Tank-Mix Applications of Cyproconazole and Chlorothalonil for Control of Foliar and Soilborne Diseases of Peanut

A. K. CULBREATH and T. B. BRENNEMAN, Department of Plant Pathology, University of Georgia, Coastal Plain Experiment Station, Tifton 31793-0748; F. M. SHOKES, Department of Plant Pathology, University of Florida Research and Education Center, Quincy 32351; A. S. CSINOS, Department of Plant Pathology, University of Georgia, Coastal Plain Experiment Station, Tifton 31793-0748; and H. S. McLEAN, Sandoz Agro North America, Inc., Cordele, GA 31015

ABSTRACT

Culbreath, A. K., Brenneman, T. B., Shokes, F. M., Csinos, A. S., and McLean, H. S. 1992. Tank-mix applications of cyproconazole and chlorothalonil for control of foliar and soilborne diseases of peanut. Plant Dis. 76:1241-1245.

Field tests were conducted during 1989–1991 at Tifton and Plains, Georgia, and Marianna, Florida, to evaluate the efficacy of full-season applications of tank-mix combinations of cyproconazole at rates of 0.062 kg a.i./ha and 0.093 kg a.i./ha with chlorothalonil at 0.63 kg a.i./ha for control of late leaf spot, caused by *Cercosporidium personatum*; southern stem rot, caused by *Sclerotium rolfsii*; and Rhizoctonia limb rot, caused by *R. solani*, of peanut (*Arachis hypogaea*). In all years and locations, tank mixes with both rates of cyproconazole controlled leaf spot as well as or better than chlorothalonil alone. In nine of 11 trials, the incidence of southern stem rot was lower in plots treated with the high rate of cyproconazole tank mix than in plots treated with 1.26 kg a.i./ha of chlorothalonil alone. In 1989 and 1990, the incidence of stem rot in plots treated with the high rate cyproconazole tank mix was significantly lower ($P \leq 0.05$) than that of plots treated with chlorothalonil plus pentachloronitrobenzene (PCNB) at 5.6 kg a.i./ha applied 60–70 days after planting. Severity of Rhizoctonia limb rot varied greatly but was lower ($P \leq 0.05$) in at least one tank-mix treatment than with chlorothalonil alone or with chlorothalonil plus PCNB in both 1989 and 1990. In nine of 11 trials, control of the soilborne diseases with one or both cyproconazole treatments resulted in yield increases compared with treatments of chlorothalonil alone. Yields were higher in tank-mix treatments of cyproconazole plus chlorothalonil than in those of chlorothalonil plus PCNB in two of three trials.

Late leaf spot, caused by *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, and early leaf spot, caused by *Cercospora arachidicola* S. Hori, of peanut (*Arachis hypogaea* L.) are serious problems in most peanut-producing areas of the world. Control of these diseases in the southeastern United States is achieved mainly by multiple applications of the fungicide chlorothalonil. Chlorothalonil provides excellent leaf spot control but has little effect on soilborne diseases, including southern stem rot caused by *Sclerotium rolfsii* Sacc. (1,10,17). Currently registered fungicides for control of stem rot provide marginal and inconsistent control (8,9). Several experimental fungicides classified as ergosterol biosynthesis inhibitors (EBIs) are active against *C. personatum, S. rolfsii* (3–5,9,10,11), and *Rhizoctonia solani* Kühn anastomosis group 4 (AG-4) (3,4,8).

Development of resistance or decreased sensitivity to the EBIs in pathogen populations, particularly in *C. personatum* and *C. arachidicola*, is a major concern, and regimes including alternating applications and the use of tank mixes are being considered for resistance management (3,14). The availability of the protectant fungicide chlorothalonil provides several options for resistance management and control of foliar pathogens. However, where control of soilborne pathogens is also sought, timing of the EBI applications must coincide with infection periods of these fungi. Brenneman and Murphy (3) reported control of late leaf spot, southern stem rot, and Rhizoctonia limb rot with the EBI fungicide tebuconazole applied alternately with chlorothalonil. Tank-mix applications of EBI fungicides with chlorothalonil represent another strategy for resistance management. This strategy offers the advantage of making possible premix products to ensure compliance with resistance management regimes in the field. It also allows repeated applications of the EBI fungicide, thus eliminating the uncertainty associated with timing fewer sprays for optimal control of soilborne pathogens.

