Effect of Metalaxyl Plus PCNB or Metalaxyl Plus Tolclofos-methyl on Peanut Pod Rot and Soil Populations of *Pythium* spp. and *Rhizoctonia solani*

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ABSTRACT

Metalaxyl plus PCNB or metalaxyl plus tolclofos-methyl were field tested in 1985-1987 in Oklahoma for their effect on pod rot of Florunner and Spanco peanut caused by *Pythium* spp. and *Rhizoctonia solani.* Total a.i. (kg/ha) of metalaxyl and PCNB applied in 1985, 1986 and 1987 were 1.12 and 11.2, 1.12 and 11.2 and 0.92 and 7.40. respectively. Total a.i. (kg/ha) of metalaxyl plus tolclofos-methyl applied in 1986 and 1987 were 1.34 and 3.36 and 1.12 and 2.24, respectively. Fungicides reduced pod rot severity on both cultivars at 2-8 wks prior to harvest; at harvest, however, none of the reductions were significant ($P \leq 0.05$). Yield increases were measured from 111-579 kg/ha, but few increases were significant ($P \leq 0.05$). Fungicides generally reduced the number of Pythium propagules in soil at several sampling dates, but few of the reductions were significant ($P \leq 0.05$). In 1986 and 1987 populations of *Pythium* spp. in soil peaked at 60 and 75 days, respectively, then declined. At these peaks treated soils generally had fewer Pythium propagules than nontreated soils. Populations of *Pythium* spp. were not significantly reduced at harvest. Populations of *R. solani* were highly variable over the seasons and control was erratic from year to year. In combination with metalaxyl, tolclofos-methyl was no more effective than PCNB in reducing pod rot or populations of *R. solani.* Populations of *R. solani* at harvest were not significantly ($P \leq 0.05$) reduced by the fungicide combinations.

Key Words: Metalaxyl, pentachloronitrobenzene, tolclofos-methyl, soil fungicides, peanut pod rot, *Pythium* spp., *Rhizoctonia solani, Arachis hypogaea,* L.

Root and pod diseases are limiting factors in the production of Oklahoma peanuts (*Arachis hypogaea,* L.). *Pythium myriotylum* Dresch. and *Rhizoctonia solani* Kühn (AG4) are pathogens frequently encountered in Oklahoma peanut soils. They cause a root and pod rot of peanut, either alone or in combination with other pathogens. Other pathogens implicated in root and pod rots of peanut in Oklahoma include other *Pythium* species (Filonow, unpublished), *Sclerotium rolfsii* Sacc. and various plant-parasitic nematodes, notably the northern root-knot nematode, *Meloidogyne hapla* Chitwood (8).

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In the past, chemical control of *Pythium* spp. has been difficult. Recently, however, metalaxyl has been labeled for use on peanuts. Metalaxyl is a fungicide with specificity and high efficacy against oomycetous phytopathogens, such as *Pythium,* and *Phytophthora.* Of the metalaxyl formulations available to growers, metalaxyl plus pentachloronitrobenzene (PCNB) appears to have the potential of broad spectrum control against several pathogens which cause seedling and pod diseases of peanut. PCNB has activity against *Rhizoctonia* spp., *S. rolfsii* and other soilborne fungi. Tolclofos-methyl (Rizolex®), similar to PCNB in its spectrum of activity, has a reported high activity against *Rhizoctonia* spp. and *S. rolfsii* (3), and offered the potential for another soil fungicide to be used with metalaxyl in management of peanut pod rot.

The value of fungicides in a disease management program can be measured by their effectiveness in reducing disease, improving yield, and/or reducing the populations of the target pathogens. The purpose of this report is to present results of field studies that assessed the efficacy of metalaxyl plus PCNB or metalaxyl plus tolclofos-methyl in the management of peanut pod rot.

Materials and Methods

Soil fungicide evaluations were conducted in 1985, 1986 and 1987 at the Caddo Research Station, Ft. Cobb, Oklahoma on a Meno fine sandy loam soil (62% sand, 24% silt and 14% clay). Soil on the station was naturally infested with *P. myriotylum* and *R. solani* (AG 4) and had a history of pod rot. Plots consisted of 4 rows, 12.1 m long with 0.91 m spacing. Plots were sprinkler irrigated 11 times in 1985 and 7 times in 1986 and 1987 with ca. 5 cm water/irrigation. There were 5 replicate plots per soil fungicide treatment. Carbofuran (1.82 kg/28.3 m) was incorporated prior to planting with a cultivator-bedder. Soil fungicides were applied as granules with a Precision Granular Applicator® (Precision Machine Co., Lincoln, NE). Plots receiving no soil fungicides were the controls. In 1985 and 1986 plots were arranged in a randomized complete block, split-plot design with the cultivars Spanco and Florunner as main plots and fungicides as subplots. Spanco and Florunner are the predominant cultivars grown in Oklahoma. In 1987 only Florunner was grown and the experiment was designed as a randomized complete block design. All data were analyzed using analysis of variance and mean differences were determined by least significant difference.

