Impact of Application Rate and Treatment Interval on the Efficacy of Pyraclostrobin in Fungicide Programs for the Control of Early Leaf Spot and Southern Stem Rot on Peanut[1]

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ABSTRACT

In 1999, 2000, and 2001, efficacy of the strobilurin fungicide pyraclostrobin (Headline F500) for the control of early leaf spot and southern stem rot was compared to that of standard fungicide programs on peanut cv. Georgia Green produced under irrigation. When applied at 2 wk intervals in 1999 and 2001, programs that included pyraclostrobin at rates ranging from 0.08 to 0.22 kg ai/ha gave better control of early leaf spot than the recommended season-long chlorothalonil program and were at least as efficacious against this disease as tebuconazole and azoxystrobin. The level of early leaf spot control provided by 0.08 to 0.16 kg ai/ha of pyraclostrobin applied every 3 wk and by chlorothalonil at the recommended 2 wk interval was similar. In all 3 yr, incidence of southern stem rot on peanut treated with pyraclostrobin alone, tank-mixed with flutolanil, or alternated with tebuconazole was significantly below damage levels recorded in plots treated with chlorothalonil alone and was usually comparable to the level of disease control obtained with recommended tebuconazole, flutolanil, or azoxystrobin programs. Compared to chlorothalonil alone, yields of the pyraclostrobin-treated peanuts were significantly greater in 2000 and 2001 and generally did not significantly differ from those yields recorded with the tebuconazole, flutolanil, or azoxystrobin programs. While pyraclostrobin often gave similar southern stem rot control over a range of treatment intervals, the most consistent yield gains were obtained when this fungicide was applied every 2 wk.

Key Words: Abound 2SC, *Arachis hypogaea*, Bravo Ultrex, *Cercospora archidicola,* Folicur 3.6F, Headline F500, Moncut 70DF, *Sclerotium rolfsii,* strobilurin fungicide.

Peanut (*Arachis hypogaea* L.) is an important agronomic crop in Alabama, Florida, and Georgia. The value of Alabama's 190,000-acre peanut crop has exceeded $120 million annually in recent years. However, the diseases early leaf spot caused by the fungus *Cercospora arachidicola* Hori, late leaf spot caused by the fungus *Cercosporidium personatum* Berk. & Curtis, and southern stem rot (SSR) caused by the soil-borne fungus *Sclerotium rolfsii* Sacc. may greatly reduce the profitability due to lower yields and poorer seed quality (9). Fungicides applied for the control of the above diseases account for a sizable percentage of the peanut production budget on many farms.

Early leaf spot and late leaf spot are potentially the most destructive diseases on peanut across the Southeast. Currently, early leaf spot is the more common and damaging of the two leaf spot diseases on Alabama's peanut crop. Prior to the introduction of efficacious leaf spot fungicides, harvesting operations started as soon as the crop was defoliated and often before the pods fully matured. Although losses due to early and late leaf spot are a small percentage of Alabama's total peanut crop, failure to control these diseases with timely fungicide applications in isolated fields may reduce expected yields by 50% (15).

In Alabama, occurrence of SSR increases as the number of years between peanut crops decreases, and fields cropped to peanut every other year or those in continuous peanut production typically suffer the heaviest losses (4). In addition, peanut yields sharply decline as the incidence of SSR increases (4). In isolated fields in Alabama, SSR-related pod losses can exceed 40% or more of anticipated yield (3). Crop rotation, the most effective weapon against SSR, is not widely used by peanut producers due to the absence of profitable alternative crops, the lack of fresh tillable land in the major peanut-producing Ala-

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bama counties, and poorly structured farm programs (3, 12). When used according to label directions, fungicide programs that include applications of tebuconazole (Folicur 3.6F), azoxystrobin (Abound 2.08SC), or flutolanil (Moncut 70DF) typically reduce SSR incidence by 60 to 70% and may increase pod yield by 990 to 1540 kg/ha (10). Although the cv. Southern Runner, C-99R, and Georgia Green are less sensitive than Florunner to SSR, none have demonstrated a high level of resistance to this disease (4, 11). When SSR was controlled on these cultivars, significant yield gains have been obtained consistently with fungicides such as tebuconazole, azoxystrobin, or flutolanil (5, 11).

Pyraclostrobin (Headline F500, BASF, Research Triangle Park, NC) is a new broad-spectrum strobilurin fungicide that is currently being reviewed for registration by the Environmental Protection Agency for use on peanut (1). This fungicide is absorbed rapidly by leaf tissues and has demonstrated translaminar movement through layers of the leaf but is not redistributed throughout the plant like a true systemic fungicide (2, 16). Selected rates of pyraclostrobin have superior activity against early and late leaf spot diseases, as well as SSR (13). Most notably, the level of leaf spot control obtained with pyraclostrobin applied at 3 wk intervals was comparable or better than that obtained with other recommended fungicides applied at 2 wk intervals (7, 13). The extended residual activity of pyraclostrobin against leaf spot diseases provides an opportunity to reduce the number of fungicide applications typically required for effective season-long disease control on peanut (13). The objective of this study was to assess the impact of application rate and treatment interval on the efficacy of pyraclostrobin as a component in a fungicide program for the control of early leaf spot and southern stem rot on peanut.