Cyproconazole is an experimental EBI fungicide that has shown promise for control of diseases caused by several foliar and soilborne pathogens, including *C. personatum* and *S. rolfsii* in peanut (14). The purpose of this study was to determine the efficacy of cyproconazole in tank-mix applications with chlorothalonil for control of late leaf spot, southern stem rot, and Rhizoctonia limb rot.

Accepted for publication 28 July 1992.

MATERIALS AND METHODS

Leaf spot tests. Experiments were conducted at the Gibbs Farm, University of Georgia Coastal Plain Experiment Station, Tifton, and at the University of Florida, North Florida Research and Education Center, Marianna, in 1989, 1990, and 1991, and at the Southwest Georgia Branch Station, Plains, in 1990 and 1991. Soil types at the Tifton, Plains, and Marianna sites were, respectively, Tifton loamy sand, Greenville loamy sand, and Chipola loamy sand. The Tifton field used in 1989 had been planted to cotton (*Gossypium hirsutum* L.) the previous year. In 1990, the field at Tifton had been fallow the previous year, whereas the field at Tifton in 1991 and all fields at Plains had been planted to peanut the previous year. Test sites at Marianna were planted to either corn (*Zea mays* L.) or grain sorghum (*Sorghum bicolor* (L.) Moench) the previous year. The most widely planted runner-type peanut cultivar, Florunner (100.8 kg of seed per hectare), was used in all tests. Planting dates were 18 May 1989, 15 May 1990, and 21 May 1991 at Tifton; 15 May 1989, 11 May 1990, and 8 May 1991 at Marianna; and 1 May 1990 and 23 May 1991 at Plains. Each replication consisted of two rows spaced 0.9 m apart at Tifton and Marianna and 0.75 m apart at Plains, with rows on a 1.8-m bed. Plot length was 7.6 m at Tifton and Plains and 6.1 m at Marianna. A randomized complete block design with four replications was used in all experiments. Plots were separated by two unsprayed border rows and by a 2.4-m fallow alley.

Treatments consisted of: untreated control; chlorothalonil at 1.26 kg a.i./ha (Bravo 720); chlorothalonil at 0.63 kg a.i./ha plus cyproconazole (SAN 619 100 SL) at 0.062 kg a.i./ha (low-rate tank mix); and chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.099 kg a.i./ha (high-rate tank mix).

Fungicides were applied on a 14-day schedule, with initial applications on 13 June 1989, 18 June 1990, and 21 June 1991 at Tifton; on 26 June 1989, 18 June 1990, and 14 June 1991 at Marianna; and on 2 June 1990 and 18 June 1991 at

Plains. At Tifton and Plains, fungicides were applied with a CO_2-powered cart-mounted sprayer with three D2-13 hollow-cone spray nozzles per row. Fungicides were applied with the equivalent of 114 L of water per hectare at 345 kPa. At Marianna, fungicides were applied with the equivalent of 234 L of water per hectare at 310 kPa with a tractor-mounted boom sprayer, with three D3-25 hollow-cone nozzles per row or with a similarly equipped CO_2-powered backpack sprayer. Leaf spot assessments were made on 15 September 1989, 25 September 1990, and 26 September 1991 at Tifton; on 21 September 1989, 24 September 1990, and 19 September 1991 at Marianna; and on 26 September 1990 and 27 September 1991 at Plains. A 1–10 scale was used, in which 1 = no spots and 10 = complete defoliation by leaf spot, resulting in death (6). Plants were dug and inverted on 2 October 1989, 25 September 1990, and 26 September 1991 at Tifton; on 8 September 1989, 24 September 1990, and 20 September 1991 at Marianna; and on 26 September 1990 and 27 September 1991 at Plains. Immediately after inverting, visual estimates of the percent of the vines colonized and damaged by Rhizoctonia limb rot were made at six 0.6-m sections of linear row per plot. The number of southern stem rot loci per row were determined for each plot, where a locus represented 30.5 cm or less of linear row with one or more plants diseased (15). These ratings were subsequently converted to a percentage of 30.5-cm sections of linear row with at least one disease locus. Plots were mechanically harvested on 10 October 1989, 5 October 1990, and 11 October 1991 at Tifton; on 31 September 1989, 27 September 1990, and 23 September 1991 at Marianna; and on 2 October 1990 and 4 October 1991 at Plains.

