Utilizing a Sterol Demethylation Inhibiting Fungicide in an Advisory Program to Manage Foliar and Soilborne Pathogens of Peanut

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ABSTRACT

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This study evaluated 11 programs using chlorothalonil (1.26 kg/ha) and/or tebuconazole (0.25 kg/ha) applied to Southern Runner peanut (*Arachis hypogaea*) according to 14- or 21-day schedules or AU-Pnuts, a rainfall-based advisory program for scheduling fungicides for foliar disease control. AU-Pnuts called for five, eight, and five sprays in 1991, 1992, and 1993, respectively, compared to seven, eight, and seven sprays on a 14-day schedule. Five sprays each year were applied on the 21-day schedule. Where the number of sprays was reduced, *Cercosporidium personatum* and *Cercospora arachidicola* leaf spots were more severe, but the effects on yield were variable. The substitution of tebuconazole for chlorothalonil resulted in consistently higher yields and reduced incidence and/or severity of both foliar and soilborne diseases. There were strong correlations between the number of tebuconazole applications and *Sclerotium rolfsii* stem rot incidence, pod yield, and both grade and percent damage of kernels. Timing of tebuconazole applications was not extremely critical, but early- and late-season sprays did not have as much effect on leaf spot or stem rot epidemics. Tebuconazole is well suited for use with an advisory system. Two to four sprays per season could be used according to one of these rule-based models as long as protectants are also used for resistance management.

Peanut (*Arachis hypogaea* L.) is susceptible to several plant pathogens that can cause serious yield losses. Although both early (*Cercospora arachidicola* S. Hori) and late (*Cercosporidium personatum* (Berk. & M.A. Curtis) Deighton) leaf spot are important, late leaf spot is generally dominant in the southeastern United States, and losses can exceed 50% (25). Soilborne pathogens are also damaging, particularly *Sclerotium rolfsii* Sacc., causal agent of southern stem rot. Limb rot, caused by *Rhizoctonia solani* Kühn anastomosis group 4 (AG-4), can cause extensive losses in irrigated or nonirrigated peanuts when the latter part of the season is cool and wet. These two soilborne pathogens account for annual yield losses in Georgia of approximately $66 million (University of Georgia Cooperative Extension Service estimates, 1988–1992).

Disease control strategies have changed very little in the past 20 yr in the southeastern United States. Peanuts are still sprayed five to eight times per season to prevent damage from peanut leaf spot (25). No chemical control of limb rot is available, and registered pesticides provide only suppression of stem rot. One cultivar, Southern Runner, has been introduced that has partial resistance to both late leaf spot and stem rot (3,12). Commercial acceptance of this cultivar has been slow, and it accounts for only a small percentage of peanuts grown in the southeastern United States.

Although not registered for use on peanut in the United States, sterol demethylation inhibiting fungicides (DMIs) have been tested extensively and have proven to be highly effective against both foliar and soilborne pathogens of peanut (4,5,8). Targeting multiple pathogens has made it difficult to determine an optimal strategy for deploying the DMIs. In general, higher rates of a DMI fungicide are required for control of soilborne than foliar diseases. Fortunately, conventional ground-spray equipment currently used to apply protectant fungicides is also suitable for DMIs. This eliminates the need for reconfiguring spray equipment and making additional applications.

Because of concerns about fungicide resistance resulting from improper use of DMIs (17), various strategies have been evaluated to integrate DMIs into existing spray schedules. These strategies included tank mixes, blocks of sprays with fungicides of different modes of action, and alternating sprays of a DMI and a protectant such as chlorothalonil.

A complicating factor is the introduction of weather-based advisory systems to target periods of greatest infection risk. An early leaf spot advisory currently is in use in the Virginia–North Carolina production area (9). This program was adopted in 1989 and was preceded by a program initiated in 1981 by Phipps and Powell (23). Theirs was a revision of an earlier model (21) that also utilized data from work by Jensen and Boyle (15). Using the current program, growers have applied an average of 2.25 fewer fungicide sprays during 1987–1990, and a 1990 survey indicated that 94% of the growers in Virginia were using the advisory system (22). Advisory programs for late leaf spot developed in Georgia (20) and Alabama (11) recently were introduced and result in reductions in fungicide applications, although not as much as the early leaf spot program. However, any reduction in the number of sprays makes it even more difficult to schedule the use of a protectant fungicide around multiple applications of a DMI fungicide.

There are currently no models in use to schedule treatments for control of soilborne pathogens. Fungicides are generally applied soon after fruit initiation, and timing can be based on the stage of plant growth or related to specific sprays in the calendar-based leaf spot management program. Treatments applied during the general time frame of 45–90 days after planting (DAP) historically provide the best control of southern stem rot and Rhizoctonia limb rot.

The purpose of this study was to integrate two emerging technologies, i.e., DMI fungicides and advisory programs for application of foliar fungicide sprays. A variety of rule-based systems was developed and evaluated for their effects on pod yield, leaf spot, limb rot, and southern stem rot. The advisory system utilized was AU-Pnuts, and the DMI was tebuconazole, a fungicide with proven activity against several pathogens of peanut (4,5).

