Late Leaf Spot, Southern Stem Rot, and Peanut Yield Responses to Rates of Cyproconazole and Chlorothalonil Applied Alone and in Combination

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ABSTRACT

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Field tests were conducted in Plains, Ga., in 1990 and 1991 and in Tifton, Ga., in 1991 to determine the effects of cyproconazole (0, 12.3, 24.6, 49.3, 73.9, and 98.7 g/ha) and chlorothalonil (0, 210, 420 and 630, g/ha), applied alone and in tank mixes, on late leaf spot (*Cercosporidium personatum*), southern stem rot (*Sclerotium rolfsii*), and yields of peanut (*Arachis hypogaea*). Asymptotic curvilinear reductions in late leaf spot and area under the disease progress curve were observed with increasing rates of cyproconazole within all levels of chlorothalonil. Late leaf spot ratings decreased linearly with increasing rates of chlorothalonil within cyproconazole rates of 24.6 g/ha or lower in 1990 and 49.3 g/ha or lower in 1991. Quadratic curvilinear reductions in the incidence of stem rot with increasing rates of cyproconazole were observed in both years. Chlorothalonil had no effect on incidence of stem rot. Yield increased linearly or curvilinearly with increasing rates of cyproconazole, with yields converging with the higher rates of cyproconazole within all rates of chlorothalonil. In 1990 and 1991, increases in yield with increasing rates of chlorothalonil diminished as rates of cyproconazole increased. When applied with 420 or 630 g/ha of chlorothalonil, rates of cyproconazole required to provide adequate leaf spot control were much lower than rates required for control of stem rot control in fields with moderate to heavy disease incidence. In field experiments conducted in Tifton in 1992 and 1993, tank mixes of 34 g/ha of cyproconazole and 420 g/ha of chlorothalonil provided control of leaf spot that was superior to that obtained with the standard recommended rate (1.26 kg/ha) of chlorothalonil alone. Incidence of stem rot and pod yields were similar for those two treatments.

Additional keywords: EBI fungicides, fungicide resistance management

Late leaf spot caused by *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton and southern stem rot caused by *Sclerotium rolfsii* Sacc. are two of the most important diseases of peanut (*Arachis hypogaea* L.) worldwide. Control of late leaf spot in the southeastern U.S. typically has been achieved with six to eight applications of the protectant fungicide chlorothalonil. Until 1994, pentachloronitrobenzene (PCNB) and the insecticide chlorpyrofos were the two primary pesticides used for stem rot suppression in the southeastern U.S. (2,8,9). Control obtained by use of these materials has been marginal and inconsistent (2,5,8,9). Several ergosterol biosynthesis inhibiting (EBI) fungicides have been shown to have activity against early (*Cercospora arachidicola* S. Hori) and late leaf spot, stem rot, and Rhizoctonia limb rot (*Rhizoctonia solani* AG-4 Kühn) (3–5,12) of peanut. Propiconazole and tebuconazole were registered for use on peanut in 1994, and other experimental EBI fungicides are being evaluated for control of foliar and soilborne diseases of peanut. Cyproconazole is an experimental EBI fungicide that has excellent activity against both foliar and soilborne pathogens of peanut (2,10). Various regimes of timing and methods of application of these materials have been examined in efforts to maximize disease control and minimize the risk of developing pathogen populations with reduced sensitivity to these fungicides.

The use of tank mix combinations of EBI fungicides with chlorothalonil represents one strategy for delaying or managing the development of populations of pathogens with reduced sensitivity to the EBI fungicides (7,16,19,20). In addition, applications of tank mix combinations of cyproconazole at 62 or 99 g/ha with chlorothalonil at 670 g/ha have been reported to provide control of late leaf spot that is superior to that achieved with chlorothalonil alone at 1.26 kg/ha (10). Those same treatments also provided better control of southern stem rot than that from recommended applications of PCNB (10). The efficacy of lower rates of cyproconazole, alone or in combination with chlorothalonil, on these diseases has not been reported.

The purpose of this study was to determine responses of late leaf spot, stem rot and peanut yield to increasing rates of cyproconazole applied alone and in tank mix combinations with reduced rates of chlorothalonil. Of particular interest was estimating the minimum rate(s) of cyproconazole required to control both late leaf spot and stem rot when used alone and in combination with chlorothalonil.

