Effects of Application Timing and Method on Control of Southern Stem Rot of Peanut With Foliar-Applied Fungicides[1]

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ABSTRACT

Foliar-applied flutolanil, diniconazole, tebuconazole, and propiconazole were compared to granular PCNB for the control of southern stem rot (*Sclerotium rolfsii*) and their effects on yield of peanut in 1988 and 1989 in southeastern Alabama. Numbers of stem rot loci were significantly decreased and yields were increased in plots treated with banded and broadcast applications of flutolanil, diniconazole, and tebucnzole. While yields of flutolanil-, diniconazole-, and tebuconazole-treated plots were significantly higher than the PCNB-treated plots, efficacy of these fungicides in controlling southern stem rot differed only in one of two years. Banded applications of flutolanil gave similar disease control but yielded less than broadcast applications of the same fungicide. Disease control and yield response with propiconazole was comparable to that obtained with PCNB in one of two years and proved far less efficacious against stem rot than the other fungicides evaluated.

Key Words: *Arachis hypogaea, Sclerotium rolfsii*, groundnut, white mold, Terraclor, Folicur, Spotless, Tilt

Southern stem rot caused by *Sclerotium rolfsii* Sacc. is a common and damaging disease of peanut in Alabama (21). A minimum two-year rotation to crops that are not hosts for *S. rolfsii* has been one of the principle controls for southern stem rot (1, 12). Recent increases in Alabama's peanut acreage, a decline in the value of non-host crops, and diversion of a sizable acreage of tillable land into the Conservation Reserve Program have largely eliminated crop rotation as a practical control for southern stem rot for most peanut producers.

Southern stem rot on peanut has not been successfully controlled with pesticides. Pentachloronitrobenzene (PCNB), once a widely used treatment for this disease, generally reduces disease incidence up to 50% and gives modest yield increases when applied at the rate of 11.2 kg a.i./ha (8, 14, 15, 23). When formulated with an insecticide/nematicide, PCNB's efficacy against southern stem rot has generally been improved (6, 8, 9, 14, 15, 23). Acreage treated with PCNB or a PCNB + insecticide/nematicide combination product has declined in recent years due to concerns about fungicide efficacy, cost, and availability. Several organophosphate insecticides, particularly the granular formulation of chlorpyrifos, have been widely used on peanut in Alabama for suppression of southern stem rot. Product cost and activity against several damaging soil insect pests largely account for its widespread use by Alabama peanut producers. However, yield response in the absence of soil insect pests to these soil insecticides often has been inferior to that obtained with PCNB or a PCNB + insecticide/nematicide combination product (14, 15).

Fungicides with activity against southern stem rot, superior compared to that of PCNB, have recently been identified. Backman and Crawford (2) demonstrated that diniconazole or tebuconazole broadcast full season (7 applications, 14 day spray schedule) gave excellent control of southern stem rot, as well as early and late leaf spot, and consequently higher yields than the standard chlorothalonil leafspot control program. Similar results against leaf spot diseases and Rhizoctonia limb rot (*Rhizoctonia solani* Kuhn AG-4) have also been noted with these fungicides (3, 5, 10). Csinos *et al.* (10) and Kvien *et al* (19) also obtained excellent control of southern stem rot and significant yield increases with diniconazole applied once at flowering, early and mid-peg, or full season for leafspot control. Flutolanil, banded once or twice at early to mid-peg at rates of 1.12 to 5.6 kg a.i./ha directly over the row, gave superior disease control and yield response compared to PCNB, PCNB + ethoprop, or chlorpyrifos (7, 8). Csinos (8) has reported that narrow band applications of flutolanil and diniconazole gave better control of southern stem rot than broadcast treatments. Improved disease control with narrow band applications has been associated with concentration of the fungicide around the plant crown, where initial infections by *S. rolfsii* usually occur (8). Barnes *et al.* (3) and Csinos (7, 8) also noted a significant reduction in Rhizoctonia limb rot incidence on flutolanil-treated peanuts.

This report presents results of on-farm comparison of the foliar-applied triazole fungicides propiconazole, diniconazole, and tebuconazole, and the benzanilide fungicide flutolanil (20) which were evaluated for the control of southern stem rot of peanut and yield response with that of the granular PCNB. A preliminary report has been published (16).