Materials and Methods

In 1999, 2000, and 2001, peanut cv. Georgia Green was planted at 17 seed/m of row in an irrigated field at the Wiregrass Res. and Ext. Center, Headland, AL. Planting dates were 18 May 1999, 19 May 2000, and 17 May 2001. Cropping histories of test areas were a minimum of 10 yr in a peanut-cotton-peanut or peanut-corn-peanut rotation. The soil type was a Dothan fine sandy loam (fine-loamy, siliceous, thermic Plinthic Palendults) with less than 1% organic matter. The test areas were infested heavily with *S. rolfsii* and significant SSR damage had been observed on previous peanut crops.

Plot areas were prepared for planting with a moldboard plow and disk harrow. Optimal soil fertility and pH were maintained according to the results of a soil fertility assay conducted by the Soil Lab. at Auburn Univ. Broadleaf and grass weeds were controlled by lightly incorporating a pre-emergence application of a tank-mixture of 0.85 kg ai/ha of ethalfluralin (Sonalan HFP, Dow AgroSciences, Indianapolis, IN) and 1.6 kg ai/ha of metolachlor (Dual Magnum, Syngenta Crop Protection, Greensboro, NC). At 5 d after seedling emergence (ground cracking), a single broadcast application of paraquat (Gramoxone Max, Syngenta Crop Protection, Greensboro, NC) at 0.138 kg ai/ha, or an equivalent rate of another formulation of this herbicide plus 0.27 kg ai/ha of 2,4 DB (Butoxone 200) and 0.55 kg ai/ha of bentazon (Basagran 4EC, BASF, Research Triangle Park, NC) were made to control weeds. At planting, aldicarb (Temik 15G, Aventis CropScience, Research Triangle Park, NC) at a rate of 0.83 kg ai/ha was applied in-furrow to control thrips. For the remainder of the production season, escape weeds were pulled by hand. Plots were irrigated with a center pivot system with 5.0 cm of water on 31 July (73 DAP), 8 Aug. (80 DAP), 21 Aug. (93 DAP), and 1 Sept. 1999 (104 DAP); on 7 June (19 DAP), 15 June (27 DAP), 28 June (40 DAP), 22 July (64 DAP), 12 Aug. (85 DAP), 18 Aug. (91 DAP), and 29 Aug. 2000 (102 DAP); and 16 July 2001 (60 DAP).

The experimental design was a randomized complete block with six replications. Individual plots consisted of four 9.2-m rows spaced 0.9 m apart. Broadcast applications of all fungicides were made with a tractor-mounted, four-row boom sprayer with three TX-8 hollow cone nozzles per row that were calibrated to deliver an approximate spray volume of 140 L/ha.

In 1999, chlorothalonil (Bravo Ultrex, Syngenta Crop Protection, Greensboro, NC) at 1.26 kg ai/ha was applied first in all programs, second in standard tebuconazole program, and once or twice at the end of the 2 wk tebuconazole and pyraclostrobin programs, respectively (Table 1). A full-season seven-spray program of the 1.26 kg ai/ha rate of chlorothalonil was included. Four applications of 0.14 kg ai/ha pyraclostrobin and 0.23 kg ai/ha tebuconazole (Folicur 3.6F, Bayer Crop Protection, Kansas City, MO) were made at 2 and 3 wk intervals and three applications were made every 4 wk. Four applications of 0.08 kg ai/ha pyraclostrobin were made at 2 and 3 wk intervals. Fungicide applications were scheduled at 2 wk intervals on 1 = 14 June (27 DAP), 2 = 29 June (42 DAP), 3 = 12 July (64 DAP), 4 = 27 July (79 DAP), 5 = 10 Aug. (93 DAP), 6 = 23 Aug. (106 DAP), and 7 = 7 Sept. (121 DAP); at 3-wk intervals on 1 = 14 June (27 DAP), 2 = 2 July (46 DAP), 3 = 27 July (79 DAP), 4 = 16 Aug. (99 DAP), and 5 = 7 Sept. (121 DAP); and at 4-wk intervals on 1 = 14 June (27 DAP), 2 = 12 July (64 DAP), 3 = 10 Aug. (93 DAP), and 4 = 7 Sept. 1999 (121 DAP). A total of seven, five, and four fungicide applications were made to the plots treated on a 2, 3, and 4 wk schedule, respectively.