Soil and plant samples were taken at 3 random locations from the outside rows of plots at harvest and at 2-4 interim times prior to harvest to assess the effect of fungicides on early symptom development. In addition, a pre-treatment soil sampling was done prior to planting. Soil and plant subsamples were composited into one sample for each plot. Populations of *Pythium* spp. in soil were determined by plating soil dilutions on a selective medium for Pythium (5) and populations of *R. solani* were estimated using the multiple-pellet technique (12) on a selective medium (15).

Pods were removed from plants (usually 6-9 plants per composited sample), hand washed and rated for pod rot disease severity based on a pod discoloration scale where 1 = no discoloration, 2 = 1-25%, 3 = 26-50%, 4 = 51-75% and 5 = >75% discoloration. Pods in disease classes 3-5 (which account for most of the economic loss to pod rot) were totaled, divided by the total number of pods and multiplied by 100 to give percent pod rot. Hull pieces were surface-disinfested in 1.05% NaOCl, followed by 70% (v/v) ethanol in water, rinsed in sterile water and placed on corn meal agar or potato dextrose agar for fungal isolations. At harvest plots were dug with a peanut digger-inverter and threshed. Peanut pods were sacked, dried to ca. 10% moisture, cleaned and weighed for pod yield.

1985 experiment

Spanco and Florunner seed were planted May 23. Applications of benefin at 1.68 kg a.i./ha and 2.24 kg a.i./ha of vernolate for weed control, and 168 kg/ha fertilizer (32-23-0) were made at preplant. Metolachlor (2.24 kg a.i./ha) was applied at pre-emergence for weed control. At flowering 560 kg/ha of agricultural grade gypsum was applied. Three applications of triphenyltin hydroxide (0.26 kg a.i./ha) were used for leafspot control. Metalaxyl (0.11 kg a.i./ha) and PCNB (1.12 kg a.i./ha) were applied at planting in a 10.0 cm band behind the planter. At 63 and 83 days after planting (DAP), metalaxyl (0.45 kg a.i./ha) plus PCNB (4.48 kg a.i./ha) and metalaxyl (0.56 kg a.i./ha) plus PCNB (5.60 kg a.i./ha) respectively, were applied in a 30 cm band. Spanco peanuts were harvested October 8 and Florunner peanuts were harvested October 24.

1986 experiment

Spanco and Florunner seed were planted May 21. Herbicide, fertilizer and gypsum applications were the same as in 1985. In addition to 3 applications of triphenyltin hydroxide, one application of Copper Count-N (8% copper from copper ammonium carbonate; 0.67 kg a.i./ha) was used for leafspot control. On Florunner the test fungicides were applied at planting, at 79 and 114 DAP. On Spanco peanut, applications were made at planting, at 55 and 120 DAP. Rates of metalaxyl and PCNB were the same as in 1985. Rates of metalaxyl plus tolcolfos-methyl were 0.22 kg a.i./ha plus 0.56 kg a.i./ha, 0.56 kg a.i./ha plus 1.12 kg a.i./ha and 0.56 kg a.i./ha plus 1.68 kg a.i./ha. Plots with Spanco were harvested October 15 and those with Florunner were harvested on October 30.

1987 experiment

Florunner was planted on May 14. For weed control trifluralin (0.56 kg a.i./ha) and vernolate (2.24 kg a.i./ha) were applied preplant, whereas metolachlor (2.24 kg a.i./ha) and acifluorfen (0.42 kg a.i./ha) were applied at preemergence. Five applications of chlorothalonil (1.32 kg a.i./ha) were used for leafspot control. Metalaxyl (0.18 kg a.i./ha) and PNCB (1.79 kg a.i./ha) were applied at planting in a 12.5 cm band in covering soil. Sixty-two days after planting, metalaxyl (0.37 kg a.i./ha) and PCNB (3.70 kg a.i./ha) or metalaxyl (0.56 kg a.i./ha) and tolclofos-methyl (1.12 kg a.i./ha) were applied to the plots. Ninety days after planting, metalaxyl (0.37 kg a.i./ha) and PCNB (3.70 kg a.i./ha) or metalaxyl (0.56 kg a.i./ha) and tolclofos-methyl (1.12 kg a.i./ha) were applied. Plots were harvested October 28.

