leaf spot increased from 45 to 76% when thresholds were extended from 48 to 96 h. However, yield loss in Spanco was averted when spray thresholds of the VA program were as high as 60 h. The apparent partial resistance of the runner cultivars permitted an increase in the spray threshold above 36 h while maintaining good disease control. The average incidence of leaf spot for thresholds of 36 to 60 h ranged from 6 to 26% for Florunner and 8 to 20% for Okrun. It was not possible to identify the maximum threshold for yield maintenance in the runner cultivars because of the minimal impact of leaf spot on their yield.

Control of leaf spot with the VA program was not always equivalent to the 14-day program as reported previously (5). In this study, trials were conducted with a continuous cropping history of peanut, which promotes increased initial inoculum and earlier disease onset compared with rotated fields (17). Differences in cultivar reaction to leaf spot also may have contributed to the results. The Virginia cultivar Florigiant was used in the development of the VA program (5). Leaf spot incidence in the field has been reported to be lower on Florigiant than on Florunner (10). Different infection thresholds may contribute to the disease reaction of cultivars. In dew chamber studies, infection was observed following intermittent 12-h periods of RH ≥ 95% that totaled 24 h for Spanco, 36 h for Florunner, and 48 h for Okrun (27). The flexibility of VA program permits adjustments to compensate for different cultivar reactions to early leaf spot. It appears that lower spray thresholds are required to improve disease control for Spanish cultivars.

Control of leaf spot with the AU-Pnuts program equaled the most effective thresholds of the VA programs, but was less efficient because more sprays were required. Two different versions of AU-Pnuts were tested because the 7/2 program appeared to be too conservative in 1991 when five sprays were applied in a year with relatively low disease incidence. In examining weather data in 1991 and 1992, the 7/3 program also would have recommended five sprays each year had it been tested, more than the VA-36 and VA-48 programs. Of the rules that trigger sprays with AU-Pnuts, rain events from irrigation were counted in one spray decision in both 1991 and 1993. The rules involving precipitation probability did not influence spray decisions in either 1991 or 1993. Five-day averages of precipitation probability ≥20% were not met in either year and may not be important in Oklahoma. Because 70% of the peanut production in Oklahoma is irrigated, it is possible that excluding irrigations from rain event counts may make the program more efficient. The contribution of irrigation to favorable infection periods in Oklahoma may be less than for rainfall, as previously discussed (7). Efficiency of the AU-Pnuts program also may be lower than that of the VA program because AU-Pnuts was developed primarily for late leaf spot, which is more difficult to control than early leaf spot (25).

The failure of the PSC program to recommend needed sprays was surprising in light of its successful use previously in Oklahoma with the same cultivars as in this study (7). The 1.2-m height of T and RH measurement used previously (7) and in this study differed from the ground-level measurements used in the development of the PSC nomogram (12) and in program deployment in North Carolina (3). The higher measurement height may have underestimated the high humidity periods in the plant canopy. The 1.2-m height was chosen to measure ambient weather rather than canopy microclimate. It is our experience that prevailing weather has a great influence on the severity of leaf spot epidemics in a given year. It also was assumed that weather rather than microclimate measurements would be better suited for providing advisories to growers on a county-wide rather than site-specific basis. In lieu of any reports on the influence of measurement height on performance of these advisory programs, it is probable that the 1.2-m measurements approximated conditions in the canopy. In the development of the VA program (5), T and RH thresholds were based on studies of the biological response of *C. arachidicola* to T and RH under controlled conditions (1,2). The VA program was effective in this study when the 1.2-m measurements were used.

It is possible that flaws in the logic of the PSC program became evident during this study. Spray decisions in the PSC program rely either entirely, as in the simplified version used in this study (3), or primarily, as in the original version (19), on 2-day periods. Moderately favorable infections indices for two consecutive days that do not exceed the spray threshold or even highly favorable indices separated by one or more unfavorable days do not result in a spray recommendation and are not considered in future spray decisions. The ability of conidia to tolerate moderately unfavorable conditions and subsequently germinate and infect plants during intermittent favorable periods is well documented for *C. arachidicola* (1,2) and other fungal pathogens. In contrast, the VA program accumulates even brief favorable periods in recommending sprays. Secondly, the use of minimum T as the input variable may not accurately reflect conditions during the entire period of RH ≥95%. In the PSC nomogram, the arrangement of infection indices is curvilinear with respect to the T and RH axes (3,13,19). Therefore, as few as 4 h of RH ≥95% are needed for a favorable index when minimum T ranges from 23.3 to 25°C, but 13 h or more are needed from 17.2 to 18.3°C. A brief drop in T during a long humidity period may negate an otherwise favorable infection period. Thirdly, the PSC nomogram may not accurately reflect all of the conditions favorable for leaf spot development. At minimum T from 16.1 to 16.7°C, which permits conidial germination and germ tube growth (1), a favorable index is not possible.

Periods of RH ≥95% were not limiting during this study as evidenced by the numerous VA infection hours accumulated each year. Both low minimum T and the occurrence of interrupted periods of RH ≥95% appeared to contribute to the failure of the PSC program. During a critical 10-day period in July 1992, high PSC infection indices were separated by one or more days with low indices. During that same period, 57 VA infection hours were accumulated and needed sprays were recommended. In 1992 and 1993, there were five and eight 3-day periods, respectively, when no favorable PSC indices occurred because of low minimum T, yet over 20 VA infection hours were accumulated during each period. T was 2.0, 0.8, and 3.8°C below normal in June, July, and August 1992, respectively. However, T was near normal in 1993, suggesting that unusual weather may not be entirely responsible for the poor performance of the PSC program.

Improving the reliability of the PSC program may require adjustment of the PSC nomogram to more accurately reflect the range of T favorable for conidial germination and germ tube growth, the use of average rather than minimum T to reflect more accurately the favorableness of an RH period (1), or consideration of a longer time period in making spray decisions.

This study demonstrated the superiority of the VA program over other advisory programs for control of early leaf spot in Oklahoma. Results from this study are being applied with the goal of improving the efficiency of fungicide use. Advisories have been successfully issued to growers in seven counties in Oklahoma since 1993 using the VA-36 program for Spanish and the VA-48 program for runner cultivars. However, the recent registration of the systemic fungicide tebuconazole has somewhat limited the utility of leaf spot advisories in Oklahoma. Superior control of leaf spot with tebuconazole using the PSC program in Oklahoma has been observed (7). Tebuconazole use also should improve performance of the VA program because of its postinfection activity. However, the optimum timing of tebuconazole, which controls Southern blight caused by *Sclerotium rolfsii* Sacc. and limb rot caused by *Rhizoctonia solani* Kühn as well as early and late leaf spots, may not coincide with advisory applications for early leaf spot. The labeled use pattern for tebuconazole for control of Southern blight, an important soilborne disease in Oklahoma, is a four-spray calendar program during mid-season. Many growers have adopted this program for Southern blight while also obtaining excellent control of leaf spot. When the AU-Pnuts program, which recommended from five to eight sprays per season in Georgia, was used, substitution of tebuconazole for chlorothalonil effectively controlled early and late leaf spots as well as Southern blight (4). Information is needed on the efficacy of integrating tebuconazole sprays for multiple disease control into the VA program, which may only recommend two or three sprays per year in Oklahoma.

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