For the 2000 trial, all programs consisted of seven applications of selected fungicides made at 2 wk intervals (Table 2). Pyraclostrobin was applied in four consecutive applications at 0.22 or 0.27 kg ai/ha, as well as alternated at 0.16 or 0.22 kg ai/ha with tebuconazole at 0.23 kg ai/ha or with 0.66 kg ai/ha flutolanil (Moncut 50W, Gowan Co., Yuma, AZ) + 1.26 kg ai/ha chlorothalonil. Standard treatment programs included 1.26 kg ai/ha chlorothalonil season-long, a four-spray block of tebuconazole at 0.23 kg ai/ha, and two applications of azoxystrobin (Abound 2.08SC, Syngenta Crop Protection, Greensboro, NC) at 0.32 kg ai/ha. Chlorothalonil at 1.26 kg ai/ha filled out the remaining treatment slots in all of the above programs. Treatment dates were 1 = 19 June (31 DAP), 2 = 30 June (42 DAP), 3 = 17 July (59 DAP), 4 = 31 July (73 DAP), 5 = 14 Aug. (87 DAP), 6 = 28 Aug. (101 DAP), and 7 = 11 Sept. 2000 (111 DAP).

In 2001, fungicides were applied at either 2 or 3 wk intervals (Table 3). Three or four applications of pyraclostrobin at 0.11 kg ai/ha were made at 2 wk intervals and at 0.16 kg ai/ha every 3 wk. Pyraclostrobin at 0.22 kg ai/ha plus 0.85 kg ai/ha of flutolanil (Moncut 70DF, Gowan Co., Yuma, AZ) was applied every 2 wk. In addition, applications of a tank-mixture of 0.22 and 0.43 kg ai/ha of pyraclostrobin and flutolanil, respectively, were made at 3 wk intervals. Chlorothalonil at 1.26 kg ai/ha filled out the remaining treatment slots in the above pyraclostrobin programs. Three applications of pyraclostrobin at 0.11 kg ai/ha were alternated with two treatments of 1.26 kg ai/ha of chlorothalonil + 0.85 kg ai/ha of flutolanil and bracketed at the beginning and end of the program by an application of 1.26 g ai/ha chlorothalonil. The treatment interval for the above program was 2 wk. Programs consisting of three or four applications of 0.23 kg ai/ha tebuconazole, which were made at

Table 1. Impact of application rate and treatment interval on fungicide efficacy for the control of early leaf spot and southern stem rot of peanut at the Wiregrass Res. and Ext. Center, 1999.

	Application[a]					
Fungicide program	Rate	Sequence[a]	Interval	Early leaf spot[b]	SSR	Pod yield
	kg ai/ha		wk		loci/30 m[c]	kg/ha
Chlorothalonil	1.26	1 to 7	2	5.0[d]	35.3[d]	3377[d]
Chlorothalonil pyraclostrobin	1.26 0.08	1,6,7 2 to 5	2	3.0	26.7	3685
Chlorothalonil pyraclostrobin	1.26 0.14	1,6,7 2 to 5	2	2.8	19.4	3925
Chlorothalonil tebuconazole	1.26 0.23	1,2,7 3 to 6	2	4.0	18.3	4826
Chlorothalonil pyraclostrobin	1.26 0.08	1 2 to 5	3	4.0	25.6	3434
Chlorothalonil pyraclostrobin	1.26 0.14	1 2 to 5	3	4.5	23.2	3913
Chlorothalonil tebuconazole	1.26 0.23	1 2 to 5	3	4.5	14.3	4450
Chlorothalonil pyraclostrobin	1.26 0.14	1 2 to 4	4	3.8	23.5	4369
Chlorothalonil tebuconazole	1.26 0.23	1 2 to 4	4	6.3[d]	25.6	3526
LSD (P = 0.05)	--	--	--	1.6	8.1	637

[a]Mean comparison in each column was according to Fisher's Protect Least Significant Difference (LSD) test ($P \leq 0.05$).
[b]Application sequence refers to the placement of a treatment application(s) in a fungicide program.
[c]On 23 Sept. (129 DAP), early leaf spot severity was assessed using the Florida leaf spot scoring system.
[d]Southern stem rot (SSR) incidence was estimated immediately after plot inversion on 29 Sept. (135 DAP).

2 and 3 wk intervals, were included also. Depending on treatment interval, one or three applications of chlorothalonil at 1.26 kg ai/ha completed the treatment list in both of the above tebuconazole programs. Two midsummer applications of azoxystrobin at 0.34 kg ai/ha were alternated with 1.26 kg ai/ha of chlorothalonil on a 2 wk schedule. The remaining three treatments in the above seven application program were chlorothalonil at 1.26 kg ai/ha. A full-season program with seven treatments of chlorothalonil at 1.26 kg ai/ha applied at 2 wk intervals was included. Application dates for fungicides applied at 2 wk intervals were 1 = 19 June (33 DAP), 2 = 3 July (47 DAP), 3 = 18 July (62 DAP), 4 = 1 Aug. (76 DAP), 5 = 16 Aug. (91 DAP), 6 = 28 Aug. (103 DAP), and 7 = 11 Sept. (113 DAP); and at 3-wk intervals on 1 = 19 June (33 DAP), 2 = 10 July (54 DAP), 3 = 31 July (75 DAP), 4 = 21 Aug. (96 DAP), and 5 = 11 Sept. 2001 (113 DAP). Seven and five fungicide applications were made to the plots treated at 2 and 3 wk intervals, respectively.