Data were analyzed across locations within each year by analysis of variance. Fisher's protected LSD (19) values were calculated for mean separations. Differences referred to in the text are significant ($P \leq 0.05$) unless otherwise specified.

Stem rot tests. Tests were conducted in 1989, 1990, and 1991 at the Gibbs Farm, in a field location that had been planted to peanut each year since the early 1980s and was known to have high populations of both *S. rolfsii* and *R. solani*. The peanut cultivar Florunner (100.8 kg of seed per hectare) was planted on 16 May 1989, 11 May 1990, and 17 May 1991. A randomized complete block design with four replications was used, each consisting of two rows 0.9 m apart and 7.6 m long in all three years. Treatments consisted of applications of: 1) chlorothalonil at 1.26 kg a.i./ha; 2) chlorothalonil at 1.26 kg a.i./ha plus two applications of pentachloronitrobenzene (PCNB) (Terraclor 10G) at 5.6 kg a.i./ha plus either terbufos (Counter 15G) at 2.24 kg a.i./ha or ethoprop (Mocap) at 1.68 kg a.i./ha; 3) chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.062 kg a.i./ha; and 4) chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.099 kg a.i./ha. In 1991, rate of cyproconazole was 0.084 kg a.i./ha in the fourth treatment regime. Sprays were applied at 14-day intervals beginning on 23, 13, and 21 June of 1989, 1990, and 1991, respectively. Sprays were applied with a CO_2-powered backpack sprayer with three D2-25 disk-core nozzles per row. Fungicides were applied in the equivalent of 187 L/ha. PCNB was applied 60–70 days after planting in a 10–15 cm band, using only the drop tube of a granule applicator positioned over the center of the row. No spreader plate was employed. Plants were dug and inverted on 9, 1, and 2 October in 1989, 1990, and 1991, respectively. Immediately after inverting, estimates of percent of vines with limb rot and incidence of southern stem rot were made as previously described. Results were analyzed across years by analysis of variance. Fisher's protected LSD (19) was calculated for mean separation.

RESULTS

Leaf spot tests, 1989. Location–treatment interaction effects on leaf spot severity and defoliation ratings were significant in all three years. Therefore, results are reported for individual locations. At both locations in 1989, plants treated with chlorothalonil alone or with tank-mix combinations of chlorothalonil and cyproconazole had final leaf spot ratings lower than those in untreated plots (Table 1). No significant differences occurred among chlorothalonil or tank-mix treatments at Tifton, but leaf spot ratings for both tank-mix treatments were lower than those of chlorothalonil alone at Marianna (Table 1). Stem rot incidence and limb rot ratings were generally lower for the tank-mix treatments than for chlorothalonil alone; differences among the fungicide treatments were not significant. Pod yields were greater for plots treated with either tank-mix combination of chlorothalonil and cyproconazole than for chlorothalonil alone at both locations (Table 1). Differences in yield between the two tank-mix treatments were not significant.