MATERIALS AND METHODS

Several rule-based spray regimes were developed and then compared to various standard treatments in 1991, 1992, and 1993 (Table 1). Chlorothalonil (Bravo 720) treatments were at the rate of 1.26 kg/ha, and tebuconazole (Folicur 3.6F) treatments were at the rate of 0.25 kg/ha. All fungicide rates are given as the amount of active ingredient per hectare. A spreader-activator (Induce, Helena Chemical Co., Memphis, TN, 0.25% v/v) was used with all tebuconazole sprays. Treatments were applied with a CO_2-pressurized backpack sprayer with three equally spaced D2-13 nozzles per row delivering 124 L/ha at 345 kPa. The cultivar used in all tests was Southern Runner, which has partial resistance to late leaf spot (12) and southern stem rot (3). Although a model has since been tested to allow for the resistance that Southern Runner has to late leaf spot

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(14), the standard rules developed for use of AU-Pnuts on Florunner peanut were used (1992 AU-Pnuts rules for peanut leaf spot control, Alabama Cooperative Extension Service). However, an earlier version of AU-Pnuts requiring seven rather than the currently used four rain events to trigger the first spray was used in 1991. The AU-Pnuts rules are based on the relationship between 24-hr rainfall and leaf spot development (11). A 10-day protection interval was used for both chlorothalonil and tebuconazole.

The experimental design was a randomized complete block with six replicates in 1991 and four replicates each in 1992 and 1993. Following deep turning and preplant incorporation of benefin (1.68 kg/ha) with a rototiller, seeds (100 kg/ha) were planted in single rows 0.91 m apart. Plots consisted of single beds with two rows per bed (7.6 × 1.8 m). The planting dates were 30 May 1991, 14 May 1992, and 17 May 1993. Standard management practices recommended by the Georgia Cooperative Extension Service were followed (16). Plots were irrigated as needed during fungicide-protected intervals for AU-Pnuts treatments. This pattern prevented the frequent, artificial application of forecasted sprays, since AU-Pnuts is triggered by rainfall and irrigation events. Rainfall and irrigation by month totaled 13.5 cm in June, 25.4 in July, 9.5 in August, and 5.7 in September 1991; 14.2 cm in June, 14.2 in July, 16.5 in August, and 12.2 in September 1992; and 6.9 cm in June, 25.7 in July, 11.4 in August, and 13.2 in September 1993.

The 1991 test was conducted in a field of Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Kandiudults, pH 5.9). The 1992 and 1993 tests were in adjacent fields of Fuquay sand (loamy, siliceous, thermic Plinthic Kandiudults, pH 6.7). All three fields had at least two consecutive years of peanut production and a history of moderate to high disease pressure from stem rot.

Leaf spot was rated several times each growing season using the Florida rating scale, where 1 = no disease and 10 = plants killed by leaf spot (7). Peanuts were inverted 16 October 1991, 19 October 1992, and 11 October 1993. The incidence of stem rot (percentage of 30.5-cm sections of linear row per plot with at least one disease locus) and the severity of Rhizoctonia limb rot were rated immediately after digging. Limb rot ratings consisted of a visual estimate of the percentage of vines colonized by *R. solani* in six 0.6-m sections of linear row per plot.

Plots were mechanically harvested on 23 October 1991, 29 October 1992, and 14 October 1993. Peanuts were dried to approximately 10% (w/w) moisture prior to storage at room temperature. One 500-g sample per plot was removed and graded according to official Federal-State Inspection Service methods. Data were evaluated with an analysis of variance, and Fisher's protected LSD ($P < 0.05$) was used to separate means. Regression analysis was used to evaluate the relationship between the number of tebuconazole sprays with disease control and pod yield (24).

RESULTS

Due to significant year by treatment interactions, all data were analyzed separately by year. Use of the AU-Pnuts model resulted in five, eight, and five sprays being applied in 1991, 1992, and 1993, respectively (Table 1). Seven, eight, and seven sprays were applied in 1991, 1992, and 1993, respectively, according to the standard 14-day schedule. Some treatment regimes had the same number of sprays, but the actual timing of sprays was different.

Peanut leaf spot was most severe in 1991 but also caused significant damage in 1992 and 1993 (Table 2). The primary leaf spot pathogen most years in Georgia is *Cercosporidium personatum,* and this was the case in 1991. However, *Cercospora arachidicola* was the dominant pathogen in the latter 2 yr of the study. Over the 3 yr of the study, defoliation averaged 79% in nonsprayed plots. When fewer chlorothalonil sprays were applied according to AU-Pnuts, as in 1991 and 1993, leaf spot was more severe than in conventionally sprayed plots. Peanuts sprayed every 14 days had only 5% defoliation at harvest, whereas those treated according to AU-Pnuts were 27% defoliated.

Treatments utilizing tebuconazole gave the best control of leaf spot. During the 3-yr study, plots receiving four applications of tebuconazole as a block (applications 3–6) had the lowest leaf spot ratings (Table 2) and no defoliation. The 3-yr average for defoliation in AU-Pnuts plots treated with chlorothalonil alone was 35%, compared to 11% when two tebuconazole sprays were substituted at the second and third spray. Other comparisons can be made from data in Table 2.