Early leaf spot was rated using the Florida leaf spot scoring system (6). The hull scrape method of estimating pod maturity was used to determine the optimum digging date (17). Incidence of SSR in the windrow was determined immediately after the peanuts were inverted by counting the number of disease loci where one locus was defined as the number of consecutive symptomatic plant(s) in ≤ 30 cm of row (14). Plots were dug with a two-row digger/inverter on 29 Sept. 1999 (131 DAP), 10 Oct. 2000 (148 DAP), and 5 Oct. 2001 (141 DAP). Peanuts were harvested with a two-row combine approximately 3 to 5 d after plot inversion. Pods were dried to 7% moisture and weighed.

In each study, analysis of variance was conducted and significance of treatment effects was compared with Fisher's least significant difference (LSD) tests at the $P \leq 0.05$ level. In addition, effects on disease levels and yield due to application intervals in the 1999 and 2001 trials were tested with single degree contrasts. Single degree contrasts also were used to

Table 2. Efficacy of selected rates of fungicides or combination programs for the control of early leaf spot diseases and southern stem rot of peanut at the Wiregrass Research and Extension Center, 2000.

Fungicide Prog.	Appl. rate	Sequence[a]	Early leaf spot[b]	SSR	Yield
	kg ai/ha			loci/ 30 m[c]	kg/ha
chlorothalonil	1.26	1 to 7	2.2[d]	15.1	3035
chlorothalonil	1.26	1,6,7	2.3	10.5	4233
pyraclostrobin	0.22	2 to 5			
chlorothalonil	1.26	1,6,7	2.2	8.1	4166
pyraclostrobin	0.27	2 to 5			
chlorothalonil	1.26	1,6,7	2.5	9.7	4410
pyraclostrobin	0.16	2,4			
tebuconazole	0.23	3,5			
chlorothalonil	1.26	1,6,7	2.3	9.7	4270
pyraclostrobin	0.22	2,4			
tebuconazole	0.23	3,5			
chlorothalonil	1.26	1,6,7	2.8	7.5	4046
pyraclostrobin	0.22	2,4			
chlorothalonil +	1.26 +	3,5			
flutolanil	0.66				
chlorothalonil	1.26	1,6,7	2.5	10.0	4270
tebuconazole	0.23	2 to 5			
chlorothalonil	1.26	1,2,4,6,7	2.7	10.5	3848
azoxystrobin	0.34	3,5			
chlorothalonil	1.26	1,2,4,6,7	3.0	10.9	4206
chlorothalonil +	1.26 +	3,5			
flutolanil	0.66				
LSD ($P \leq 0.05$)	--	--	0.5	3.6	702

[a]Application sequence refers to the placement of a treatment application(s) in a fungicide program.
[b]On 26 Sept. (131 DAP), early leaf spot severity was assessed using the Florida leaf spot scoring system.
[c]Southern stem rot (SSR) incidence was logged immediately after plot inversion on 10 Oct. (148 DAP).
[d]Mean comparison in each column was according to Fisher's Protect Least Significant Difference (LSD) test ($P \leq 0.05$).

determine the effect of pyraclostrobin in a fungicide program versus that for tebuconazole, azoxystrobin, flutolanil, and chlorothalonil, as well as the impact of application rate and treatment interval on the efficacy of pyraclostrobin for the control of early leaf spot and SSR and on peanut yield. The significance level used in tests was $P \leq 0.05$, unless otherwise noted.

Results

When applied at 2 wk intervals, pyraclostrobin at 0.08 kg ai/ha and 0.14 kg ai/ha with chlorothalonil gave better control of early leaf spot in 1999 than chlorothalonil alone (Table 1). At both rates of pyraclostrobin, symptoms were limited to light spotting of the leaves in the lower and upper canopy, compared to moderate leaf spotting and light defoliation on the peanuts treated season-long with chlorothalonil. Also, the level of

Table 3. Effect of fungicide rate and treatment interval on the control of early leaf spot and southern stem rot of peanut at the Wiregrass Research and Extension Center, 2001.

Fungicide Prog.	Rate	Application Sequence[a]	Int.	Early leaf spot[b]	SSR	Yield
	kg ai/ha		wk		loci/ 30m[c]	kg/ha
chlorothalonil	1.26	1 to 7	2	4.5[d]	26.7	4297
chlorothalonil	0.85	1,2,4,6,7	2	4.8	12.5	4555
chlorothalonil +	1.26+					
flutolanil	1.26	3,5				
chlorothalonil	1.26	1,2,4,6,7	2	3.8	15.9	5118
azoxystrobin	0.34	3,5				
chlorothalonil	1.26	1,6,7	2	3.0	18.3	4973
pyraclostrobin	0.11	2,4,6				
chlorothalonil	1.26	1,3,5,7	2	3.3	14.1	5385
pyraclostrobin	0.11	2,4,6				
chlorothalonil	1.26	1,6,7	2	3.7	12.5	5042
tebuconazole	0.23	2 to 5				
chlorothalonil	1.26	1,2,4,6,7	2	3.0	8.9	5513
pyraclostrobin +	0.22+	3,5				
flutolanil	0.85					
chlorothalonil	1.26	1	3	4.2	12.5	4677
pyraclostrobin	0.16	2 to 4				
chlorothalonil	1.26	1	3	4.8	17.8	4129
tebuconazole	0.23	2 to 4				
chlorothalonil	1.26	1	3	3.8	11.7	4662
pyraclostrobin +	0.22+	2 to 4				
flutolanil	0.43					
chlorothalonil	1.26	1,7	2	3.0	10.5	5612
pyraclostrobin	0.11	2,4,6				
chlorothalonil +	1.26+					
flutolanil	0.85	3,5				
LSD ($P \leq 0.05$)	--	--	--	0.4	6.5	561