Results

1985

At all interim sampling dates prior to harvest, metalaxyl plus PCNB had reduced pod rot severity in both cultivars when compared to controls (Table 1). However, with Florunner only disease reductions at 97 and 131 DAP were significant at $P \leq 0.05$. Significant disease reductions on Spanco pods were seen only at 118 DAP and virtually no reduction was seen at harvest. Florunner generally had more pod rot than Spanco, but differences were not significant. Fungicide treatment significantly increased yields for Spanco by 468 kg/ha but only increased yields by 194 kg/ha for Florunner.

Predominant fungi isolated from infected pods included *P. myriotylum, P. irregulare* (tentative identification), other as yet unidentified *Pythium* spp., *R. solani* (AG 4), *Fusarium* spp., *Penicillium* spp. and *Rhizopus* spp. In addition, *Sclerotinia minor* and *Sclerotium rolfsii* were sometimes isolated.

Compared to pre-treatment levels in soil, populations of Pythium were reduced at the first sampling (97 DAP) following three metalaxyl plus PCNB applications, but differences were not significant (Fig. 1). Populations of Pythium in treated soils were not significantly different from those in untreated soils, which had also decreased by this sampling. At 118 DAP, populations of Pythium in untreated and treated soils had both increased; however, treated soils had fewer Pythium propagules than untreated, although the differences were not significant. By 131 DAP (Spanco harvest), the effect of metalaxyl

Table 1. Effect of fungicides on severity of pod rot and yield of Spanco and Florunner peanut in 1985.

Cultivar	Treatment	Percent pod rot severity at DAP[a] 97	118	131[b]	149[c]	Yield kg/ha
Spanco	Metalaxyl + PCNB	9.2	8.3	11.0	--	3873
	Control	10.5	20.2	11.2	--	3405
Florunner	Metalaxyl + PCNB	8.4	10.1	11.6	7.2	3639
	Control	13.5	17.5	20.9	17.7	3445
LSD (P≤0.05)		4.9	8.7	6.7	11.4	268

[a] DAP=days after planting. Pod rot severity was rated using a scale of 1-5, where 1=no discoloration on a pod and 5=>75% of pod discolored. Percent pod rot was calculated by summing pods in disease classes 3-5, dividing the sum by the total number of pods and multiplying by 100.

[b] Spanco harvested.

[c] Florunner harvested.

plus PCNB was clearly noticed, in that treated soil had significantly lower populations of Pythium than untreated soil. At this sampling, untreated soil planted to Spanco or Florunner, had 99 propagules (p)/g or 109 p/g soil, respectively, compared to 30 p/g in treated soil with either cultivar. At 149 DAP (Florunner harvest) populations in treated soils were lower than those in untreated soils (15 p/g compared to 47 p/g soil), but these differences were not significant. Cultivars did not appear to influence populations of Pythium in soil, as there were no significant differences at any sampling between populations in soil planted to either cultivar, whether treated or not.

Prior to planting, populations of *R. solani* ranged from 30.0-46.5 p/100 g soil (Fig. 1). Following fungicide applications, the number of propagules in soil planted to either cultivar were greater, but not significantly different from the number in untreated soil. At 131 DAP populations were lower in the treated soil planted to either cultivar but this difference was significant only in soil planted to Florunner. Populations of *R. solani* were also lower in treated soil at 149 DAP (Florunner harvest).

1986

Fungicides did not reduce pod rot severity in the Spanco cultivar at either sampling date (Table 2). In Florunner significant reductions in pod rot were seen only at 113 DAP with metalaxyl and tolclofos-methyl. In untreated soil Florunner had more pod rot than Spanco, but differences were not significant. Yields were increased by both fungicides, but only in the Florunner plots treated with metalaxyl plus tolclofos-methyl was there a significant yield increase (579 kg/ha) over the control. Fungi isolated from pods were similar to those isolated in 1985.