The timing of tebuconazole sprays influenced the development of leaf spot epidemics. For example, in 1992, the early application of tebuconazole in treatment 11 resulted in less leaf spot on July 17 than in plots treated with only chlorothalonil (Table 3). When chlorothalonil sprays were resumed, the disease increased in severity. In contrast, when the tebuconazole sprays were delayed until midseason, there was an initial surge of leaf spot, which then dropped and remained stable until the last rating. This trend was also evident in 1993, where plots treated at midseason with tebuconazole had less leaf spot by harvest than those treated early in the season with the same number of sprays.

Stem rot was severe in 1991 and 1993, and moderate in 1992. The 3-yr average disease incidence for all treatments using only chlorothalonil was 37%. The current standard, PCNB, reduced this by 40%. As with leaf spot, plots receiving the four-

Table 1. Spray regimes evaluated and number of sprays applied, 1991–1993

Fungicide	Application regime[v]	Applications per year 1991	1992	1993	Avg.
Nontreated		0	0	0	0
Chlorothalonil[w]	14-day calendar (1–7)[x]	7	8	7	7.3
Chlorothalonil					
+ PCNB[y]	14-day calendar (1–7)[x]	7	8	7	7.3
Chlorothalonil	14-day calendar 1, 2, 7)[x]	3	4	3	3.3
+ Tebuconazole[w]	14-day calendar (3–6)	4	4	4	4.0
Chlorothalonil	21-day calendar (1, 5)	2	2	2	2.0
+ Tebuconazole	21-day calendar (2–4)	3	3	3	3.0
Chlorothalonil	21-day calendar (1–5)	5	5	5	5.0
Chlorothalonil	AU-Pnuts (full season)[z]	5	8	5	6.0
Chlorothalonil	AU-Pnuts (early and late season)[z]	2	4	2	2.7
+ Tebuconazole	AU-Pnuts (midseason)[z]	3	4	3	3.3
Chlorothalonil	14-day calendar for 2 sprays (1, 2)	2	2	2	2.0
+ Tebuconazole	AU-Pnuts (3, 4, 5, etc.)	3	6	4	4.3
Chlorothalonil	14-day calendar for 2 sprays (1, 2)	2	2	2	2.0
+ Chlorothalonil	AU-Pnuts (3, 4, 5, etc.)	3	6	4	4.3
Chlorothalonil	AU-Pnuts (1, 4, 5, etc.)	3	6	3	4.0
+Tebuconazole	AU-Pnuts (2, 3)	2	2	2	2.0
Chlorothalonil	AU-Pnuts (all except 60 and 90 DAP)	4	6	3	4.3
+ Tebuconazole	60 and 90 DAP	2	2	2	2.0

[v] The number in parentheses refers to the sequence in which each fungicide was applied.
[w] Chlorothalonil (Bravo 720) used at 1.26 kg/ha and tebuconazole (Folicur 3.6F) used at 0.25 kg/ha plus Induce at 0.25% (v/v).
[x] A total of eight sprays was applied on the 14-day schedule in 1992.
[y] PCNB (Terraclor 10G) was applied 60 days after planting (DAP) at 5.60 kg a.i./ha in a narrow band using a drop tube applicator centered over each row.
[z] Spray periods defined as follows: Full season is from plant emergence until 2–3 wk before digging, early season is from emergence until 59 days after planting (DAP), midseason is 60–115 DAP, and late season is >115 DAP. Note that these dates were set for Southern Runner, which has a late maturity.

spray block of tebuconazole had the least stem rot, with a 58% reduction.

The timing of tebuconazole sprays influenced the effectiveness against soilborne pathogens, at least in some years. For example, two applications of tebuconazole at midseason gave 18% better control of stem rot than did two early-season applications in 1992 (Table 4). Control of Rhizoctonia limb rot was increased even more (38%), although going from two to four, or even six applications of tebuconazole gave no additional control. Overall, there was a strong negative correlation between the

Table 2. Final leaf spot and stem rot ratings of Southern Runner peanut with 12 different fungicide regimes

Treatment[v]	Final leaf spot rating[w] 1991	1992	1993	Avg.	Stem rot at digging[x] 1991	1992	1993	Avg.
Nontreated	8.3	8.0	7.4	7.9	...	...[y]	...	...
Ctl, 14-day (1–7)[z]	3.4	6.5	4.5	4.8	54.2	18.5	36.5	36.4
Ctl, 14-day (1–7)[z] + PCNB	3.0	5.9	4.5	4.5	37.9	9.5	19.0	22.1
Ctl, 14-day (1, 2, 7)[z] + Teb, 14-day (3–6)	2.4	1.8	2.9	2.4	24.6	3.5	17.5	15.2
Ctl, 21-day (1, 5) + Teb, 21-day (2–4)	3.4	5.3	2.7	3.8	31.2	6.5	14.5	17.4
Ctl, 21-day	5.1	7.2	5.5	5.9	46.7	21.5	40.0	36.0
Ctl, AU-P full season	5.3	6.0	5.2	5.5	43.3	20.0	36.5	33.3
Ctl, AU-P early and late + Teb, AU-P midseason	4.7	2.3	2.5	3.2	40.0	4.0	16.5	20.2
Ctl, 14-day (1, 2) + Teb, AU-P (3, 4, etc.)	4.0	1.5	2.9	2.8	32.5	4.0	11.0	15.8
Ctl, 14-day (1, 2) + Ctl, AU-P (3, 4, etc.)	4.8	5.5	4.3	4.9	48.8	33.0	44.5	42.1
Ctl, AU-P (1, 4, 5, etc.) + Teb, AU-P (2, 3)	5.4	4.3	3.6	4.4	29.2	11.5	25.5	22.0
Ctl, AU-P (exc. 60 and 90 DAP) + Teb, 60 and 90 DAP	5.3	2.6	2.8	3.6	37.1	7.0	25.5	23.2
LSD ($P \leq 0.05$)	0.6	0.7	0.6		12.7	14.4	8.4	