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MATERIALS AND METHODS

Determination of fungicide rate response. Field experiments were conducted at one location in Plains, Ga., in 1990 and 1991, and one location in Tifton, Ga., in 1991. Fields in Plains were located at the University of Georgia Southwest Branch Experiment Station. Both fields had Greenville sandy clay loam (pH = 5.8) soil, and had been planted to peanut the previous year. The field in Tifton was located on the University of Georgia Coastal Plain Experiment Station Gibbs Farm. The soil type was a Tifton loamy sand (pH = 5.8), and the field had been planted to cotton (*Gossypium hirsutum* L.) the previous year. All trials were planted to the peanut cultivar Florunner at a seed rate of 112 kg/ha. Planting dates were 1 May 1990 and 15 May 1991 at Plains, and 25 May 1991 at Tifton. Aldicarb (Temik 15G, 1.2 kg/ha) was applied in furrow at planting for control of thrips.

In all tests, the experimental design was a randomized complete block with four replications. Plots consisted of 2 rows (1 bed), 7.6 m long. In Tifton, row spacing was a uniform 0.91 m (1.83 m bed); in Plains, rows were 0.71 m apart within the bed and 0.91 m between rows in adjacent beds (1.63 m bed). Plots were separated by two nonsprayed border rows, and blocks were separated by 2.4-m fallow alleys. Calcium sulfate was applied as gypsum (896 kg/ha) 74 days after planting (DAP) in 1990, 64 DAP in 1991 at Plains, and 58 DAP in 1991 (336 kg/ha) at Tifton.

Twenty-four treatments consisted of all possible combinations of 0, 12.3, 24.6, 49.3, 73.9, and 98.7 g/ha of cyproconazole (Alto 100SL, Sandoz Corp., Des Plaines, Ill.) with four rates (0, 210, 420, and 630 g/ha) of chlorothalonil (Bravo 720, ISK Biotech, Mentor, Ohio). All rates are expressed in terms of active ingredient. Combination treatments were applied as tank mixes. Fungicide applications were made on 42, 56, 70, 84, 99, 112, and 139 DAP in 1990; 34, 47, 65, 76, 90, 103, and 117 DAP in 1991 at Plains; and 26, 38, 52, 66, 81, 95, and 109 DAP in 1991 at Tifton. Fungicides were applied using a two-wheeled pull spray cart with a CO_2-

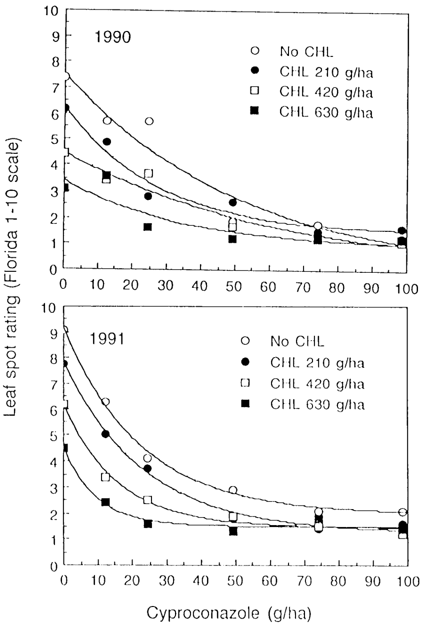

Fig. 1. Effect of rate (g/ha) of cyproconazole (CYP) on ratings of late leaf spot (LS) of peanut within rates (g/ha) of chlorothalonil (CHL). Circles and squares represent actual means; lines represent predicted disease ratings.

powered sprayer with three D2-13 nozzles per row. Fungicides were applied in the equivalent of 114 liters of water per ha at a pressure of 345 kPa.

Leaf spot intensity (severity and defoliation) was assessed by use of the Florida 1 to 10 scale: 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot (6). Leaf spot evaluations were made on 121, 129, 135, 142, and 147 DAP in 1990; 76, 90, 103, 117, and 135 DAP in 1991 at Plains; and 75, 89, 117, and 124 DAP in 1991 at Tifton. Area under the disease progress curve (AUDPC) was used as an index of leaf spot ratings over time, and was calculated by the method of Shaner and Finney (15).