Leaf spot tests, 1990. At all locations, leaf spot ratings were lower for plots treated with chlorothalonil or either tank mix of chlorothalonil and cyproconazole than for unsprayed plots. No differences in leaf spot severity and defoliation occurred among the chlorothalonil or tank-mix treatments at Tifton or Plains, but at Marianna, leaf spot was less severe on plants treated with chlorothalonil at 0.63 kg a.i./ha plus cyproconazole 0.099 at kg a.i./ha than on plants treated with chlorothalonil alone (Table 2). At all sites, stem rot incidence was lower for plots treated with either cyproconazole plus chlorothalonil tank mix than with chlorothalonil alone. No difference among treatments occurred for Rhizoctonia limb rot severity at Tifton. Levels of limb rot in the Plains test were too low to allow treatment comparisons. At Marianna, limb rot was less severe in plots treated with either tank mix than with chlorothalonil alone. No difference in severity occurred between the two tank-mix treatments. Yields of plots treated with chlorothalonil alone were higher than those of untreated plots at the three locations. At Tifton, plots treated with either tank-mix treatment had pod yields higher than those treated with chlorothalonil alone, whereas yields from those three treatments were similar at the Plains site (Table 2). At Marianna, plots treated with chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.062

Table 1. Effect of chlorothalonil and cyproconazole applied in combination as tank mixes for control of late leaf spot, caused by *Cercosporidium personatum*; southern stem rot, caused by *Sclerotium rolfsii*; and Rhizoctonia limb rot, caused by *R. solani*, on peanut at Tifton (T), Georgia, and Marianna (M), Florida, in 1989

Treatment	Rate (kg a.i./ha)	Leaf spot[a]		Stem rot[b]		Limb rot[c]		Yield (kg/ha)	
		T	M	T	M	T	M	T	M
Untreated	...	9.5	8.8	...[d]	26.2	...[d]	11.3	742	2,424
Chlorothalonil	1.26	1.6	3.4	26.6	12.6	30.0	4.0	2,570	6,238
Chlorothalonil + cyproconazole	0.65 + 0.062	1.4	2.5	15.6	5.0	35.8	3.5	3,622	7,444
Chlorothalonil + cyproconazole	0.65 + 0.099	1.4	2.4	11.0	3.8	22.7	3.8	3,789	7,458
LSD ($P \leq 0.05$)		1.3	0.6	16.4	10.0	21.5	5.8	599	1,120

[a] Based on Florida 1–10 scale, where 1 = no leaf spot and 10 = plants completely defoliated and killed by leaf spot. Assessment dates were 15 September at Tifton and 21 September at Marianna.

[b] Percentage of 30.5-cm sections of linear row per plot, with at least one disease locus rated immediately after inverting peanuts. Assessment dates were 2 October at Tifton and 28 September at Marianna.

[c] Rhizoctonia limb rot, measured as visual estimate of percentage of vines colonized by *R. solani* at six 0.6-m sections of linear row per plot immediately after inverting peanuts. Assessment dates were 2 October at Tifton and 28 September at Marianna.

[d] Not rated, because of severe defoliation and/or death of plants as a result of uncontrolled leaf spot.

kg a.i./ha had yields higher than plots treated with chlorothalonil alone.

Leaf spot tests, 1991. Leaf spot ratings for all three fungicide treatments were lower than for untreated plots at all locations (Table 2). Leaf spot ratings of both tank-mix treatments were lower than those of the chlorothalonil treatment at all locations (Table 2). Incidence of stem rot was reduced significantly by the tank mix containing the higher concentration of cyproconazole at Tifton, but both tank-mix treatments had lower incidence of stem rot than the chlorothalonil treatment in the Plains and Marianna tests (Table 2). Only the Marianna test had significant levels of rhizoctonia limb rot. Limb rot severity ranked lower for either tank-mix treatment than chlorothalonil alone, but differences among treatments were not significant.

Yields in all three fungicide treatments were higher than those of untreated plots at all locations (Table 2). Pod yield of plots treated with either tank mix was higher than that of chlorothalonil-treated plots at Marianna (Table 2). At Tifton, the yield of plants treated with chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.099 kg a.i./ha was higher than that of the other tank-mix treatment or chlorothalonil alone. Yields did not differ significantly between the tank-mix treatments at Plains or Marianna.