[a]Application sequence refers to the placement of a treatment application(s) in a fungicide program.
[b]On 20 Sep. (126 DAP), early leaf spot severity was assessed using the Florida leaf spot scoring system.
[c]Southern stem rot (SSR) incidence was logged immediately after plot inversion on 5 Oct. (141 DAP).
[d]Mean comparison in each column was according to Fisher's Protect Least Significant Difference (LSD) test ($P \leq 0.05$).

disease control provided by 0.08 and 0.14 kg ai/ha pyraclostrobin programs was similar to that given by the recommended tebuconazole program. Surprisingly, the level of early leaf spot control provided by the 0.08 g ai/ha pyraclostrobin program did not significantly diminish as the interval between applications was lengthened from 2 to 3 wk but did decline at 0.14 kg ai/ha. Early leaf spot severity on peanuts treated with 0.28 kg ai/ha pyraclostrobin at 3 and 4 wk intervals did not significantly differ. When applied at 3 wk intervals, efficacy of the tebuconazole program for the control of early leaf spot did not decline compared to applications at 2 wk intervals, but a significant increase in leaf spotting and defoliation was recorded at the 4 wk treatment interval with this fungicide.

In 1999, significant reductions in the incidence of SSR were obtained with all pyraclostrobin + chlorothalonil and tebuconazole + chlorothalonil programs, compared to chlorothalonil alone (Table 1). Pyraclostrobin programs were slightly less effective than tebuconazole in reducing SSR incidence at the 2 and 3 wk intervals but gave similar control when applied at 4 wk intervals. A similar level of SSR control was obtained with both rates of pyraclostrobin at 2 and 3 wk treatment intervals. When applied at 2 and 3 wk intervals, the recommended tebuconazole program also gave better SSR control than the same fungicide applied at 4 wk intervals.

Yields in 1999 of the chlorothalonil/pyraclostrobin programs were not significantly higher than those treated season long with chlorothalonil alone and were below the yields recorded for the tebuconazole programs (Table 1). Except for the 0.14 kg ai/ha rate applied at 4 wk intervals, yields of the pyraclostrobin treatments were similar to those obtained with the standard seven-spray chlorothalonil program. In contrast, significant yield gains were obtained with tebuconazole applied at 2 and 3 wk intervals. When applied at 2 and 3 wk intervals, tebuconazole-treated peanuts yielded significantly higher than the peanuts sprayed with 0.08 kg ai/ha pyraclostrobin with the same treatment intervals. At a 2 wk interval, yield response to the tebuconazole treatments was superior to that obtained with 0.14 kg ai/ha pyraclostrobin but was similar at the 3 wk treatment interval. When applied at 4 wk intervals, yield of the tebuconazole-treated peanuts was significantly lower than for those receiving applications of pyraclostrobin.

The 2000 growing season was among the driest ever recorded at the Wiregrass Res. Educ. Center. Rainfall total for April through August of 14.5 cm was significantly less than the historical 62.2 cm average for that 5 mo period. As a result of the extended drought, overall pressure from early leaf spot was exceptionally low. No symptoms of late leaf spot were noted. The incidence of SSR also was lower in 2000 than in the previous year.

Although significant differences in early leaf spot severity were noted among the fungicide programs, symptoms, as indicated by disease ratings of 2.2 to 3.0, were restricted to light spotting in the lower and sometimes upper plant canopy (Table 2). The chlorothalonil + flutolanil program had a significantly higher early leaf spot rating than did the peanuts receiving a block of four applications of pyraclostrobin at 0.27 kg ai/ha or twice with 0.22 kg ai/ha pyraclostrobin and 0.23 kg ai/ha tebuconazole. Otherwise, early leaf spot ratings for all remaining fungicide programs were similar.

When compared with chlorothalonil alone, all fungicides significantly reduced SSR incidence (Table 2). Four applications of pyraclostrobin at 0.22 and 0.27 kg ai/ha were as effective in controlling SSR on peanut as the programs that included recommended rates of tebuconazole, azoxystrobin, and chlorothalonil + flutolanil. Also, programs where two applications of 0.16 or 0.22 kg ai/ha pyraclostrobin were alternated with tebuconazole or chlorothalonil + flutolanil gave the same level of SSR control as programs that included four applications of the pyraclostrobin at 0.22 and 0.27 kg ai/ha.