Except for fungicide treatments, plots were maintained as recommended for commercial peanut production. Plots were dug and inverted 148 DAP in 1990 and 135 DAP in 1991 at Plains and 123 DAP in 1991 at Tifton. Immediately after plants were inverted, loci of southern stem rot were counted for each plot; a locus represented 31 cm or less of linear row with one or more plants infected (14). Incidence of stem rot was calculated as the percentage of 31-cm sections of row with symptoms of stem rot and/or signs of the pathogen. Plants were allowed to dry in the wind row for 6 to 13 days, after which time, pods were harvested mechanically. Pod yields were determined for each plot, and adjusted to 12% wt/wt moisture.

Data from each year were analyzed independently by analysis of variance (21). Data were combined for the two locations in 1991. All subsequent reference to significant effects of factors, interactions, or differences among means indicates significance at $P \leq 0.05$ unless otherwise stated. Regression analysis (18,21) was used to evaluate the response of late leaf spot ratings and AUDPC values, stem rot incidence, and pod yield to increasing rates of cyproconazole. Regression analysis was also used to evaluate the response of late leaf spot ratings and pod yield to increasing rates of chlorothalonil.

Responses of late leaf spot ratings (LS) and AUDPCs to increasing rates of cyproconazole were also evaluated by nonlinear regression (18) for fit to a negative exponential equation: LS or AUDPC = $a + be^{-c \times CYP}$, where a = the asymptotic minimum late leaf spot rating or AUDPC, b = the disease rating or AUDPC when no cyproconazole was applied, c = the rate parameter describing change in late leaf spot ratings or AUDPC per g of cyproconazole, CYP = the rate of cyproconazole in g/ha, and e = base of the natural log system (2.718...). Yield response to increasing rates of cyproconazole was examined for fit to this equation: yield (kg/ha) = $a - be^{-c \times CYP}$, where a = the asymptotic maximum yield, b = the reduction in yield when no cyproconazole was applied, c = the rate parameter describing change in yield per g of cyproconazole, and the other terms are as described previously. Criteria for goodness of fit included coefficients of determination (R^2), and plots of residuals from the regression.

Comparison of tank mix combinations to a standard. Field experiments were conducted to compare low rates of cyproconazole (34 g/ha) and chlorothalonil (420 g/ha), applied alone and as tank mixes, to the standard recommended rate (1.26 kg/ha) of chlorothalonil for control of late leaf spot. Experiments were conducted in two fields (designated A and B) at the Coastal Plain Experiment Station, Gibbs Farm, in each year (1992 and 1993). Soil type in all fields was Tifton loamy sand (pH = 5.6 to 6.3). Fields used in test

Table 1. Regression equations of late leaf spot ratings, area under the disease progress curve (AUDPC), and pod yield on rate of cyproconazole within rates of chlorothalonil (CHL)

Leaf spot ratings[a]			AUDPC[b]			Yield (kg/ha)		
CHL[c]	Equation[d]	R^2	CHL[c]	Equation[d]	R^2	CHL[c]	Equation[d]	R^2
1990								
0	$0 + 7.54 \times e^{(-0.020 \times CYPd)}$	0.85	0	$21.5 + 162.9 \times e^{(-0.025 \times CYP)}$	0.91	0	$2{,}917 + 33.3 \times CYP - 0.23 \times CYP^2$	0.78
210	$1.45 + 4.82 \times e^{(-0.038 \times CYP)}$	0.81	210	$35.4 + 102.6 \times e^{(-0.044 \times CYP)}$	0.93	210	$3{,}741 + 7.24 \times CYP$	0.33
420	$0 + 4.48 \times e^{(-0.016 \times CYP)}$	0.80	420	$29.4 + 71.3 \times e^{(-0.032 \times CYP)}$	0.83	420	No significant response	...
630	$0.87 + 2.54 \times e^{(-0.029 \times CYP)}$	0.65	630	$26.6 + 58.7 \times e^{(-0.033 \times CYP)}$	0.65	630	$3{,}933 + 4.95 \times CYP$	0.17
1991[e]								
0	$1.99 + 7.18 \times e^{(-0.045 \times CYP)}$	0.88	0	$88.6 + 239.8 \times e^{(-0.077 \times CYP)}$	0.97	0	$4{,}438 - 2{,}570 \times e^{(-0.135 \times CYP)}$	0.87
210	$1.26 + 6.56 \times e^{(-0.043 \times CYP)}$	0.90	210	$65.6 + 192.8 \times e^{(-0.071 \times CYP)}$	0.98	210	$4{,}571 - 1{,}582 \times e^{(-0.044 \times CYP)}$	0.57
420	$1.46 + 4.68 \times e^{(-0.063 \times CYP)}$	0.81	420	$71.7 + 147.3 \times e^{(-0.127 \times CYP)}$	0.97	420	$4{,}552 - 1{,}787 \times e^{(-0.051 \times CYP)}$	0.59
630	$1.50 + 3.01 \times e^{(-0.104 \times CYP)}$	0.70	630	$70.9 + 100.2 \times e^{(-0.121 \times CYP)}$	0.70	630	$4{,}718 - 1{,}388 \times e^{(-0.019 \times CYP)}$	0.36
...[f]	...	...	0	$80.2 + 324.4 \times e^{(-0.041 \times CYP)}$	0.98	...	...	...
...	...	...	210	$84.3 + 247.9 \times e^{(-0.048 \times CYP)}$	0.96	...	...	...
...	...	...	420	$83.0 + 160.7 \times e^{(-0.053 \times CYP)}$	0.94	...	...	...
...	...	...	630	$72.6 + 108.5 \times e^{(-0.058 \times CYP)}$	0.91	...	...	...