Stem rot tests. Year–treatment interactions were significant for stem rot incidence, limb rot severity, and pod yield. Therefore, data are presented for each year.

Fewer stem rot loci occurred in chlorothalonil plus PCNB plots than those treated with chlorothalonil alone in 1990, but incidence of stem rot for this treatment did not differ from that of chlorothalonil alone in 1989 or 1991 (Table 3). Incidence of stem rot was lower in both tank-mix treatments than chlorothalonil alone in all three years. Fewer stem rot loci occurred in either tank-mix treatment than in the chlorothalonil plus PCNB treatment in 1989. In 1990, only the tank-mix treatment consisting of chlorothalonil at 0.63 kg a.i. plus cyproconazole at 0.099 kg a.i. had fewer stem rot loci than the chlorothalonil plus

Table 2. Effect of chlorothalonil and cyproconazole applied in combination as tank mixes for control of late leaf spot, caused by *Cercosporidium personatum*; southern stem rot, caused by *Sclerotium rolfsii*; and Rhizoctonia limb rot, caused by *R. solani*, on peanut diseases at Tifton (T) and Plains (P), Georgia, and Marianna (M), Florida, in 1990 and 1991

		Rate	Leaf spot[a]			Stem rot[b]			Limb rot[c]			Yield (kg/ha)		
Year	Treatment	(kg a.i./ha)	T	P	M	T	P	M	T	P	M	T	P	M
1990	Untreated	...	9.2	6.9	9.2	25.6	29.6	13.8	...[d]	...[e]	8.8	2,563	3,498	2,335
	Chlorothalonil	1.26	2.2	1.6	2.4	28.6	30.6	18.8	27.5	...	5.8	3,717	4,650	5,072
	Chlorothalonil + cyproconazole	0.65 + 0.062	2.1	1.1	1.8	7.0	8.0	5.6	23.8	...	2.2	4,792	4,201	6,271
	Chlorothalonil + cyproconazole	0.65 + 0.099	2.1	1.1	1.6	5.6	7.0	6.2	19.0	...	1.5	5,024	4,381	5,780
LSD ($P \leq 0.05$)			0.7	0.6	0.6	9.2	6.6	7.8	26.6	...	3.1	781	528	1,007
1991	Untreated	...	10.0	8.8	9.1	...[d]	37.6	...[d]	...[e]	...[e]	...[d]	1,869	1,528	2,257
	Chlorothalonil	1.26	1.7	4.4	5.6	21.6	20.0	25.6	...	...	7.0	4,038	3,681	4,614
	Chlorothalonil + cyproconazole	0.65 + 0.062	1.1	1.8	2.0	9.0	6.0	9.6	...	...	2.8	4,055	4,461	6,363
	Chlorothalonil + cyproconazole	0.65 + 0.099	1.2	1.5	2.1	3.6	3.6	5.0	...	...	3.5	4,957	4,737	6,291
LSD ($P \leq 0.05$)			0.2	1.1	0.9	16.2	9.2	5.8	...	...	11.3	611	625	701

[a]Based on Florida 1–10 scale, where 1 = no leaf spot and 10 = plants completely defoliated and killed by leaf spot. Assessment dates were 25 September 1990 and 26 September 1991 at Tifton, 26 September 1990 and 27 September 1991 at Plains, and 24 September 1990 and 19 September 1991 at Marianna.

[b]Percentage of 30.5-cm sections of linear row per plot, with at least one disease locus rated immediately after inverting peanuts. Assessment dates were 25 September 1990 and 26 September 1991 at Tifton, 26 September 1990 and 27 September 1991 at Plains, and 24 September 1990 and 20 September 1991 at Marianna.

[c]Rhizoctonia limb rot, measured as visual estimate of percentage of vines colonized by *R. solani* at six 0.6-m sections of linear row per plot immediately after inverting peanuts. Assessment dates were 25 September 1990 and 26 September 1991 at Tifton, 26 September 1990 and 27 September 1991 at Plains, and 24 September 1990 and 20 September 1991 at Marianna.