Pretreatment populations of *Pythium* spp. in soil

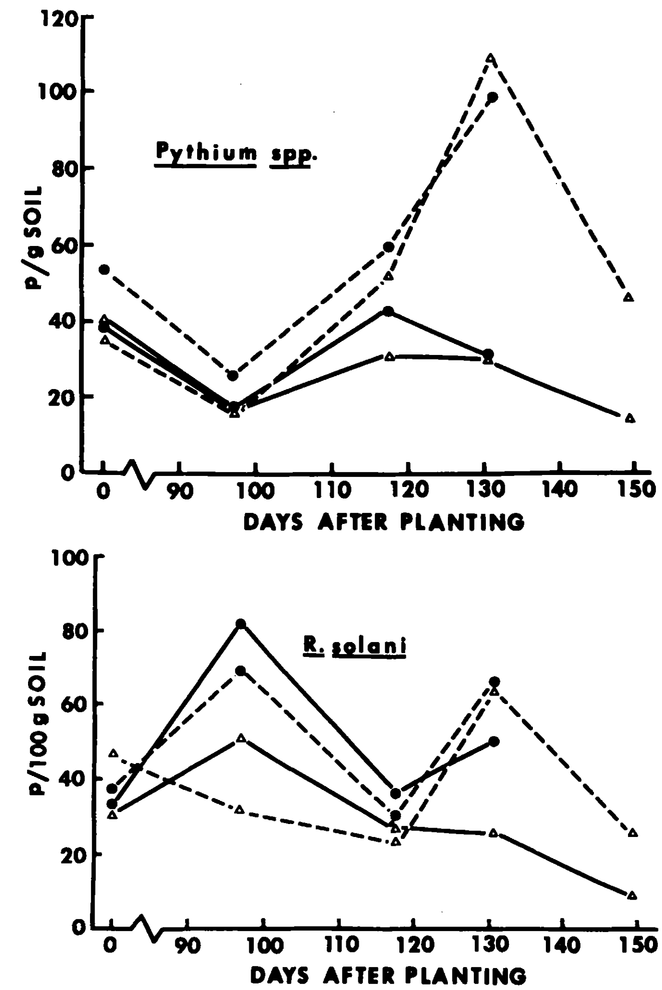


Fig. 1. Populations of *Pythium* spp. or *Rhizoctonia solani* in soil planted with Spanco (●) or Florunner (Δ) cultivars and treated (—) or untreated (---) with metalaxyl + PCNB in 1985.

Table 2. Effect of fungicides on severity of pod rot and yield of Spanco and Florunner peanut in 1986.

Cultivar	Treatment	Percent pod rot severity at DAP[a] 113	147[b]	162[c]	Yield kg/ha
Spanco	Metalaxyl + PCNB	7.6	15.6	- -	1891
	Metalaxyl + Tolclofos-methyl	7.0	12.7	- -	1748
	Control	5.7	13.0	- -	1504
Florunner	Metalaxyl + PCNB	4.9	- -	16.8	2257
	Metalaxyl + Tolclofos-methyl	2.6	- -	22.5	2602
	Control	8.1	- -	27.4	2023
LSD ($P \leq 0.05$)		4.5	6.1	10.9	404

[a] DAP=days after planting. Pod rot severity was rated using a scale of 1-5, where 1=no discoloration on a pod and 5=>75% of pod discolored. Percent pod rot was calculated by summing pods in disease classes 3-5, dividing the sum by the total number of pods and multiplying by 100.

[b] Spanco harvested.

[c] Florunner harvested.

planted with Florunner (Fig. 2A) or Spanco (Fig. 2B) were 4.2-16.7 p/g or 12.7-34.0 p/g soil, respectively. Populations of Pythium in treated and untreated soil did not appreciably change until 75 DAP, when populations markedly increased by approximately 10-100 times (Fig. 2A and 2B). Thereafter, populations of Pythium generally decreased to levels similar to those at planting, except for soil treated with metalaxyl plus PCNB and planted to Spanco which increased at 113 DAP and declined (Fig. 2B). Fungicide treatments generally reduced populations of Pythium during the study; however, only at 75 DAP were significant reductions observed. Metalaxyl and tolclofos-methyl effectively reduced populations of Pythium in soil planted with either cultivar at this sampling date; whereas metalaxyl and PCNB significantly reduced the population in soil planted with Spanco.

Populations of *R. solani* in soils (Fig. 2A and 2B) planted to either cultivar were highly variable, and responses to fungicide applications were erratic. Populations of *R. solani* were generally nondetectable at planting and thereafter fluctuated considerably with treated soil often having greater populations than untreated soil. For example, at harvest, population of *R. solani* in soil planted to Spanco peanut (Fig. 2B) and treated with metalaxyl and PCNB was 37.5 p/100g compared to 15 p/100g in nontreated soil. None of the reductions of *R. solani* populations in treated soils was statistically significant ($P \leq 0.05$).