[a] The Florida 1 to 10 scale was used, in which 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.
[b] Disease-days calculated using Florida 1 to -10 scale ratings from five evaluations in both years at Plains and four evaluations at Tifton in 1991.
[c] Rate of chlorothalonil in g/ha.
[d] Equations listed are functions of the rate (g/ha) of cyproconazole (CYP).
[e] Leaf spot rating values for Plains and Tifton sites; AUDPC values for Plains site only; yield values for Tifton and Plains sites.
[f] AUDPC values for Tifton site only.

A had been planted to cotton the previous year; fields used in test B had been planted to peanut the previous 2 years.

Florunner peanuts were planted on 1 June 1992 and 31 May 1993 in test A and on 21 May 1992 and 1993 in test B. Seeding rates were 112 kg/ha in 1992 and 78.4 kg/ha in 1993 in test A, and 121 kg/ha in both years for test B. Plots in all tests received aldicarb (1.12 kg/ha) in-furrow at planting. All plots received calcium sulfate as gypsum, 504 kg/ha 46 DAP in 1992 and 38 DAP in 1993 for test A, and 672 kg/ha 54 DAP in both years for test B.

Plot size and layout for test A was as described for previous tests in Tifton. Plots in test B in both years were similar, but plots were 7 m long and were not separated by border rows. A randomized complete block design with four (test A) and five (test B) replications was used. Treatments in all tests consisted of (i) nonsprayed control; (ii) cyproconazole at 34 g/ha; (iii) chlorothalonil at 420 g/ha; (iv) a tank mix of cyproconazole at 34 g/ha + chlorothalonil at 420 g/ha; and (v) chlorothalonil at 1.26 kg/ha. Chlorothalonil at 1.26 kg/ha represents the standard recommended rate for control of leaf spot.

Fungicides were applied 36, 50, 64, 78, 93, 107, and 121 DAP in 1992, and 36, 49, 64, 78, 92, 106, and 120 DAP in 1993 for test A. In test B, fungicides were applied 32, 43, 60, 74, 88, 102, and 116 DAP in 1992, and 33, 46, 61, 75, 88, 103, and 115 DAP in 1993. In test A, fungicides were applied using spray equipment and spray specifications described previously. In test B, fungicides were applied with a CO_2-propellant back-pack boom sprayer with three D3-23 nozzles per row delivering 187 liters/ha at 317 kPa.

Late leaf spot ratings were made 126 DAP in 1992 and 134 DAP in 1993 for test A, and 146 DAP in 1992 and 136 DAP in 1993 for test B, as described previously. Plants were dug and inverted 130 DAP in 1992 and 147 DAP in 1993 in test A, and 147 DAP in 1992 and 138 DAP in 1993 in test B. Incidence of southern stem rot was determined for all plots as described previously. Inverted plants in both tests were dried in the windrow for 7 to 13 days and were harvested mechanically. Data, including leaf spot ratings, incidence of stem rot, and pod yield, were subjected to analysis of variance. Fisher's protected least significant difference (21) was calculated for mean separations.