[v] Ctl = chlorothalonil at 1.26 kg/ha, PCNB = pentachloronitrobenzene 5.60 kg/ha, Teb = tebuconazole at 0.25 kg/ha, and AU-P = sprays applied according to the AU-Pnuts advisory.
[w] Florida 1–10 scale, where 1 = no disease and 10 = dead plant; rating done prior to inverting.
[x] Percent 30.5-cm sections of linear row per plot with at least one disease locus.
[y] Not rated due to confounding effect of severe leaf spot.
[z] Eight sprays were applied in 1992.

Table 3. Effect of timing of tebuconazole sprays on control of leaf spot, 1992

Treatment[y]	Spray date 6/16	6/30	7/16	7/28	8/10	8/25	9/8	9/25	Leaf spot rating (Florida 1–10) 6/17	7/17	8/18	9/9	9/24	10/19
Nontreated	...	...	...	...	...	...	...	...	0	3.7 a[z]	5.8 a	6.5 a	7.6 a	8.0 a
Ctl, AU-P (full season)	C	C	C	C	C	C	C	C	0	2.2 b	2.9 b	3.2 b	4.5 b	6.0 b
Ctl, AU-P (1, 4–8) + Teb, AU-P (2, 3)	C	T	T	C	C	C	C	C	0	1.8 c	1.9 c	3.0 c	3.8 c	4.3 c
Ctl, AU-P (exc. 60 and 90 DAP) + Teb, 60 and 90 DAP	C	C	T	C	T	C	C	C	0	2.5 b	1.8 c	2.1 d	2.1 d	2.6 d

[y] Ctl or C = chlorothalonil at 1.26 kg/ha, PCNB = pentachloronitrobenzene 5.60 kg/ha, Teb or T = tebuconazole at 0.25 kg/ha, AU-P = sprays applied according to the AU-Pnuts advisory, and DAP = days after planting.
[z] Differences within columns determined by Fisher's protected LSD ($P \leq 0.05$).

Table 4. Effect of timing of tebuconazole sprays on control of soilborne pathogens, 1992

Treatment[x]	Spray date 6/16	6/30	7/16	7/28[y]	8/10[y]	8/25[y]	9/8[y]	9/25	Stem rot at digging (% control)	Rhizoctonia limb rot at digging (% control)
Ctl, AU-P (1, 4–8) + Teb, AU-P (2, 3)	C	T	T	C	C	C	C	C	55 b[z]	18 b
Ctl, AU-P (exc. 60 and 90 DAP) + Teb, 60 and 90 DAP	C	C	T	C	T	C	C	C	73 ab	56 a
Ctl, 14-day (1, 2, 7, 8) + Teb, 14-day (3–6)	C	C	T	T	T	T	C	C	86 a	56 a
Ctl, 14-day (1, 2) + Teb, AU-P (3–8)	C	C	T	T	T	T	T	T	84 a	56 a

[x] Ctl or C = chlorothalonil at 1.26 kg/ha. PCNB = pentachloronitrobenzene 5.60 kg/ha, Teb or T = tebuconazole at 0.25 kg/ha, and AU-P = sprays applied according to the AU-Pnuts advisory.
[y] For the third treatment, which was sprayed on a 14-day schedule full season, these sprays were actually applied on 7/30, 8/14, 8/28, and 9/11, respectively.
[z] Differences within columns determined by Fisher's protected LSD ($P \leq 0.10$). Percent control was based on comparison with mean disease incidence from plots receiving only full-season chlorothalonil sprays, i.e., treatments 2, 7, and 10.

number of tebuconazole sprays and stem rot incidence, regardless of when sprays were applied (Fig. 1). The correlation coefficients for all 3 yr were all significant ($P \leq 0.01$) and ranged from −0.83 to −0.95.

Pod yields were quite variable among years, primarily due to extremes in growing conditions. A severe infestation of peanut root-knot nematode (*Meloidogyne arenaria* (Neal) Chitwood) resulted in low yields for all plots in 1991, with none of the treatments producing more than 2,500 kg/ha (Table 5). Excellent growing conditions in 1992 resulted in yields in excess of 5,400 kg/ha for several treatments. Although 1993 was a disaster for farmers in the southeastern United States due to extreme heat and drought, regular irrigation resulted in moderate yields in this study.

Based on the mean yields of 1992 and 1993 (1991 was not included due to the severe nematode damage and extremely low yields), plots receiving the four-spray block of tebuconazole had the highest yields, although the treatment consisting of six tebuconazole sprays was similar. Both treatments increased yields by more than 2,100 kg/ha compared to nonsprayed plots. Chlorothalonil increased yields by 1,330 and 1,147 kg/ha when applied on 14-day and AU-Pnuts schedules, respectively. The use of PCNB increased yields 435 kg/ha compared to chlorothalonil alone.