1987

Significant ($P \leq 0.05$) reductions of pod rot severity in fungicide treated soils at either sampling date did not occur. Yields were increased (111-335 kg/ha) by the fungicides but not significantly. Fungi isolated in 1987 were similar to those in 1985 and 1986, except that *S. minor* was more frequently isolated from infected pods.

At planting, the number of Pythium propagules in both treated and nontreated soils (Fig. 3) ranged from 12.5 to 29.1 p/g. At 28 DAP changes were negligible, but at 60 DAP an 11-27 fold increase was observed. Thereafter, populations declined to the levels observed at planting. At all sampling dates, treated soil contained fewer propagules than nontreated soil; however, only at 60 and 87 DAP were these reductions significant. At 60 DAP the metalaxyl and PCNB treatment was more effective than metalaxyl plus tolclofos-methyl. No significant differences as to fungicide effectiveness were seen at 87 DAP.

Rhizoctonia solani (Fig. 3) was not detected in soils until 60 DAP and only then in fungicide-treated soils. Populations in nontreated soil peaked at 121 DAP (64.8 p/100g) and declined at harvest. Fungicides reduced populations of *R. solani* only at 87 and 121 DAP, but none of these reductions was significant ($P \leq 0.05$).

Discussion

The value of a fungicide in disease management can be measured by its effectiveness in reducing disease in-

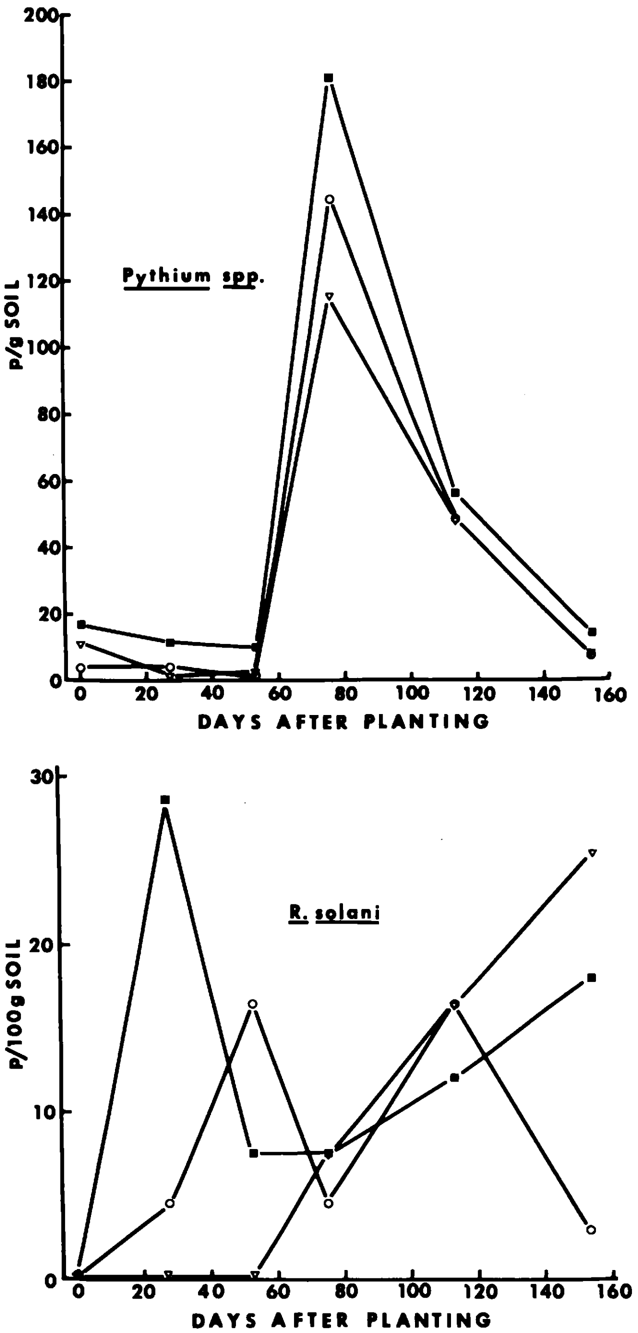


Fig. 2A. Populations of *Pythium* spp. or *Rhizoctonia solani* in soil planted with the cultivar Florunner untreated (■) or treated with metalaxyl + PCNB (○) or metalaxyl + tolclofos-methyl (▽) in 1986.

cidence and/or severity, improving yield, and/or reducing the population buildup of the target pathogen. Based on these criteria, metalaxyl combined with PCNB or tolclofos-methyl did not appear to be effective in our pod rot management studies.