RESULTS

Fungicide rate response. In 1990, incidence of leaf spot was low throughout much of the season, due largely to drought. Epidemics, however, did develop during the last 6 weeks of the season, and moderate to heavy final infestations were observed. Nontreated plots showed significant levels of defoliation by digging time. Rainfall during the first half of the growing season promoted development of severe epidemics at both Plains and Tifton in 1991. Most plants in nontreated plots at both locations were completely defoliated and killed by leaf spot by time of harvest.

Effects of chlorothalonil, cyproconazole, and tank mixtures on late leaf spot ratings and AUDPC were significant in both years. Because of the interaction, responses to cyproconazole and chlorothalonil were considered for each rate of the other fungicide. Leaf spot ratings decreased as described by negative exponential functions of rate of cyproconazole (Fig. 1; Table 1). All equations but that describing the response to cyproconazole with no chlorothalonil in 1990 converged as leaf spot ratings approached the minimum of 1 on the rating scale. In 1990, final leaf spot ratings diminished linearly with increasing rates of chlorothalonil within rates of cyproconazole of 24.6 g/ha or lower. Late leaf spot rating responses to increasing rates (g/ha) of chlorothalonil (CHL) were described by these equations: LS = 7.71 – 0.0076 × CHL, R^2 = 0.79, when no cyproconazole was applied; LS = 5.56 – 0.0038 × CHL, R^2 = 0.47, when 12.3 g/ha of cyproconazole was applied; and LS = 5.17 – 0.055 × CHL, R^2 = 0.56, when 24.6 g/ha of cyproconazole was applied.

There were no significant location × treatment interactions for final leaf spot ratings in 1991, and results reported are from data pooled across locations. Responses to increasing rates of cyproconazole within all rates of chlorothalonil were described by negative exponential functions (Fig. 1; Table 1). There was a significant negative linear response to chlorothalonil within rates of cyproconazole lower than 43 g/ha in 1991. Late leaf spot rating responses to increasing rates (g/ha) of chlorothalonil were described by these equations: LS = 9.5 – 0.0079 × CHL, R^2 = 0.77, when no cyproconazole was applied; LS = 6.3 – 0.0063 × CHL, R^2 = 0.71, when 12.3 g/ha of cyproconazole was applied; LS = 4.3 – 0.041 × CHL, R^2 = 0.56, when 24.6 g/ha of cyproconazole was applied; and LS = 2.7 – 0.022 × CHL, R^2 = 0.27, when 49.3 g/ha of cyproconazole was applied.

Location × chlorothalonil, location × cyproconazole, and location × chlorothalonil × cyproconazole interactions were significant for AUDPC in 1991. Therefore, data from locations were analyzed and are presented separately (Fig. 2; Table 1). Decreases in AUDPC with increasing rates of cyproconazole were described by negative exponential functions within all rates of chlorothalonil (Fig. 2; Table 1).

Location effects on stem rot incidence were significant in 1991, but location × treatment effects were not. To illustrate the differences in incidence among locations, however, data from the two locations were analyzed and are presented independently. Effects of cyproconazole on incidence of stem rot were significant in all cases, but chlorothalonil, and chlorothalonil × cyproconazole, effects were not significant in any test. Therefore, regression of incidence of stem rot on rate of cyproconazole was done using data pooled across all rates of chlorothalonil. Decreases in incidence of stem rot with increasing rates of cyproconazole were described by quadratic equations (Fig. 3), but amounts of vari-

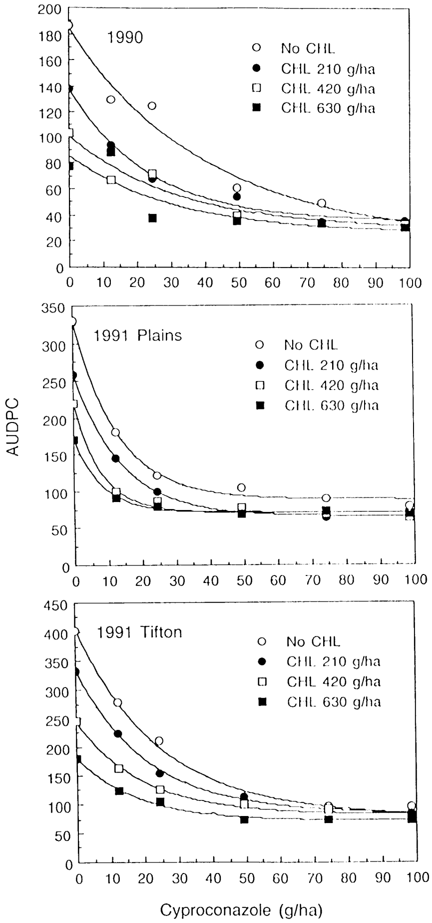

Fig. 2. Effect of rate (g/ha) of cyproconazole (CYP) on area under the disease progress curve values of leaf spot ratings on peanut within each rate of chlorothalonil (CHL). Circles and squares represent actual means; lines represent predicted values.