As with stem rot, there was a good correlation between the number of tebuconazole sprays and pod yields, regardless of when they were applied (Fig. 2). The correlation coefficients were all highly significant and ranged from 0.70 to 0.92.

Due to adverse growing conditions, peanut grades were low for all treatments in 1991 and 1993 (Table 5). Significant differences among treatments were observed only in 1993, when peanuts receiving no fungicides had a higher grade than all other treatments. Regression analysis demonstrated a positive relationship between the number of tebuconazole sprays and grade, regardless of when sprays were applied (Fig. 3). This relationship was most apparent in the drier years of 1991 and 1993.

Crop value per ton, which is determined in part by grade, was not significantly different among treatments in 2 of the 3 yr (Table 6). In 1993, peanuts receiving no fungicide had the highest value per ton. Mean crop values per ton across all 3 yr of the study were $619, $602, and $625 for all treatments receiving tebuconazole, chlorothalonil alone, and no fungicide, respectively.

Crop value per hectare, which reflects both yield and value per ton, was signifi-

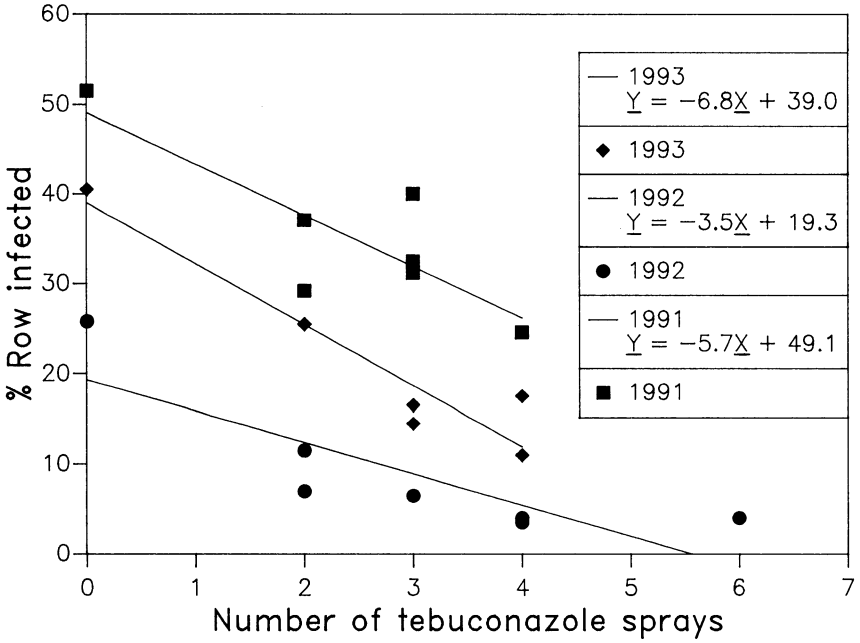

Fig. 1. Relationship between the number of tebuconazole sprays per season (0.25 kg/ha) and the incidence of stem rot. Correlation coefficients for 1991, 1992, and 1993 are −0.83, −0.84, and −0.95, respectively.

Table 5. Pod yield and grade of Southern Runner peanut with 12 different fungicide regimes

	Pod yield[w]				Grade[x]			
Treatment[v]	**1991**	**1992**	**1993**	**Avg.[y]**	**1991**	**1992**	**1993**	**Avg.**
Nontreated	1,926	3,073	2,724	2,898	61.1	71.4	72.0	68.2
Ctl, 14-day (1–7)[z]	1,797	5,001	3,456	4,228	58.7	72.8	65.7	65.7
Ctl, 14-day (1–7)[z] + PCNB	1,872	4,919	4,407	4,663	60.2	71.6	68.1	66.6
Ctl, 14-day (1, 2, 7)[z] + Teb, 14-day (3–6)	2,475	5,708	4,448	5,078	63.6	70.7	67.6	67.3
Ctl, 21-day (1, 5) + Teb, 21-day (2–4)	2,313	4,984	4,293	4,638	61.6	73.1	68.9	67.9
Ctl, 21-day	1,898	4,001	3,041	3,521	61.5	72.2	66.1	66.6
Ctl, AU-P full season	1,682	4,423	3,667	4,045	62.9	71.3	68.0	67.4
Ctl, AU-P early and late + Teb, AU-P midseason	1,946	5,350	4,472	4,911	61.8	71.6	67.2	66.9
Ctl, 14-day (1, 2) + Teb, AU-P (3, 4, etc.)	2,157	5,806	4,301	5,053	62.3	72.1	66.0	66.8
Ctl, 14-day (1, 2) + Ctl, AU-P (3, 4, etc.)	1,709	3,862	3,204	3,533	58.4	68.6	64.7	63.9
Ctl, AU-P (1, 4, 5, etc.) + Teb, AU-P (2, 3)	2,177	5,407	3,903	4,655	62.9	72.3	65.7	67.0
Ctl, AU-P (exc. 60 and 90 DAP) + Teb, 60 and 90 DAP	1,987	5,415	4,090	4,752	63.1	71.1	67.6	67.2
LSD ($P \leq 0.05$)	481	795	591		NS	NS	2.5	