The levels of SSR control given by pyraclostrobin alone or when alternated with tebuconazole, azoxystrobin, or flutolanil were reflected in significantly higher yields than those obtained with chlorothalonil alone (Table 2). Yield in plots treated with both rates of pyraclostrobin alone or when alternated with tebuconazole or flutolanil did not significantly differ. In addition, yield gains observed in the pyraclostrobin-treated plots were similar to those that were obtained with the recommended tebuconazole, azoxystrobin, and flutolanil programs.

While rainfall totals for April and May 2001 were well below average, precipitation levels for the remainder of the production season were sufficient for high peanut yields and disease development. As indicated by a disease rating of 4.5, moderate leaf spotting and light defoliation attributed to early leaf spot were noted on the peanuts treated season-long with chlorothalonil alone (Table 3). When compared with the standard seven-treatment chlorothalonil program and chlorothalonil + flutolanil, three or four applications of pyraclostrobin at 0.11 kg ai/ha, pyraclostrobin + flutolanil, and 0.11 kg ai/ha pyraclostrobin alternated with chlorothalonil + flutolanil applied at 2 wk intervals gave superior early leaf spot control. All three pyraclostrobin programs gave better or the same level of leaf spot control as was recorded with the recommended azoxystrobin or tebuconazole programs. When applied at 3 wk intervals, 0.16 kg ai/ha pyraclostrobin and tebuconazole programs were as effective in controlling early leaf spot as the standard chlorothalonil program but significantly better disease control was obtained with the pyraclostrobin + flutolanil program.

When compared to chlorothalonil alone, significant reductions in SSR incidence were noted in the plots treated with pyraclostrobin alone, with a tank mixed with flutolanil, or when alternated with flutolanil, tebuconazole, azoxystrobin, or chlorothalonil + flutolanil (Table 3). Three or four applications of pyraclostrobin made at 2 wk intervals controlled SSR as effectively as recommended rates of chlorothalonil + flutolanil, azoxystrobin, and tebuconazole. Programs that included two applications of pyraclostrobin + flutolanil and the alternation of pyraclostrobin and chlorothalonil + flutolanil gave better SSR control than four applications but not three applications of 0.11 kg ai/ha pyraclostrobin. Incidence of SSR in the plots receiving three applications of 0.16 kg ai/ha pyraclostrobin at 3 wk intervals did not differ significantly from that of peanuts treated with the same fungicide at 2 wk intervals. Also, no decline in the level of SSR control was noted when the treatment interval with tebuconazole was increased to 3 wk and the number of applications reduced from four to three.

When compared with chlorothalonil alone, yield was significantly higher in the plots treated at 2 wk intervals with three or four pyraclostrobin applications. Significantly higher yields were noted also in plots treated with azoxystrobin, tebuconazole, pyraclostrobin + flutolanil, and alternation of pyraclostrobin with chlorothalonil + flutolanil (Table 3). Yield gains observed where 0.11 kg ai/ha pyraclostrobin was alternated with chlorothalonil + flutolanil were significantly above those obtained with four but not three applications of the same rate of pyraclostrobin. Yield increases, which were reported for the three or four application pyraclostrobin programs, were similar to those noted with the recommended azoxystrobin and tebuconazole programs. Peanuts receiving three pyraclostrobin applications at 2 wk intervals had significantly higher yields than those treated at the same schedule with chlorothalonil + flutolanil.

On a 3 wk treatment schedule, yield of peanuts treated with three applications of 0.16 kg ai/ha pyraclostrobin was significantly lower than the yield reported for three applications of the lower rate of the same fungicide applied on a 2 wk schedule (Table 3). Despite similar SSR control, peanuts treated at 2 wk intervals with tebuconazole or pyraclostrobin + flutolanil yielded significantly higher than those treated with the same fungicide or a pyraclostrobin tank-mixture on a 3 wk schedule.

In both 1999 and 2001, single degree of contrast analysis indicated that 2 wk intervals between fungicide applications allowed significantly less early leaf spot development than did longer treatment intervals (Table 4). Application interval had no significant impact on SSR incidence or on yield in 1999. In 2001, yield was significantly improved when fungicide applications were made at 2 wk rather than at 3 wk intervals. Although optimum early leaf spot control was maintained in 1999 when 0.14 kg ai/ha pyraclostrobin was applied at 2 wk intervals, contrast analyses showed that SSR control and yield did not decline when application intervals were lengthened to 3 wk. When pyraclostrobin at 0.11 kg ai/ha was applied at 2 wk intervals in 2001, yield was significantly higher compared to the 0.16 kg ai/ha rate of the same fungicide applied every 3 wk.