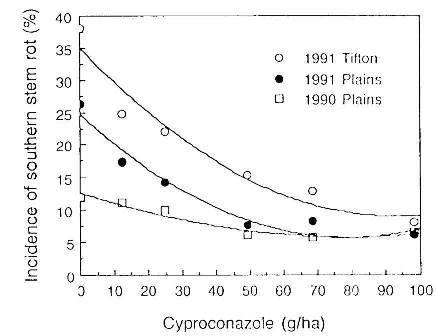

Fig. 3. Effect of rate (g/ha) of cyproconazole (CYP) on incidence of southern stem rot (SR) of peanut. Circles and squares represent actual means; lines represent predicted incidence.

ability accounted for by the models were small, as indicated by R^2 values of 0.50 or less.

Chlorothalonil, cyproconazole, and chlorothalonil × cyproconazole effects on pod yield were significant in 1990. The yield response to increasing rates of cyproconazole was described by a quadratic polynomial when no chlorothalonil was applied, and by linear equations when 210 or 630 g/ha of chlorothalonil was applied (Fig. 4; Table 1). There was no yield response to cyproconazole applied with chlorothalonil at the 430 g/ha rate.

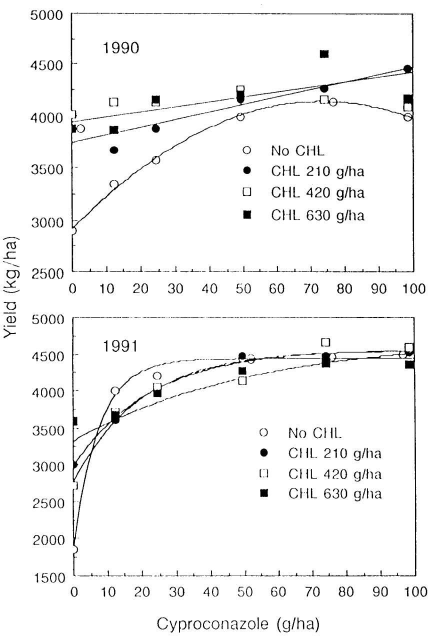

Fig. 4. Effect of rate (g/ha) cyproconazole rate (CYP) on pod yield (Y) of peanut in 1990 and 1991 within each rate of chlorothalonil (CHL). Circles and squares represent actual means; lines represent predicted yields.

Among plots that received no cyproconazole, yield increased with increasing rates (g/ha) of chlorothalonil according to this equation: yield (kg/ha) = 2,923 + 5.5 × CHL − 0.006 × CHL^2, R^2 = 0.73. Yield increased with increasing rates of chlorothalonil according to these equations: yield (kg/ha) = 3,639 + 0.963 × CHL, R^2 = 0.55, when 24.6 g/ha of cyproconazole was applied; and, yield (kg/ha) = 4,106 + 0.606 × CHL, R^2 = 0.30, when 73.9 g/ha of cyproconazole was applied.

In 1991, there were no significant location × treatment effects on yield; therefore, data from the two locations were pooled for analysis. Chlorothalonil main effects on yield were not significant. Cyproconazole main effects and cyproconazole × chlorothalonil interaction effects on yield were significant; therefore, yield was regressed on cyproconazole within rates of chlorothalonil.

Within all rates of chlorothalonil, yield increased with increasing rates of cyproconazole according to nonlinear asymptotic functions (Fig. 4; Table 1). Pod yields converged at the higher two rates of cyproconazole. Variability accounted for by the model decreased as rate of chlorothalonil increased. Yield increased linearly with increasing rates of chlorothalonil according to this equation: yield (kg/ha) = 2,115 + 1.94 × CHL, R^2 = 0.35, when no cyproconazole was applied. Although the regression was significant, increasing rates of chlorothalonil did not account for a high amount of the variability in yield. There was no response with increasing rates of chlorothalonil in the presence of cyproconazole.