[d]Not rated, because of severe defoliation and/or death of plants as a result of uncontrolled leaf spot.

[e]Insufficient disease to warrant rating.

Table 3. Effect of chlorothalonil and cyproconazole applied in combination as tank mixes for control of southern stem rot, caused by *Sclerotium rolfsii*, and Rhizoctonia limb rot, caused by *R. solani*, on peanut in Tifton, Georgia, during 1989–1991

	Rate	Stem rot[a]			Limb rot[b]			Yield (kg/ha)		
Treatment	(kg a.i./ha)	1989	1990	1991	1989	1990	1991	1989	1990	1991
Chlorothalonil	1.26	42.0	53.0	44.8	27.9	28.5	47.5	2,968	2,962	3,428
Chlorothalonil + PCNB[c]	1.26 + 5.6	34.5	33.3	34.0	29.0	30.8	43.8	3,562	4,384	4,082
Chlorothalonil + cyproconazole	0.63 + 0.062	17.0	24.0	27.5	22.7	18.4	36.9	4,497	4,680	4,505
Chlorothalonil + cyproconazole	0.63 + 0.099[d]	13.0	14.5	31.5	18.1	24.0	40.6	4,432	5,241	4,253
LSD ($P \leq 0.05$)		13.7	11.3	11.2	6.5	9.6	5.3	718	529	840

[a]Percentage of 30.5-cm sections of linear row per plot, with at least one disease locus rated immediately after inverting peanuts. Assessments were made on 9 October 1989, 1 October 1990, and 2 October 1991.

[b]Rhizoctonia limb rot, measured as visual estimate of percentage of vines colonized by *R. solani* at six 0.6-m sections of linear row per plot immediately after inverting peanuts. Assessments were made on 9 October 1989, 1 October 1990, and 2 October 1991.

[c]PCNB applied in a 10- to 15-cm band centered over the furrow at 60–70 days after planting. This treatment also contained the following insecticides: in 1989, terbufos at 2.24 kg a.i./ha; in 1990 and 1991, ethoprop at 1.68 kg a.i./ha.

[d]In 1991, this rate of cyproconazole was actually 0.084 kg a.i./ha, because of an application error.

PCNB treatment (Table 3). The incidence of stem rot in the tank-mix treatment containing the higher rate of cyproconazole differed from that of the chlorothalonil plus PCNB treatment in 1989 and 1990, whereas the lower-rate tank mix differed from the chlorothalonil plus PCNB treatment only in 1989.

Limb rot severity was similar for chlorothalonil and chlorothalonil plus PCNB treatments in all years. Percentages of vines with limb rot generally were lower for both tank mixes than in plots treated with chlorothalonil plus PCNB or chlorothalonil alone. In 1990, chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.062 kg a.i./ha had lower severity of limb rot than did either chlorothalonil or chlorothalonil plus PCNB, but limb rot severity of chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.099 kg a.i./ha did not differ from any of the other three treatments.

In 1991, both tank-mix treatments had a lower percentage of vines with limb rot than did chlorothalonil alone, but only the treatment with chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.062 kg a.i./ha was lower than that of chlorothalonil plus PCNB (Table 3). The yield of plots receiving chlorothalonil plus PCNB was significantly higher than that of plots treated with chlorothalonil alone in 1990, but not in 1989 and 1991 (Table 3). In 1989, yields of tank mixes were significantly higher than those from plots receiving the other two treatments. In 1990, both tank-mix treatments had yields greater than those of plots treated with chlorothalonil alone, but only the tank mix with chlorothalonil at 0.63 kg a.i./ha plus cyproconazole at 0.099 kg a.i./ha resulted in higher yield than the chlorothalonil plus PCNB treatments. Yields were similar for chlorothalonil plus PCNB and both tank-mix treatments in 1991. Only chlorothalonil 0.63 plus 0.062 kg a.i./ha cyproconazole produced yields higher than that of chlorothalonil alone, although the differences in yield between the tank mix with the higher rate of cyproconazole and chlorothalonil alone was only 15 kg/ha from being significant.