Material and Methods

Peanuts (*Aachis hypogaea* L.) cv. Florunner were planted over a two week period from late April to early May 1988 and 1989, in five and three production fields, respectively. Each field has a history of southern stem rot. In all fields, a cover crop of rye (*Secale cereale* L.) was turned under with a moldboard plow prior to planting peanuts. Corn (*Zea mays* L.), grain sorghum (*Sorghum bicolor* L.), or cotton (*Gossypium hirtustum* L.) was cropped the year before peanuts. Soil types at the test sites were either an Orangeburg fine sandy loam (fine-loamy, siliceous, thermic Typic Palendults) or a Dothan sandy loam (fine-loamy, siliceous thermic Plinthic Plaendults). Tillage, fertility, weed control, insect control, and leafspot control recommendations of the Alabama Cooperative Extension Service were followed (11). Several fields each year were watered with a center pivot irrigation system. At all sites in 1988 and 1989, plots consisted of two 15.2 to 18.3 m long rows spaced 0.9-m row apart. Treatments were randomized in four complete blocks.

Diniconazole 25W (Valent, Richmond Calif.), tebuconazole 1.2E (Mobay Crop., Kansas City, Mo.), flutolanil 50W (Nor-Am Chemical, Wilmington Del.), and propiconazole 3.6E (Ciba-Giegy, Greensboro, N. C.), were evaluated at manufacturer suggested application rates for control of southern stem rot as foliar sprays. In 1988, diniconazole at 0.28 kg a.i./ha, tebuconazole at 0.25 kg a.i./ha, and flutolanil at 1.1 kg a.i./ha were banded over the row center with one D4-25 solid cone nozzle (Spray Systems, Wheaton, IL) in a spray volume of 94 l/ha.

[1]Journal Article no. 18-902748P of the Alabama Agricultural Experiment Station. This study was funded in part by the Alabama Peanut Producers Association.

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Propiconazole at 0.25 kg a.i./ha and the second flutolanil treatment at 1.1 kg a.i./ha in 1988 and diniconazole at 0.28 kg a.i./ha, tebuconazole at 0.25 ka a.i./ha, and flutolanil at 1.1 ka a.i./ha in 1989 were broadcast with three D2-25 solid cone nozzles per row at a spray volume of 140 l/ha. In both years, applications were made approximately 70 and 90 days after planting (growth stages R4 and R6 (4)). In 1989, propiconazole at 0.17 kg a.i./ha was applied on the same schedule as the other fungicides using two TX-12 hollow cone nozzles mounted on a drop nozzle rig set to run 5 - 10 cm below the top of the peanut canopy at a rate of 140 l/ha spray volume centered over the row on a 25 cm band on the soil surface. At each site, PCNB 10G (Terraclor 10G, Uniroyal Chemical, Raleigh, N.C.) at 11.2 kg a.i./ha was applied once with a 10 cm bander on a 30 cm band width centerd over the row with a two-row Gandy granular applicator approximately 80 to 90 days after planting (growth stage R5-R6). The spray adjuvant X-77 (Valent) (0.25% v/v) was tank-mixed with diniconazole and propiconazole while tebuconazole was tank-mixed (0.25% v/v) with the spray adjuvant Induce (Helena Chemical, Memphis, Tenn.).

At a single site in 1988, treatments were: diniconazole broadcast six times (full season) at 0.08 kg a.i./ha and one to three times at mid-season at 0.28 kg a.i./ha; flutolanil broadcast six times (full season) at 0.34 kg a.i./ha; flutolanil broadcast and banded at 2.2 kg a.i./ha once and 1.1 kg a.i./ha twice. Applications were made with a CO_2 pressurized backpack sprayer with a two-row boom using either a single D4-25 solid cone nozzle delivering 94 l/ha directly over the row center for an effective band width of 45 cm for banded treatments or three D2-25 solid cone nozzles per row delivering 140 l/ha for broadcast applications. Leaf spot control was maintained with chlorothalonil 6F (Bravo 720, Fermenta ASC Plant Protection, Paynesville, OH) broadcast at 1.24 kg a.i./ha using three solid cone D2-25 nozzles per row in 140 l/ha except in the full-season diniconazole-treated plots. Chlorothalonil applications were also omitted when the mid-season diniconazole applications were scheduled. Application dates for the full-season spray programs were June 23, July 8, July 21, August 3, August 17, and August 31. The spray adjuvant X-77 (0.25% v/v) was tank-mixed with diniconazole. Water was applied by a center pivot irrigation system as needed.