[v] Ctl = chlorothalonil at 1.26 kg/ha, PCNB = pentachloronitrobenzene 5.60 kg/ha, Teb = tebuconazole at 0.25 kg/ha, and AU-P = sprays applied according to the AU-Pnuts advisory.
[w] Kilograms per hectare of pods at 10% moisture.
[x] Grade = percent sound mature kernels and sound split kernels.
[y] Mean of 1992 and 1993 only. Yield from 1991 not used due to severe nematode damage.
[z] Eight sprays were applied in 1992.

cantly different among treatments each year of the study (Table 6). Except for 1991, when all yields were suppressed, plots receiving no fungicide had the lowest value per hectare. Chlorothalonil-treated plots consistently had lower values than those treated with tebuconazole, primarily due to the differences in pod yield. Mean crop values per hectare across all 3 yr were $2,768, $2,161, and $1,810 for all plots receiving tebuconazole, chlorothalonil alone, and no fungicide, respectively. The addition of PCNB to the chlorothalonil program resulted in an average 3-yr return of $2,606 per hectare.

The mean percentage of damaged kernels from all treatments was 4.8, 2.4, and 3.5% in 1991, 1992, and 1993, respectively. There were no significant differences when all treatments were analyzed, but regression analysis of treatments utilizing tebuconazole demonstrated a strong negative relationship between the number of applications of that fungicide and the percentage of damaged kernels (Fig. 4).

DISCUSSION

This study demonstrated the importance of chemical control of foliar diseases of peanut even when a partially resistant cultivar (Southern Runner) is grown. The occurrence of early leaf spot as the primary disease in 1992 and 1993 is still not understood. The fact that Southern Runner has partial resistance to late but not to early leaf spot (1) may have contributed to this occurrence. However, early leaf spot was evident throughout the state on all cultivars and represents a significant shift from previous years. Late leaf spot has been the predominant pathogen since the mid 1970s (25), but early leaf spot can also cause severe defoliation and yield loss. Although the models for early and late leaf spots are different, AU-Pnuts was effective on both diseases. Another late leaf spot advisory program (20) evaluated in 1993 did not detect at least one *Cercospora arachidicola* infection period, and substantial defoliation resulted (T. B. Brenneman, *unpublished*). The AU-Pnuts advisory system is a useful tool for scheduling foliar fungicide applications, although it resulted in only 1.3 fewer sprays per season.

Results from 1991 verified previous findings by Culbreath et al (10) concerning the susceptibility of Southern Runner to the peanut root-knot nematode. Although this cultivar has valuable resistance to several pathogens, such resistances may not be expressed when plants suffer severe nematode damage.

Other findings verified in this study were the effects of tebuconazole on peanut grades and the percentage of damaged kernels. Evaluations of peanuts treated with spray programs including four applications of tebuconazole compared to chlorothalonil alone have shown increases in grade (R. Rudolph, *unpublished*). In this study, the increase in grade with tebuconazole was most evident in 1991 and 1993. Due to rotational history, inoculum levels of *S. rolfsii* were lower in the field used in 1992, and stem rot incidence was much lower than in either the 1991 or the 1993 test (Fig. 1). The first pods set by the plant are the most mature and grade highest at harvest. Therefore, the loss of these pods to stem rot would result in lower grades. Tebuconazole would increase grades by inhibiting stem rot and preventing pod loss. During the 3-yr study, the nontreated plots had the highest grades. This was probably due to the late-season effects of leaf spot. Even though Southern Runner has a more indeterminant growth habit (12), defoliated plants probably would not have continued to set pods later in the season. These pods on fungicide-protected plants would have been less mature at harvest and thus contributed to lower grades.

Jacobi and Backman (13) reported a decrease in the percentage of damaged kernels in Florunner peanut treated with tebuconazole compared to those treated with chlorothalonil alone. Our data

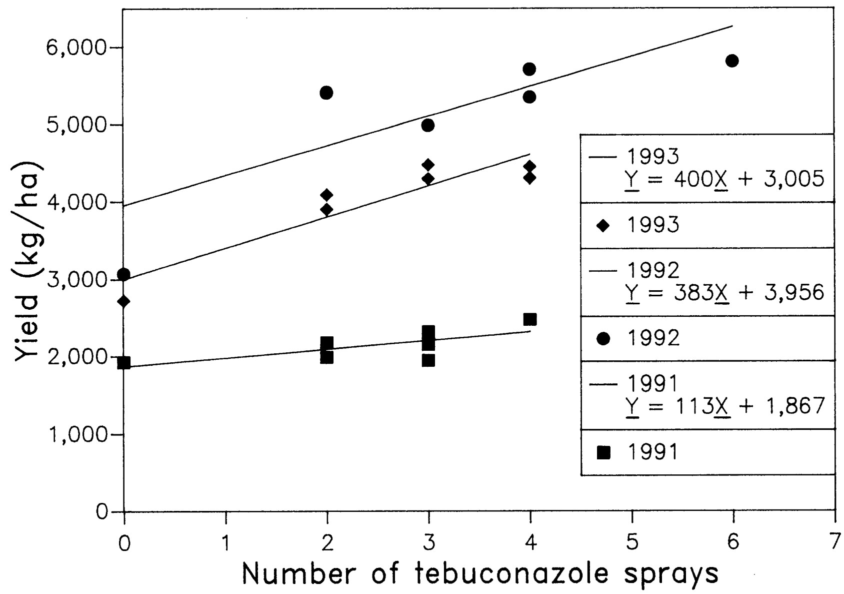

Fig. 2. Relationship between the number of tebuconazole sprays per season (0.25 kg/ha) and peanut yields. Correlation coefficients for 1991, 1992, and 1993 are 0.70, 0.79, and 0.92, respectively.