A single degree of contrast analyses on 1999 and 2001 data suggest that control strategies involving applications of pyraclostrobin gave significantly better early leaf spot control than those fungicide programs that included tebuconazole or azoxystrobin ($P \leq 0.10$) (Table 4). In 1999, pyraclostrobin provided significantly less SSR control and lower yield gains than did the tebuconazole programs but no differences in SSR control or yields were noted between the pyraclostrobin and tebuconazole programs in 2000. No significant difference in the level of SSR control provided by pyraclostrobin and tebuconazole programs was noted in 2000 or 2001. In 2001 study, yield gains obtained with the pyraclostrobin programs were significantly greater than those obtained with tebuconazole. The level of SSR control and yield response for all pyraclostrobin and azoxystrobin programs in 2000 and 2001 were similar. All pyraclostrobin programs gave better control of early leaf spot and SSR than chlorothalonil alone in 1999 and 2001 but not in 2000. The contrasts for yield also were higher in 2000 and 2001 at the $P < 0.05$ level and in 1999 at the $P < 0.10$ level. In 2001, the program that included applications of a combination of

Table 4. Summary of contrasts comparing the efficacy of fungicide treatments for the control of early leaf spot and southern stem rot, as well as their impact on peanut yield.

Contrast	Early leaf spot F value	Early leaf spot P value	SSR F value	SSR P value	Yield F value	Yield P value
1999						
Pyraclostrobin at 2-wk interval vs. other programs	6.32	0.0182	1.82	NS	0.01	NS
Pyraclostrobin at 2- vs. 3-wk interval	2.44	NS[a]	3.42	0.0753	0.02	NS
Pyraclostrobin at 3- vs. 4-wk interval	1.82	NS	1.93	NS	0.01	NS
All pyraclostrobin programs vs. tebuconazole program	11.11	0.0025	4.46	0.0441	6.28	0.0185
High vs. low rate of pyraclostrobin	0.05	NS	2.97	0.0961	2.68	NS
All pyraclostrobin programs vs. chlorothalonil alone	5.58	0.0256	14.07	0.0009	4.13	0.0522
2000						
Pyraclostrobin vs. other programs	6.36	0.0153	0.33	NS	0.00	NS
All pyraclostrobin programs vs. tebuconazole programs	1.25	NS	0.02	NS	0.01	NS
Pyraclostrobin + tebuconazole vs. tebuconazole	0.00	NS	0.00	NS	0.97	NS
All pyraclostrobin vs. flutolanil programs	11.25	0.0016	0.22	NS	0.04	NS
Pyraclostrobin + flutolanil vs. flutolanil program	0.42	NS	0.00	NS	0.01	NS
All pyraclostrobin programs vs. chlorothalonil alone	0.14	NS	1.19	NS	5.75	0.022
All pyraclostrobin programs vs. azoxystrobin program	3.47	0.069	0.22	NS	1.01	NS
2001						
Pyraclostrobin at 2-wk interval vs. other programs	132.70	<0.0001	0.34	NS	28.50	0.001
All 2- vs. 3-wk programs	59.90	<0.0001	0.14	NS	21.06	0.001
Pyraclostrobin at 2- vs. 3- wk interval	42.50	<0.0001	0.71	NS	12.11	0.001
All pyraclostrobin programs vs. tebuconazole programs	30.24	<0.0001	0.02	NS	5.69	0.028
Pyraclostrobin + flutolanil vs. flutolanil program	81.30	<0.0001	0.62	NS	9.82	0.0029
All pyraclostrobin programs vs. chlorothalonil alone	33.60	<0.0001	20.17	0.0001	10.03	0.0026
All pyraclostrobin programs vs. azoxystrobin program	3.73	0.059	0.14	NS	0.22	NS

[a]NS = not significant.

pyraclostrobin + flutolanil did not provide significantly better early leaf spot control and higher yield than the flutolanil program in 2000 but did in the following year. Similar SSR control was given by both of the above programs in 2000 and 2001.

Discussion

Portillo *et al.* (13) previously noted that the efficacy of pyraclostrobin for the control of several destructive diseases of peanut is equal to or superior to that of available fungicides. In this study, pyraclostrobin clearly demonstrated efficacy against early leaf spot and SSR on peanut.

When applied from 0.08 to 0.27 kg ai/ha on a 2 wk schedule, pyraclostrobin consistently gave better control of early leaf spot than the standard seven-spray chlorothalonil program or those programs that included applications of chlorothalonil + flutolanil. On the cv. Georgia Green, Culbreath and Brenneman (7) also obtained similar results in their comparison of chlorothalonil and pyraclostrobin programs for the control of early leaf spot. In all 3 yr, the level of early leaf spot control provided by pyraclostrobin when applied over a range of application rates at 2 wk intervals was at least equal to and sometimes better than the level of control maintained with the recommended tebuconazole and azoxystrobin programs. As previously noted (7), pyraclostrobin applied at 3 wk intervals was as effective in controlling early leaf spot as recommended rates of chlorothalonil, tebuconazole, and azoxystrobin applied every 2 wk. When applied at 4 wk intervals in 1999, tebuconazole was less active against early leaf spot than the 0.14 kg ai/ha rate of pyraclostrobin applied on the same schedule. Our data support the conclusion of Portillo *et al.* (13) that the superior efficacy of pyraclostrobin at 3 and 4 wk spray intervals raises the possibility of reducing the total number of fungicide applications without sacrificing control of early leaf spot or pod yields. The enhanced residual activity of pyraclostrobin against early leaf spot may make a weather-based disease advisory such as AU-Pnut a more attractive and possibly less costly option for scheduling fungicide applications than the traditional 2 wk calendar spray program. However, contrast analysis indicated that pyraclostrobin was most efficacious when applied at less than 3 wk intervals.