Reductions in pod rot severity following fungicide treatments were erratic from year to year. In 1985, pod rot suppression was significant at all sampling dates including harvest, but only for Florunner. However, in 1986 and 1987 little suppression with either fungicide combination was observed. Although yields were con-

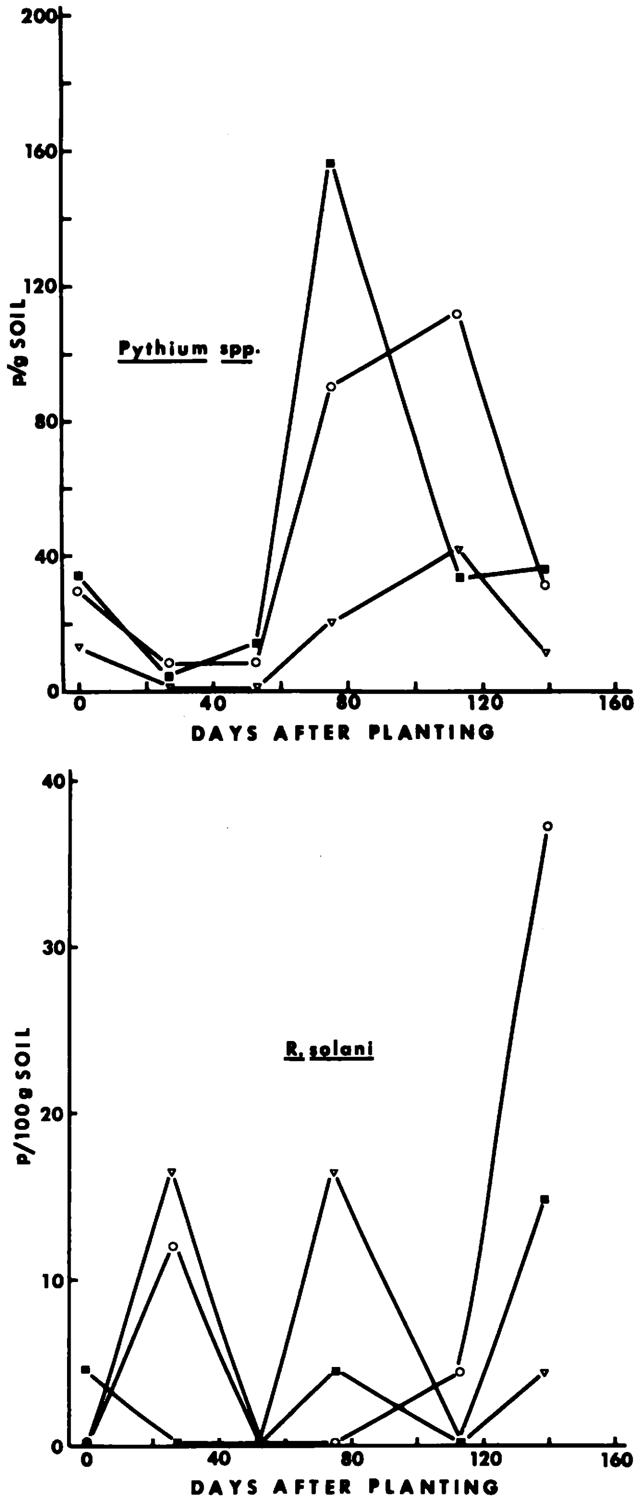


Fig. 2B. Populations of *Pythium* spp. or *Rhizoctonia solani* in soil planted with the cultivar Spanco and untreated (■) or treated with metalaxyl + PCNB (○) or metalaxyl + tolclofos-methyl (▽) in 1986.

sistently increased by the fungicides, and some of these were substantial, e.g. 579 kg/ha in 1986, few were statistically significant ($P \leq 0.05$). In 1987 Sclerotinia blight may have influenced yields.

Compared to untreated soils, reductions in populations of Pythium in metalaxyl treated soils at the end of

Table 3. Effect of fungicides on severity of pod rot and yield of Florunner peanut in 1987.