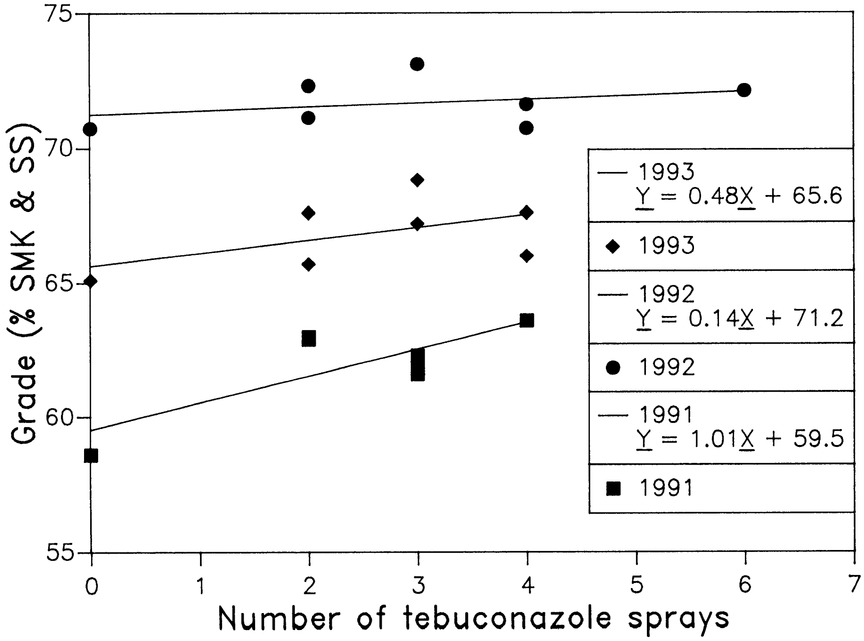

Fig. 3. Relationship between the number of tebuconazole sprays per season (0.25 kg/ha) and peanut grades (percent sound mature kernels and sound splits). Correlation coefficients for 1991, 1992, and 1993 are 0.78, 0.30, and 0.51, respectively.

Table 6. Crop value of Southern Runner peanut with 12 different fungicide regimes

Treatment[x]	Dollars/ton[y] 1991	1992	1993	Avg.	Dollars/ha[y] 1991	1992	1993	Avg.
Nontreated	539	652	685	625	1,152	2,220	2,057	1,810
Ctl, 14-day (1–7)[z]	513	668	621	601	1,039	3,696	2,372	2,369
Ctl, 14-day (1–7)[z] + PCNB	532	656	650	613	1,097	3,559	3,162	2,606
Ctl, 14-day (1, 2, 7)[z] + Teb, 14-day (3–6)	583	650	646	626	1,602	4,091	3,172	2,955
Ctl, 21- day (1, 5) + Teb, 21-day (2–4)	545	670	660	625	1,416	3,679	3,125	2,740
Ctl, 21-day	552	660	624	612	1,168	2,912	2,098	2,059
Ctl, AU-P full season	547	655	646	616	1,037	3,205	2,632	2,291
Ctl, AU-P early and late + Teb, AU-P midseason	543	657	639	613	1,168	3,877	3,154	2,733
Ctl, 14-day (1, 2) + Teb, AU-P (3, 4, etc.)	559	662	624	615	1,346	4,283	2,966	2,850
Ctl, 14-day (1, 2) + Ctl, AU-P (3, 4, etc.)	510	618	605	578	979	2,653	2,142	1,925
Ctl, AU-P (1, 4, 5, etc.) + Teb, AU-P (2, 3)	562	660	618	613	1,353	3,937	2,660	2,650
Ctl, AU-P (exc. 60 and 90 DAP) + Teb, 60 and 90 DAP	566	652	643	620	1,240	3,891	2,903	2,678
LSD ($P \leq 0.05$)	NS	NS	33		374	644	496	

[x] Ctl = chlorothalonil at 1.26 kg/ha, PCNB = pentachloronitrobenzene 5.60 kg/ha, Teb = tebuconazole at 0.25 kg/ha, and AU-P = sprays applied according to the AU-Pnuts advisory.
[y] Values were calculated from a 500-g pod sample per plot graded according to official Federal–State Inspection Service methods.
[z] Eight sprays were applied in 1992.