Comparison of tank mix combinations to a standard. There were significant year × location × treatment interaction effects on intensity of leaf spot, incidence of stem rot, and pod yields. Within years, there were no significant location × treatment interaction effects on any of the three variables. Therefore, data from the two locations were pooled for comparison of treatments. In both years, final leaf spot ratings of plants treated with cyproconazole at 34 g/ha alone were similar to those treated with chlorothalonil at 1.26 kg/ha (Table 2).

Leaf spot ratings in both of these treatments were lower than those of the nontreated control and of plants treated with 420 g/ha of chlorothalonil alone (Table 2). Leaf spot ratings of plants treated with tank mix combinations of 34 g/ha of cyproconazole and 420 g/ha of chlorothalonil were lower than those of plants treated with 1.26 kg/ha of chlorothalonil in both years (Table 2).

Severe defoliation and plant death caused by leaf spot prevented use of the nontreated plots for stem rot evaluations. Among the other four treatments, incidence of stem rot was highest in the plots treated with 420 g/ha of chlorothalonil in 1992 (Table 2). There were no differences in incidence of stem rot among the treatments receiving cyproconazole or the 1.26 kg/ha of chlorothalonil in either year (Table 2).

Pod yields were similar for plots treated with 34 g/ha of cyproconazole alone, cyproconazole plus chlorothalonil, and 1.26 kg/ha of chlorothalonil alone. There was a trend toward higher yields in plots treated with the tank mix combination of cyproconazole and chlorothalonil than with either cyproconazole alone or 1.26 kg/ha of chlorothalonil alone, but these differences were not significant. Pod yields were lowest in nontreated plots in both years.

Table 2. Effect of cyproconazole and chlorothalonil alone and in tank mix combinations on late leaf spot, southern stem rot, and yield of peanut in 1992 and 1993

	Rate	Leaf spot[a]			Southern stem rot[b]			Pod yield (kg/ha)		
Treatment	(g/ha)	Test A	Test B	Mean	Test A	Test B	Mean	Test A	Test B	Mean
1992										
Control	...	9.4	9.2	9.3	...[c]	...[c]	...	1,675	1,676	1,676
Cyproconazole	34	6.0	4.6	5.2	5.5	31.7	20.1	5,068	4,398	4,696
Chlorothalonil	420	8.7	7.6	8.1	13.0	56.1	36.9	2,668	3,775	3,283
Cyproconazole +	34	4.9	2.6	3.6	5.5	25.7	15.8	5,354	5,048	5,183
Chlorothalonil[d]	420									
Chlorothalonil	1,260	6.0	4.0	4.9	10.0	36.1	24.5	4,808	4,737	4,768
LSD ($P \leq 0.05$)				0.8			11.5			626
1993										
Control	...	7.9	8.8	8.3	...[c]	...[c]	...	2,416	2,128	2,256
Cyproconazole	34	1.9	3.8	3.0	27.5	36.5	32.5	2,977	3,054	3,020
Chlorothalonil	420	4.0	6.4	5.4	34.0	46.0	40.7	3,132	2,552	2,810
Cyproconazole +	34	1.4	2.8	2.2	28.5	26.9	27.6	3,457	3,223	3,328
Chlorothalonil[d]	420									
Chlorothalonil	1,260	2.2	4.5	3.5	21.5	36.1	29.6	3,628	2,580	3,046
LSD ($P \leq 0.05$)				0.6			8.4			424

[a] The Florida 1 to 10 scale was used, in which 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spot.
[b] Percentage of 31-cm sections of row with symptoms of stem rot and/or signs of *Sclerotium rolfsii*.
[c] Damage caused by leaf spot prevented determination of incidence of stem rot.
[d] Combinations of fungicides were applied as tank mixes.

DISCUSSION

Tank mix combinations of 62 g/ha of cyproconazole and 650 g/ha of chlorothalonil have been reported to provide control of late leaf spot and southern stem rot equivalent or superior to that achieved with the previous standard recommended fungicides for these diseases (10). Results of our study indicate that tank mix combinations of much lower rates of both fungicides than previously reported can provide excellent leaf spot control, even in years such as 1991 and 1992 in which conditions were very conducive to development of leaf spot epidemics. Amounts of chlorothalonil applied, however, must be sufficient to prevent development of problems with resistance to cyproconazole in pathogen populations, and the amount of cyproconazole applied must be sufficient to provide control of southern stem rot.