In all 3 yr, the efficacy of pyraclostrobin for the control of SSR was usually equal to that provided by the recommended tebuconazole, azoxystrobin, or chlorothalonil + flutolanil programs. In a previous study, this fungicide alone or when alternated with other registered fungicides proved as effective as the above fungicides in controlling SSR in peanut (13). Most notably, pyraclostrobin at 0.08 and 0.14 kg ai/ha in 1999 and 0.11 kg ai/ha in 2001 was as effective as the previously mentioned fungicide programs in controlling SSR. Alternating pyraclostrobin with flutolanil + chlorothalonil or applying a tank mixture of pyraclostrobin + flutolanil gave better SSR control than pyraclostrobin alone in 2001. Differences in SSR control noted between these treatments were not observed in 2000 due to low disease pressure. In 2001, application number did not have a noticeable impact on the efficacy of 0.11 kg ai/ha pyraclostrobin for the control of SSR. Frequent showers in July and August 2001, which facilitated the redistribution of pyraclostrobin from the foliage to soil surface around the collar and vines, may have enhanced the effectiveness of the three-application program against SSR.

Despite significant reductions in the ratings for early leaf spot and/or SSR in 1999, the 0.08 and 0.14 kg ai/ha pyraclostrobin programs failed to stimulate a significant increase in yield above that of the chlorothalonil-treated peanuts. In the following 2 yr, the combination of early leaf spot and SSR control provided by the pyraclostrobin programs was reflected in higher yields compared with those of the chlorothalonil standard. In addition, yield gains recorded in both years with pyraclostrobin at 0.11, 0.22, and 0.27 kg ai/ha when applied at 2 wk intervals were usually comparable to those obtained with the recommended tebuconazole, azoxystrobin, and chlorothalonil + flutolanil programs. Typically, alternating pyraclostrobin with tebuconazole or flutolanil, as well as applications of the pyraclostrobin + flutolanil tank-mix combination, did not increase yield above that in the plots treated with selected rates of pyraclostrobin alone. However, tank mixing or alternating fungicides with different modes of action has been suggested by FRAC (Fungicide Resistance Action Committee) as a strategy for reducing the risk of control failures resulting from a decline in sensitivity to triazole or strobilurin fungicides in fungal plant pathogen populations (8).

The efficacy data supporting the proposed registration of pyraclostrobin for the control of early leaf spot and SSR on peanut is incomplete. While the treatment rates that have been screened here are within the rate range listed on the proposed label, the number of applications of pyraclostrobin often has exceeded the maximum of two specified on the product label under FRAC guidelines. With exception of a pyraclostrobin + flutolanil combination program in 2001, however, all pyraclostrobin programs included three or four applications of this fungicide. While Culbreath and Brenneman (7) noted the efficacy of pyraclostrobin over a range of treatment rates for the control of early leaf spot, the number of applications of this fungicide in the programs evaluated in that study were not specified. As a result, programs that include two applications pyraclostrobin at label rates may not prove as efficacious in controlling early leaf spot and SSR as three and four application programs evaluated in this study. To insure effective SSR control, particularly under intense disease pressure, pyraclostrobin may have to be alternated or tank mixed with non-strobilurin fungicides such as tebuconazole or flutolanil.

Significant yield increases were obtained in all 3 yr with recommended rates of tebuconazole, as well as with azoxystrobin in the 2000 and 2001 trials, compared with those yields recorded for the chlorothalonil standard. In previously published reports, the impact of application rate or treatment interval on the yield of pyraclostrobin-treated peanut was not addressed, nor was the yield response to pyraclostrobin and other recommended fungicides compared (7, 13).

As previously noted (1, 7, 13), the efficacy of pyraclostrobin for the control of early leaf spot and SSR on peanut was equal and in some cases superior to that demonstrated by registered fungicides. Despite significant reductions in the incidence of these diseases, pyraclostrobin failed to consistently increase pod yields in all 3 yr above those recorded for the standard, season-long chlorothalonil program. When compared to tebuconazole, however, pyraclostrobin was less consistent in minimizing SSR incidence or improving peanut yield. As a result, pyraclostrobin may be best adapted for use on a peanut cultivar that is partially resistant to SSR. Further studies are need to clearly establish the optimum application rate for effective control of both early and late leaf spot, and SSR, as well as increasing peanut yield with two applications specified on the proposed pyraclostrobin label. Additional information concerning the impact of treatment interval on the efficacy of pyraclostrobin for the control of early leaf spot and SSR must be collected, as well as peanut cultivar choice, particularly those resistant to multiple diseases, on fungicide performance.

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