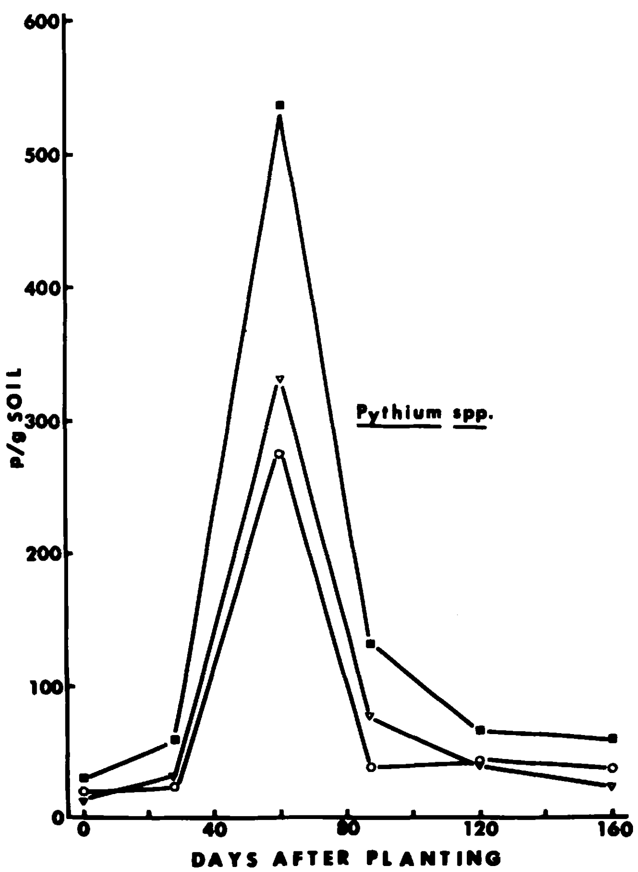
Treatment	Percent pod rot severity at DAP[a] 125	165[b]	Yield kg/ha
Metalaxyl + PCNB	18.6	32.2	2988
Metalaxyl + Tolclofos-methyl	21.4	26.5	2764
Control	24.3	28.6	2653
LSD (P≤0.05)	7.6	5.9	383

[a] DAP=days after planting. Pod rot severity was rated using a scale of 1-5, where 1=no discoloration on a pod and 5=>75% of pod discolored. Percent pod rot was calculated by summing pods in disease classes 3-5, dividing the sum by the total number of pods and multiplying by 100.

[b] Harvest.

the growing seasons generally were observed; however, none of these was statistically significant. There were, however, reductions in populations early in each season, indicating that control of *Pythium* spp. was occurring following treatment. For instance, substantial control following treatment was achieved during the population peaks of *Pythium* spp. observed during 1986 and 1987. Early season control of Pythium in soil, however, generally did not bring about reductions in pod rot severity later in the season. In 1986, for instance, there was not subsequent, significant reduction in pod rot on Spanco in treated soil at 113 DAP following the significant control of Pythium at 75 DAP.

The peaks of *Pythium* spp. in soil observed in 1986 and 1987 at 60 and 75 DAP, respectively, appear to be a real phenomenon. Similar peaks were also observed at 65 DAP in a different 1987 study in soils from Caddo and Marshall counties, Oklahoma (Lewis, Filonow and



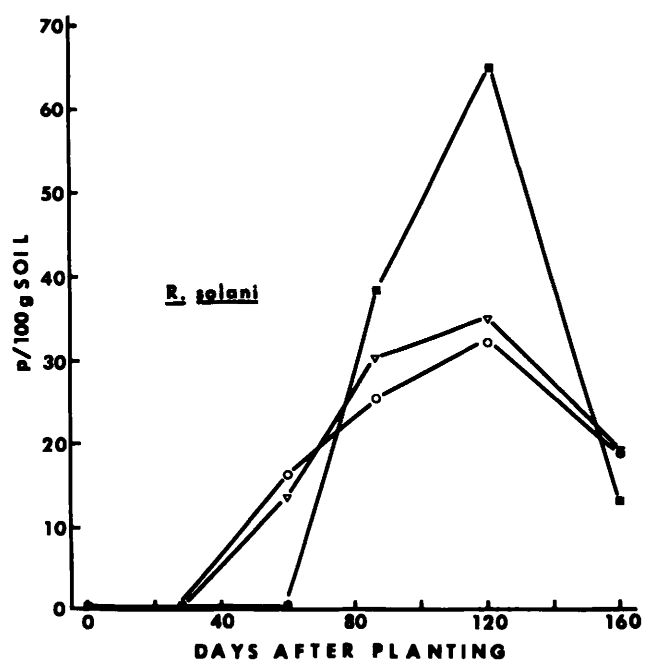


Fig. 3. Populations of *Pythium* spp. or *Rhizoctonia solani* in soil planted with the cultivar Florunner and untreated (■) or treated with metalaxyl + PCNB (○) or metalaxyl + tolclofos-methyl (∇) in 1987.