Köller and Scheinpflug (13) discussed the theoretical limitations of using a conventional fungicide such as chlorothalonil for resistance management; however, chlorothalonil is presently the only viable non-

EBI option. Köller and Scheinpflug (13) also indicated no clear consensus concerning preference for the use of alternate sprays or tank mixes. In his review of EBI sensitivity, Staub (19) cited results in which both tank mixes and alternations were superior to the use of single products for both efficacy and delaying shifts in sensitivity to EBI fungicides. If efficacy for controlling disease and preventing development of pathogen populations are equal, Staub points out that it is easier to enforce the use of mixtures than alternations (19).

Considering the apparent efficacy and enforcement advantages of pre-mixes, the use of pre-mixes would appear to be a good choice in this system. The question of required rates for management of populations of *C. personatum* with reduced sensitivity to EBI fungicides remains unanswered. The directional selection hypothesized for EBI fungicides (13) would be best slowed or prevented by avoiding exposure to low rates of EBI fungicides. Additionally, the amount of chlorothalonil required to prevent development of resistance to *C. personatum* is not known. In our study, application of chlorothalonil alone at 420 or 630 g/ha provided moderate control of late leaf spot. Therefore, either of these rates should be a significant deterrent to buildup of populations of *C. personatum* that might include portions with reduced sensitivity to the EBI fungicides.

Chlorothalonil has little direct effect on incidence or severity of southern stem rot, as evidenced by previous studies (1,11,17) and corroborated by this study. Therefore, the amount of chlorothalonil in a tank mix is probably of little direct consequence for control of this disease. In our tests, rates of cyproconazole required to provide control of southern stem rot were much higher than rates needed for high levels of control of leaf spot with any of the three rates of chlorothalonil tested. Therefore, control of southern stem rot appears to be the critical factor for determining the amount of cyproconazole to use in the tank mix. Rates used for disease control also may be affected by cost of the fungicide. Predicted costs of cyproconazole are not available. Therefore, estimated economic limitations of the fungicide rates are not calculable. The response to increasing rates of cyproconazole in 1990 compared to 1991 indicates that the amount of cyproconazole needed for control of stem rot varies, depending upon the inoculum potential, which is affected by the number of sclerotia in the soil and environmental conditions.

Our results indicate that tank mix combinations of chlorothalonil at 420 g/ha plus 49.3 g/ha of cyproconazole can provide excellent control of late leaf spot even with severe epidemics such as occurred at the Tifton location in 1991. These rates might also provide adequate suppression of southern stem rot in fields with light infestations of *S. rolfsii.* Results from tests in 1992 and 1993 indicate that tank mix combinations of 34 g/ha of cyproconazole and 420 g/ha of chlorothalonil are superior to the standard rate of chlorothalonil alone for control of leaf spot. In fields in which control of stem rot is not needed, use of these fungicide combinations could represent a reduction in the total amount of fungicide required for leaf spot control compared to the standard recommendation.

Our results indicate that the rate of cyproconazole required to provide control of stem rot will vary among locations and years. Application of cyproconazole at rates greater than 49.3 g/ha provided no additional stem rot control in either year at Plains, whereas increases in rates up to 98.7 g/ha resulted in greater levels of control at the Tifton site in 1991.

Since chlorothalonil has little effect on southern stem rot of peanut, yield increases with increasing rates of chlorothalonil are hypothesized as being due primarily to control of leaf spot diseases. It is difficult to determine in this test what portion of yield increases with increasing rates of cyproconazole were due to control of late leaf spot or control of stem rot. Leaf spot intensity ratings of less than 3.0 (6) indicate that the lower rates of cyproconazole (mixed with chlorothalonil) examined in this study were sufficient to prevent significant defoliation. Therefore, yield increases observed with higher rates of cyproconazole probably are attributable to control of other diseases.

Our results indicate that the combinations of cyproconazole and chlorothalonil as reported previously (10) will be needed to control both leaf spot and stem rot in fields with severe stem rot problems. Where stem rot is not a problem or occurs infrequently, combinations of cyproconazole at 25 g/ha with 630 g/ha of chlorothalonil or 34 g/ha of cyproconazole with 420 g/ha of chlorothalonil could provide control of leaf spot equivalent or superior to that currently achieved with 1.26 kg/ha of chlorothalonil alone.

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