DISCUSSION

Tank-mixing a fungicide at risk for resistance development, such as an EBI, with a broad-spectrum protectant like chlorothalonil has been proposed as a means of coping with fungicide resistance (7,16). Tank-mix applications of chlorothalonil at rates lower than currently recommended with cyproconazole can apparently provide control of leaf spot that is at least as effective as full recommended rates of chlorothalonil alone. In several tests in which leaf spot epidemics were extremely severe, control achieved with tank mixes of the two fungicides was significantly better than with chlorothalonil alone. Improved efficacy for leaf spot control, especially in years with heavy disease pressure, could serve as an additional reason for growers to use tank mixes of these two materials, thereby helping to ensure that some resistance management strategy would be used. Marketing the EBI only as a premix is another option that would guarantee adherence to this strategy. The significance of this "enforceability" factor has been discussed by Staub and Sozzi (18).

At the rates of chlorothalonil and cyproconazole evaluated in this study, it was not possible to determine if the superior leaf spot control with cyproconazole tank mixes compared with chlorothalonil alone observed in some cases was caused by synergistic or additive effects of the two fungicides. Treatment regimes used in this study did not allow us to determine minimum or optimum rates of these two fungicides for disease control. More specific studies are in progress to address these points.

The peanut system represents a potential high-risk situation for the development of resistance to EBI fungicides. First, repeated applications of fungicides are required over an extended period of time for leaf spot control. Second, *C. personatum* and *C. arachidicola* both have large reproductive potential. Populations of *C. personatum* resistant to benomyl were prevalent within a very short time after the initiation of large-scale use of this fungicide for leaf spot control (17). Although the EBIs appear to have a lower inherent risk for resistance than the benzimidazoles (12), the threat of resistance still must be considered significant.

Tank-mix applications of fungicides with different modes of action have been used in other systems for management of resistance to fungicides in pathogen populations (7). Resistance to benomyl in *C. personatum* and *C. arachidicola* did not become a problem of practical importance in peanut-growing areas of Texas and Oklahoma where benomyl typically was applied in tank-mix combinations with mancozeb (17). Other strategies, such as block applications of different fungicides, alternation of an EBI with protectant fungicides such as chlorothalonil, and combinations of these strategies with tank-mix applications are being considered. At present, however, it is not known how effective any of these strategies will be for preventing development of resistant populations of pathogens in these pathosystems.

Tank-mix applications of chlorothalonil and cyproconazole can provide effective control of southern stem rot. This is evident from differences in severity of this soilborne disease in tests from 1989 through 1991. This disease is a major limiting factor to peanut production in the southeastern United States, and fungicides currently used have provided only limited control. The level of control of Rhizoctonia limb rot by cyproconazole plus chlorothalonil tank mixes was not as high as previously reported for tebuconazole (4) or diniconazole (9); however, the level of control demonstrated in our trials is still significant. This may be caused by lower rates of active ingredients in the late-season tank mixes of cyproconazole than in the reported field tests with tebuconazole or diniconazole. Barnes et al (2) reported lower EC_{50} values for cyproconazole than for tebuconazole in laboratory in vitro tests with *R. solani* AG-4.

The primary need for materials like cyproconazole in peanut production is control of soilborne diseases such as southern stem rot. As indicated in previous studies (13) as well as here, effective control of leaf spot can be achieved with chlorothalonil alone in most cases. However, use of the foliar disease control potential of cyproconazole is necessary if this fungicide is to be used for maximum efficiency. The extended utility of this fungicide for control of multiple peanut diseases is dependent upon prevention of development of resistance in populations of *C. personatum* and *C. arachidicola*. Thus, tank-mix applications of cyproconazole and chlorothalonil should provide leaf spot control that is equal to or better than that possible with applications of chlorothalonil alone and should provide significant control of southern stem rot. The mixture should also reduce the risk of developing populations of *C. personatum* and *C. arachidicola* with reduced sensitivity to the EBI fungicides.