At a single site in 1989, broadcast applications of a chlorothalonil + flutolanil formulation (ASC 66783, Fermenta ASC Plant Protection) at 0.22 + 0.83, 0.33 + 1.24, and 0.67 + 2.48 kg a.i./ha of flutolanil + chlorothaloil, diniconazole at 0.28 kg a.i./.ha, tebuconazole at 0.25 kg a.i./ha, PCNB at 11.2 kg a.i./ha, propiconazole at 0.25 kg a.i./ha, and propiconazole applied on an effective band width of 45 cm at 0.17 kg a.i./ha, were evaluated for control of southern stem rot. The banded and broadcast applications were made on June 16, June 23, July 5, July 18, August 1, and August 10. A two-row Gandy applicator was used to apply PCNB on July 18. Leafspot control was maintained with chlorothalonil 6F broadcast as described above. Chlorothalonil was not applied to those plots scheduled to be treated with broadcast sprays of diniconazole, tebuconazole, and propiconazole. The spray adjuvant X-77 (0.25% v/v) was tank-mixed with diniconazole. Water was applied by an overhead irrigation system as needed.

Counts of southern stem rot loci per 30 m row (1 locus was defined as ≤ 30 cm of consecutive stem rot damaged plants in a row (21) were made after the peanuts were inverted about 140 days after planting. Plots were harvested five to 14 days later and yields were adjusted to 10% moisture. Data from treatments that were similar between sites and years were analyzed as a split plot with sites*year as the largest experimental unit. Analysis of variance were performed on southern stem rot loci and yield data. For the multiple sites in 1988 and 1989, the interaction between years, sites, and treatments was found to be significant ($P<0.05$). Analyses of variance were then done on data from each year. Not all treatments were included at all sites in each year of the study. However, if the interaction term of sites by treatment was not significant ($P>0.05$), then those treatments not included at all sites were assumed to behave similarly to those that were included. Analyses were also performed separately on the single site studies both years, since different treatments were included in these. Where a significant ($P<0.05$) treatment effect was observed, Fisher's protected least significant difference (LSD) was calculated for comparing treatment means (22).

Results

All fungicides significantly reduced the incidence of southern stem rot across five locations in 1988 as compared with the control (Table 1). Disease loci counts in the diniconazole-treated plots were significantly lower than in those treated with PCNB and propiconazole but not the other fungicide treatments. PCNB gave similar disease control as tebuconazole and both the banded and broadcast flutolanil treatments. No difference in disease incidence was noted between the broadcast and banded flutolanil treatments. Treatment with propiconazole resulted in the highest disease incidence.

Table 1. Summary of results with several experimental fungicides compared with PCNB for the control of southern stem rot and yield response on peanut across five sites in 1988.

Treatment and rate* (kg a.i./ha)	Application methods**	Disease loci no./30 m row	Yield kg/ha
Diniconazole 0.28	NB	3.9	4306
Flutolanil 1.1	BR	4.6	4293
Flutolanil 1.1	NB	6.1	3927
Tebuconazole 0.25	NB	5.4	4462
Propiconazole 0.25	NB	9.0	3172
PCNB 11.2	-	6.7	3845
Control	-	12.4	3454
LSD (P=0.05)***		2.2	336

*Applied 70 and 90 days after planting except PCNB, which was applied once 70 days after planting (Number of applications in parenthesis). **Foliar application method: NB=narrow band, BR=broadcast. ***Mean separation within columns according to Fisher's protected least significance difference (LSD) test (22).

Yields of the fungicide-treated plots, except those treated with propiconazole, were significantly higher than the control (Table 1). Yields from plots treated with diniconazole, tebuconazole, and the broadcast application of flutolanil were significantly higher than those from the PCNB-treated plots. Similar yields were obtained with the banded flutolanil treatment and PCNB. The broadcast application of flutolanil resulted in higher yields than the plots receiving banded applications of flutolanil. Yields from the propiconazole-treated plots were below those recorded for the other fungicide treatments and the control. The interaction term of site*treatment was not significant for disease loci ($P=0.61$) and yield ($P=0.67$), thereby allowing combination of data across sites.

Across three sites in 1989, significant reductions in the incidence of southern stem rot were obtained with flutolanil, diniconazole, and tebuconazole, but not with PCNB and propiconazole when compared to the control (Table 2). Numbers of disease loci in the diniconazole-, tebuconazole-, and flutolanil-treated plots were the same. Numbers of disease loci did not differ significantly between the PCNB, propiconazole-treated plots and control.

Yield responses from the different treatments were similar to levels of disease control (Table 2). Yields from diniconazole-, tebuconazole-, and flutolanil-treated plots were significantly greater than the control. Differences in yield among diniconazole-, tebuconazole-, and flutolanil-treated plots were not significant. Yields from the PCNB-treated plots were significantly higher than those from the propiconazole-treated plots but not the non-treated control. The interaction term for site*treatment was not significant with ($P=0.34$) or yield ($P=0.08$), so data was combined for both parameters over all locations.