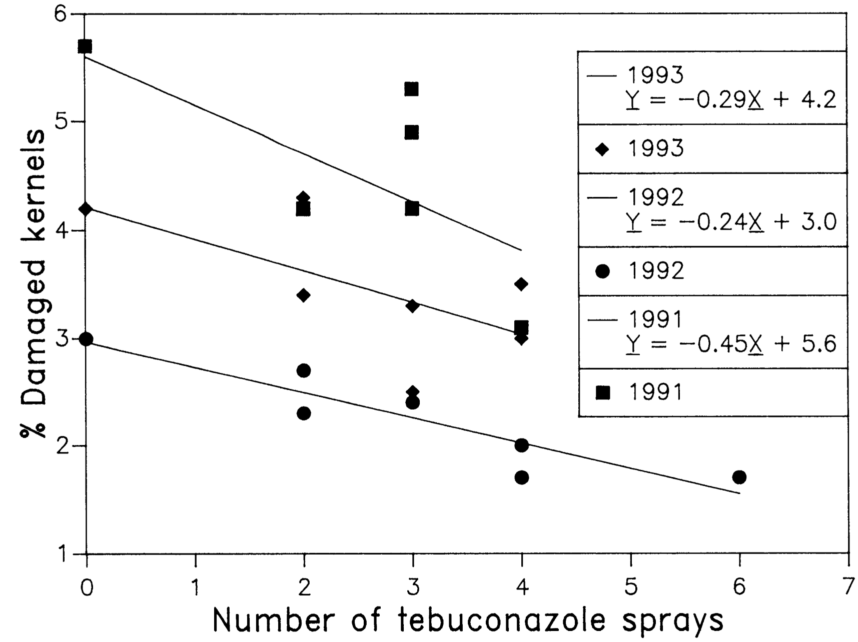

Fig. 4. Relationship between the number of tebuconazole sprays per season (0.25 kg/ha) and the percent damaged kernels. Correlation coefficients for 1991, 1992, and 1993 are 0.66, 0.92, and 0.64, respectively.

corroborate those findings and further show this effect to be cumulative with additional applications of tebuconazole. This trend was evident all 3 yr, even though Southern Runner may have fewer damaged kernels than Florunner (13). With deductions of $11, $25, $40, and $60 per ton for 4, 5, 6, and 7% damaged kernels, respectively, this could certainly alter the profit margin for growers. The mechanism by which tebuconazole reduces kernel damage is unknown, but it could be due in part to control of soilborne pathogens. Also, Chapin and Thomas (6) noted reduced pod damage from the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller)) and wireworms (Elateridae) where tebuconazole was used.

In 1992, the favorable conditions for both peanut growth and leaf spot development accentuated the effects of disease on yield. For example, a recommended reduced-input program for Southern Runner is a 21-day chlorothalonil schedule (12). However, in a leaf spot–conducive year like 1992, especially with early leaf spot present, this regime yielded 1,000 kg/ha less than plots treated on a 14-day schedule. This illustrates the importance of good management for optimizing the benefits of partial resistance. It also illustrates the necessity of scouting so that emerging problems can be corrected, particularly where reduced inputs are utilized.

The use of chlorothalonil alone resulted in an average return of $351 per hectare. The cost of seven sprays of chlorothalonil, including fungicide and application, is approximately $190 per hectare. The addition of PCNB to the chlorothalonil program resulted in an extra $445 of crop value at an additional cost of approximately $124 per hectare. Use of tebuconazole resulted in an average increased crop value of $607 per hectare compared to use of chlorothalonil alone. Since the cost of tebuconazole is not available, a complete economic analysis is not possible. However, it is apparent that the potential economic return is quite high. The economic returns of all treatments would be even higher if the unusually poor crop of 1991 were omitted from the analysis. With that scenario, the crop values per hectare would be $2,139, $2,714, $3,361, and $3,475 for all plots receiving no fungicide, chlorothalonil alone, chlorothalonil plus PCNB, or chlorothalonil plus tebuconazole, respectively.

Tebuconazole proved to be a valuable tool for management of both foliar and soilborne pathogens of peanut. Utilization of tebuconazole consistently resulted in improved control of leaf spot, both on the 14-day calendar program and the AU-Pnuts program. Tebuconazole affects several infection components of *Cercosporidium personatum* and moves systemically in peanut (18). The combined effects of improved leaf spot control and the reduction in stem rot resulted in significant yield increases (Fig. 2). In general, stem rot was more highly correlated with yield than was leaf spot. When yield was evaluated as a function of stem rot by linear regression, the correlation coefficient for all tests combined was −0.92 vs. −0.59 for leaf spot. There may have been a higher correlation for leaf spot in a more leaf spot–susceptible cultivar and if stem rot had been less severe.

The optimum number of tebuconazole applications to use in a given season remains to be determined. The manufacturer has requested a four-spray block program (19), while others have called for two or three sprays of a DMI (2). The results of this study suggest that improved disease control, pod yield, and kernel quality can be obtained with up to four applications. Certainly this would be a maximum-use scenario because of resistance concerns, and its practicality would depend on the cost/benefit analysis. These results were obtained in "worst case" scenarios of heavy disease pressure. In fields with high stem rot incidence, three or four applications may be needed regardless of leaf spot considerations. Growers using better crop rotations might obtain optimum yields with fewer applications of a DMI.

Tebuconazole showed great flexibility in spray scheduling while still maintaining good control of both foliar and soilborne pathogens. Although the early and late applications did not have as much impact on leaf spot or stem rot, no single rule-based system for incorporating tebuconazole into an advisory system was clearly the best for all situations. An advisory model for the soilborne pathogens would allow optimum efficacy of any DMI and perhaps fewer applications.

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