LITERATURE CITED

1. Backman, P. A., Rodriguez-Kabana, R., and Williams, J. C. 1975. The effect of peanut leafspot fungicides on the nontarget pathogen *Sclerotium rolfsii*. Phytopathology 65:773-776.
2. Barnes, J. S., Csinos, A. S., and Branch, W. D. 1990. Sensitivity of *Rhizoctonia solani* isolates to fungicides and evaluation of peanut cultivars to Rhizoctonia limb rot. Peanut Sci. 18:62-65.
3. Brenneman, T. B., and Murphy, A. P. 1991. Activity of tebuconazole on *Cercosporidium personatum*, a foliar pathogen of peanut. Plant Dis. 75:699-703.
4. Brenneman, T. B., Murphy, A. P., and Csinos, A. S. 1991. Activity of tebuconazole on *Sclerotium rolfsii* and *Rhizoctonia solani*, two soilborne pathogens of peanut. Plant Dis. 75:744-747.
5. Brenneman, T. B., and Sumner, D. R. 1989. Effects of chemigated and conventionally sprayed tebuconazole and tractor traffic on peanut diseases and pod yields. Plant Dis. 73:843-846.
6. Chiteka, Z. A., Gorbet, D. W., Shokes, F. M., Kucharek, T. A., and Knauft, D. A. 1988. Components of resistance to late leaf spot in peanut. I. Levels of variability—implications for selection. Peanut Sci. 15:25-30.
7. Cohen, Y., and Levy, Y. 1990. Joint action of fungicides in mixtures: Theory and practice. Phytoparasitica 18:159-169.
8. Csinos, A. S. 1984. Evaluation of the insecticide chlorpyrifos for activity against southern stem rot of peanut. Peanut Sci. 11:98-102.

9. Csinos, A. S., Kvien, C. S., and Littrell, R. H. 1987. Activity of diniconazole on foliar and soil-borne diseases of peanut. Appl. Agric. Res. 2:113-116.
10. Culbreath, A. K., Minton, N. M., and Brenneman, T. B. 1991. Influence of *Meloidogyne arenaria* and *Sclerotium rolfsii* on performance of Florunner and Southern Runner cultivars in three leaf spot control regimes. (Abstr.) Proc. Am. Peanut Res. Educ. Soc. 23:50.
11. Hancock, H. G., and Weete, J. D. 1985. Effects of triazoles on fungi. IV. Growth and lipids of *Cercospora arachidicola* and *Cercosporidium personatum*. Pest. Biochem. Physiol. 24:395-405.
12. Köller, W., and Scheinpflug, H. 1987. Fungal resistance to sterol biosynthesis inhibitors: A new challenge. Plant Dis. 71:1066-1074.
13. Kucharek, T. A., Shokes, F. M., and Gorbet, D. W. 1991. Considerations for spraying foliar fungicides to control plant diseases as exemplified by studies in Florida from 1968 to 1989 on the control of peanut leaf spot. Fla. Coop. Ext. Serv. Bull. 269. 31 pp.
14. McLean, H. S., and Yoder, J. F. 1991. Performance of cyproconazole on foliar and soil-borne diseases. (Abstr.) Proc. Am. Peanut Res. Educ. Soc. 23:62.
15. Rodriguez-Kabana, R., Backman, P. A., and Williams, J. C. 1975. Determination of yield losses to *Sclerotium rolfsii* in peanut fields. Plant Dis. Rep. 59:855-858.
16. Skylakakis, G. 1981. Effects of alternating and mixing pesticides on the buildup of fungal resistance. Phytopathology 71:1119-1121.
17. Smith, D. H., and Littrell, R. H. 1980. Management of peanut foliar diseases with fungicides. Plant Dis. 64:356-361.
18. Staub, T., and Sozzi, D. 1984. Fungicide resistance: A continuing challenge. Plant Dis. 68:1026-1031.
19. Steel, R. G. B., and Torrie, J. H. 1980. Principles and Procedures of Statistics. McGraw-Hill, New York. 633 pp.