In the single site study in 1988, a significant reduction in stem rot incidence compared with the non-treated control was provided by diniconazole and flutolanil applied full season (6 applications, 14 day spray schedule) (Table 3).

Table 2. Comparison of several experimental fungicides with PCNB for the control of southern stem rot and effect on peanut yield summarized across three sites in southeastern Alabama, 1989.

Treatment and rate* (kg a.i./ha)	Application method**	Disease loci no. 30 m row	Yield kg/ha
PCNB 11.2	-	10.0	4237
Propiconazole 0.17	NB	10.0	3817
Flutolanil 1.1	BR	2.1	4615
Diniconazole 0.28	BR	1.3	4857
Tebuconazole 0.25	BR	2.8	4962
Control	-	14.2	4095
LSD (P=0.05)***		5.2	353

*Applied 70 and 90 days after planting except PCNB, which was applied once about 70 days after planting (Number of applications in parenthesis). **Foliar application method: NB=narrow band, BR= broadcast. ***Mean separation within columns according to Fisher's protected least significance difference (LSD) test (22).

Disease loci counts were also reduced in plots receiving one or two applications of diniconazole and one banded or two broadcast applications of flutolanil compared to the control. Diniconazole applied full season did not provide significantly better disease control than one to three mid-season applications of the same fungicide. Of the plots treated in mid-season with flutolanil, only those receiving two banded applications failed to reduce stem rot incidence as well as flutolanil applied full season.

Yields from plots treated full season with diniconazole were higher than those receiving one or three mid-season applications of diniconzaole (Table 3). Only yields in the plots treated twice with diniconazole were similar to those treated full season with diniconazole. Yields of the plots treated full season with flutolanil were not significantly different from those of the other flutolanil treatments. Similar yields were obtained with single and multiple mid-season applications of diniconazole and for all treatments receiving flutolanil.

In the single site study in 1989, diniconazole, tebuconazole, and all rates of the flutolanil + chlorothalonil significantly reduced stem rot incidence compared to the control (Table 4). No significant differences in the numbers of disease loci were noted among the diniconazole-, tebuconazole-, and

Table 3. Evaluation of diniconazole and flutolanil for the control of southern stem rot and ffect on peanut yield at single site in southeastern Alabama in 1988.

Treatment and rate* (kg a.i./ha)	Application method**	Disease loci no./30 m row	Yield kg/ha
Diniconazole 0.08(1-6)	BR	1.3	4292
Diniconazole 0.28(4)	NB	5.0	3440
Diniconazole 0.28(3,5)	NB	4.8	3742
Diniconazole 0.28(2,4,6)	NB	6.3	3355
Flutolanil 0.34(1-6)	BR	2.3	4139
Flutolanil 2.2(4)	BR	8.3	3725
Flutolanil 1.1(3,5)	BR	4.5	3994
Flutolanil 2.2(4)	NB	5.8	3768
Flutolanil 1.1(3,5)	NB	9.5	3608
Non-treated Control	-	12.9	2853
LSD (P=0.05)***		6.7	673

*Treatment dates: 1=June 23, 2=July 8, 3=July 21, 4=Aug. 3, 5=Aug. 17, 6=Aug. 31. **Foliar application method: NB=narrow band, BR=broadcast. ***Mean separation within columns according to Fisher's protected least significance difference (LSD) test (22).

flutolanil + chlorothalonil-treated plots. Disease loci counts in the plots treated with banded or broadcast sprays of propiconazole or PCNB did not differ from the control. Only yield from the flutolanil + chlorothalonil-treated plots was significantly higher than the control.

Table 4. Comparison of several fungicides and method of application with PCNB for the control of southern stem rot and effect on yield of peanut in southeastern Alabama, 1989.

Treatment and rate* (kg a.i./ha)	Application method**	Disease loci no./30 m row	Yield kg/ha
PCNB 11.2(4)	-	8.3	5341
Diniconazole 0.28(4,5)	BR	1.3	5552
Tebuconazole 0.25(4,5)	BR	2.8	5653
Propiconazole 0.28(4,5)	BR	10.1	5372
Propiconazole 0.22(4-6)	NB	10.0	5077
Flutolanil 0.22 + Chlorothalonil 0.83(4-6)	BR	3.4	5733
Flutolanil 0.33 + Chlorothalonil 1.24(4-6)	BR	2.3	5708
Flutolanil 0.67 + Chlorothalonil 2.48(4,6)	BR	1.3	5894
Control	-	12.8	4980
LSD (P=0.05)***		5.3	675

*Spray dates: 1=June 16, 2=June 23, 3=July 5, 4=July 18, 5=Aug. 1, 6=Aug. 10. **Foliar application method: NB=narrow band, BR=broadcast. ***Mean separation within columns according to Fisher's protected least significance difference (LSD) test (22).