Jackson, unpublished). In 1985 the peak was not seen, probably because soil sampling was not begun until 97 DAP, when the peak had most likely subsided. The factor(s) that accounted for these peaks are not known. Possibly, increased soil temperature during July and early August may have favored increased saprophytic growth of *Pythium* spp. *Pythium myriotylum* is a warm-temperature-loving species (16) commonly found in Oklahoma peanut soils, and would be expected to grow well at Oklahoma soil temperatures (30-38 C) in July and August, but not in the cooler (25-18 C) months of September and October. In addition, soil moisture would influence populations of *Pythium* spp., although it is difficult to evaluate the effect that soil moisture had on the population dynamics of Pythium in a season, since it was not monitored in this study.

A marked increase in peanut root and/or pod development during these months may have also favored growth of *Pythium* spp. The timing of the population peaks at 60 and 75 DAP coincides with the R_4 - R_6 growth stages for peanut (1). Vegetative growth is at a maximum and plants have added significant pod numbers and weight at this time. Hale (11) showed that sugars in exudate from peanut fruit growing in axenic culture were greatest at pegging and decreased as fruit matured. Possibly, growth of *Pythium* spp. may have responded to exudates released from developing pods. Following subsidence of exudation as pods mature, populations may have declined due to microbe-induced lysis of hyphae. Thus, the observed proliferation in propagules of Pythium in soil may be attuned to peanut phenology. More research is needed to ascertain the factors affecting Pythium dynamics in soil planted to peanut, as this knowledge may be helpful in better scheduling fungicides for optimum pod rot suppression.

Neither PCNB or tolclofos-methyl in combination with metalaxyl consistently reduced pod rot. Control of populations of *R. solani* in soils was erratic over the span of this study, and except for 1985, populations in treated soils were not significantly ($P \leq 0.05$) lower at harvest. Indeed, at harvest in 1986 and 1987, populations of *R. solani* in some treated soils were greater than in non-treated soils. Csinos *et al.* (4) in Georgia reported that PCNB at 11.2 kg/ha had no significant effect on populations of *R. solani* in soil planted to Florunner or Early Bunch cultivars. In addition, Csinos and Gaines (2) reported erratic populations of *R. solani* in soil that was planted to Early Bunch. In Oklahoma, PCNB by itself has given variable control of pod rot (Jackson, unpublished). Possibly, decades of PCNB use to control southern blight in Oklahoma have resulted in the development of PCNB resistance in *R. solani* (7).

Inskeep and Filonow (14) considered the majority of *R. solani* isolates from Oklahoma peanut fields to be sensitive to tolclofos-methyl in agar tests. Tolclofos-methyl (11.2 kg/ha at pre-peg) lowered the populations of *R. solani* in microplots planted with Spanco or Florunner at harvest (13) and in Georgia, tolclofos-methyl was shown to be effective in reducing Rhizoctonia limb rot (3). Thus, the ineffectiveness of tolclofos-methyl to control populations of *R. solani* in these field tests was unexpected.

Our results with metalaxyl plus PCNB disagree with those of Grichar (10). He reported that metalaxyl (1.12 kg a.i./ha) plus PCNB (11.2 kg a.i./ha) applied at planting or in split applications (0.56 kg metalaxyl plus 5.6 kg PCNB a.i./ha) at planting and at pegging significantly reduced Pythium pod rot on Florunner peanut in Texas. The at planting rates used in his study were about 3-10X greater than those tested in our study, and this may account for the greater control observed in Texas. In addition, statistically significant increases in peanut yields from metalaxyl plus PCNB in some other Oklahoma field trials have been shown (R. Sholar, personal communication). In our study, we placed emphasis on early season application of metalaxyl to manage *Pythium* spp., so it is possible that pod rot was increased and yields reduced from infections of *R. solani* occurring later in the season. Moreover, PCNB may increase Pythium-induced disease by suppressing antagonists of *Pythium* spp. (6,9). The extent to which this effect occurred in our study is not known, although it should be a factor to consider in management of pod rot where *Pythium* spp. are the only or dominant pathogens in peanut soils. Although our results did not show dramatic benefit from use of metalaxyl plus PCNB or tolclofos-methyl in pod rot management, we are continuing to evaluate metalaxyl plus other soil fungicides at different application rates and schedules.

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