Rhizoctonia limb rot was observed at two irrigated locations in 1988 and one in 1989. Disease development in the plot area was associated with significant limb damage caused by excess spray equipment traffic. No reduction in disease was associated with any fungicide treatment (data not shown). Outbreaks of early and late leafspot were not observed at any location either year.

Discussion

Reductions in southern stem rot incidence and yield loss with partial and full season (6 applications, 14 day spray schedule) programs of diniconazole, flutolanil, and tebuconazole were similar to those reported in previous studies (2, 3, 7, 8, 7, 10, 17, 19). Backman and Crawford (2) and Csinos *et al.* (10) showed that control of southern stem rot and increased yields were obtained with full season programs employing diniconazole. Control of southern stem rot obtained in this study with flutolanil broadcast full season was similar to that noted by Csinos (7). Banded and broadcast applications of propiconazole was generally less efficacious against southern stem rot than the other fungicides evaluated other than PCNB.

The risk of a complete control breakdown with sterol biosynthesis-inhibiting morpholine, pyrimidine, and triazole fungicides may be overstated (13, 18). However, concern about the development of fungicide resistance in the fungi that cause early and late leafspot may limit the number of mid to late season applications of triazole fungicides from two to four. Results of this study agree with those of Csinos (8), Csinos *et al.* (10), and Kvien *et al.* (19) in that one to three applications of diniconazole between flowering and late-pegging resulted in improved control of stem rot than the current fungicide standard, PCNB. Csinos (7) and Jacobi and Backman (17) also noted reductions in southern stem rot incidence with one or two mid-peg applications of flutolanil. In these studies, better southern stem rot control was provided by two at-peg applications of tebuconazole than previously reported by Jacobi and Backman (17). Therefore, late season applications of some of these fungicides may not be required protect peanuts from southern stem rot damage.

Reductions in disease incidence obtained with flutolanil, diniconazole, and tebuconazole generally were associated with higher yields and generally, those yields were similar. Similar yields were recorded with flutolanil applied full season and twice at-pegging time. Csinos (7) also noted significant yield increases over the control with single or split applications of flutolanil. Yield response with one or more mid-season applications of diniconazole and tebuconazole were similar to previously reported results (3, 8, 10, 17).

Few direct comparisons of yield responses from diniconazole, tebuconazole, and flutolanil with those of PCNB have been reported (7). Our results confirmed those of Csinos (7) that plots treated with flutolanil generally have higher yields than those treated with PCNB. Yields from diniconazole- and tebuconazole- treated plots were also significantly higher than those treated with PCNB. Yields were also increased over those from the PCNB-treated plots by broadcast, but not banded, applications of the flutolanil in 1988. Plots treated with the three rates of the flutolanil + chlorothalonil combination product also did not result in improved yield than those treated with PCNB in the 1989 single site study. Barnes *et al.* (3) noted similar yields from plots treated with single and split applications of diniconazole, flutolanil, and PCNB + ethoprop.

Fungicide placement did not have a clear impact on disease control or yield. Csinos (8) noted that narrow band width (10 cm) applications of flutolanil and diniconazole proved more effective than wider band widths. In both 1988 studies, however, broadcast applications of flutolanil controlled stem rot as effectively as directed sprays. In 1988 multi-site study, yields where flutolanil was broadcast were higher than where banded. Differences in yields noted in these studies may be due to the use of a narrower band width by Csinos (8) or control of Rhizoctonia limb rot.

Despite the modest advantage in stem rot control in some studies (8) by banded over broadcast fungicide applications, broadcast applications are more likely to be accepted by farmers because they can employ existing spray equipment. In addition, broadcast applications would also permit farmers to take maximum advantage of the broad-spectrum disease control offered by diniconazole, flutolanil, and tebuconazole. Banded fungicide applications would also require additional trips which could injure peanut vines, thereby resulting in higher yield loss due to soil compaction and increasing the incidence of Rhizoctonia limb rot (5).

In summary, diniconazole, flutolanil, and tebuconazole have greater potential to reduce the widespread and often damaging southern stem rot outbreaks in Alabama's peanut crop than PCNB and propiconazole. Broadcast applications a benzanilide and several triazole fungicides proved surprisingly effective in reducing the incidence of southern stem rot and increasing peanut yield.

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Accepted March 2, 1991