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Evaluation of Trichoderma spp., Fungicides, and Chemical Combinations for Control of Southern Stem Rot on Peanuts[1]

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ABSTRACT

Field experiments evaluating three isolates of *Trichoderma harzianum* Rifai and a white spored *Trichoderma* sp. alone and in combination with fungicides and fungicide-insecticide/ nematicide combinations were conducted during 1979-81 in an area with a history of high incidence of *Sclerotium rolfsii* Sacc. None of the *Trichoderma* sp. treatments alone, mixed with wheat middlings, or combined with carboxin reduced disease or increased yield over the control; however, disease was reduced when *T. harzianum* was applied with PCNB at 11.2 kg/ha. *Trichoderma* spp. appeared to be active only over a 3-8 day period, which was inadequate for control of *S. rolfsii* for the entire season. Treatments containing PCNB (11.2 kg ai/ha) alone or with the insecticide/ nematicides ethoprop (3.4 kg ai/ha), fensulfothion (3.4 kg ai/ha), and aldicarb (1.7 kg ai/ha) significantly increased yields 9 of 12 times with an average increase of 790 kg/ha; and significantly reduced disease loci at harvest 5 of 12 times with an average reduction of 36%. Ethoprop 10G alone at 3.4 kg ai/ha increased yield one of 3 times, but did not reduce disease. Aldicarb and phenamiphos alone did not decrease disease or increase yield. Carboxin 4G decreased disease and increased yield only when applied at 1.12 kg ai/ha six times on an as required basis. Carboxin 3F at 0.84 kg ai/ha applied 6 times and carboxin 75W at 1.27 kg ai/ha applied one time did not increase yield or reduce disease at harvest.

Key Words: *Sclerotium rolfsii* Sacc., *Trichoderma harzianum*, ethoprop, fensulfothion, aldicarb, carboxin 3F, carboxin 75W, groundnut, disease.

Southern stem rot of peanut caused by *Sclerotium rolfsii* Sacc. is responsible for losses of 10% of the crop annually in Georgia (14). The fungus grows on dead organic matter in the soil and moves to the crown of living plants, killing plants outright or damaging pods and pegs. Sclerotia are produced in abundance and act as overwintering inoculum. Effective rotations are difficult because the fungus is pathogenic to most non grass crops grown in the area (1). However, rotations with corn or grass crops, which are less susceptible than peanut, are

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Mention of a pesticide herein neither constitutes a recommendation nor implies registration under FIFRA.

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recommended (16). Deep plowing, reducing crop litter near the surface, and non-dirting cultivation are also effective methods of reducing the disease (5, 6). Deep plowing buries the sclerotia and mycelium to a depth where they are less likely to be close enough to the soil surface to attack peanut plants.

Chemicals have also been used but they provide only limited control. PCNB with fensulfothion or ethoprop have been used to reduce the disease (9, 11, 13, 15). Several other insecticide-nematicides are commercially available for peanuts, but their effect on *S. rolfsii* alone, and in combination with PCNB, is not known.

During the last several years biological control of soilborne pathogens have been demonstrated by several workers (2, 8, 13, 18). Wells et al. (18) demonstrated the value of *Trichoderma harzianum* Rifai as a biological control of *S. rolfsii* on tomato. The fungus, originally isolated from *S. rolfsii* sclerotia, reduced disease in the field when applied once or twice to an area infested with *S. rolfsii*. This was the first reported practical application of biological control of *S. rolfsii* using a *Trichoderma* sp. Since that time several workers have attempted biological control using several *Trichoderma* spp. (2, 8, 10, 12, 18) and have reported antagonism of plant pathogens by *Trichoderma* spp. (3, 4, 7, 12, 17).

This report describes experiments evaluating *Trichoderma* spp. alone, fungicides plus *Trichoderma* spp. and chemicals alone, and in combinations for control of *S. rolfsii* on peanuts in field experiments during 1979-81.

Materials and Methods

Viable preparations of *Trichoderma harzianum* (1970-3A, ATCC 24274) from Abbott Laboratories U.S.A. (A), Binab Laboratories, Sweden (B), and Tate and Lyle Laboratories, England (T+L), and a white spored *Trichoderma* sp. (79 WT-6) formulated in the Plant Pathology Department, Coastal Plain Experiment Station, Tifton, Georgia (CPES) were tested for biological control of *S. rolfsii*. In addition the following chemicals were evaluated: (PCNB [pentachloronitrobenzene], PCNB + ethoprop [O-Ethyl S, S-dipropyl phosphorodithiate], PCNB + phenamiphos [Ethyl 3-methyl-4-(methylthion) phenyl (l-methylethyl phosphoramidate], carboxin (5,6-dihydro-2-methyl-N-phenyl-l, 4-oxathiin-3-carboxamide], daminozide [butanedioic acid mono (2,2-dimethyl hydrazide], aldicarb, [2-Methyl-2(methylthion) propronaldehyde O-(methylcarbamoyl) oxime], and PCNB + aldicarb.

Before seeding, all plots were treated with ethylene dibromide (EDB) injected 20 cm deep with two chisels per row spaced 25 cm apart at the rate of 31.5 kg ai/ha for nematode control, except in one test (Table 5) where EDB was a treatment and the other treatments were untreated for nematodes. Granular materials were applied by either a tractor mounted Gandy^R or Demco^R applicator, or preweighed for each plot and applied with salt shaker-like container in a 35-46 cm band over the row. Emulsifiable concentrates (EC), flowable materials (F) and wettable powders (WP) were applied with a pressurized knapsack sprayer or a tractor mounted sprayer in a 15-35 cm band over the crown of the plants in approximately 234 L of water/ha. *Trichoderma* test materials were applied in a 46 cm band over the row by hand and brushed through the foliage.

Most materials were applied at pegging time or later when the first sign of disease was apparent as recommended by the manufacturer. Some materials which have a short residual soil life were applied on demand, which consisted of reapplication of the test materials each time the disease became active in the plots.

Plots consisted of two rows of Florunner peanut, 0.9 m apart, 7.6 m long. Treatments were replicated four to eight times. Recommended fertilization, gypsum, cultural practices, and insect and foliar disease control were followed. Water was applied by over-head irrigation as required when water stress was apparent. In some experiments *S. rolfsii* disease loci counts were made three times, twice during the growing season and just after digging and inverting. A disease locus consisted of a 31 cm section of row, or less, infected with *S. rolfsii*. An area more than 31 cm, but less than 64 cm long was considered 2 disease loci. After plots were combined, peanuts were dried and weighed and yeilds were determined. Data were statistically analyzed by analysis of variance, Duncan's Multiple Range Test or Waller-Duncan K-ratio T. Test and regression.

Results

Disease incidence was generally high with the first signs occuring about 50-60 days after seeding and was most severe about 100 days post seeding.

Trichoderma Treatments

None of the *Trichoderma* treatments alone or in combination with PCNB or carboxin decreased the numbers of disease loci over the control (Table 1). However,

Table 1. Effects of *Trichoderma harzianum* alone and with PCNB and carboxin on incidence of southern stem rot and peanut yields, 1979.

Treatment and[1] formulation	Rate[2] (kg ai/ha)	Application[3] time	Disease loci[4] (no/15.2 m row)	Yield[5] (kg/ha)
T. harzianum (B)+ PCNB 10G	11.2	OD	6.5 a	5916 a
T. harzianum (B)+ PCNB 10G	11.2	EP	8.0 ab	5465 ab
T. harzianum (B)		EP	10.3 ab	5364 abc
T. harzianum (A)		EP	12.3 ab	4790 bcd
T. harzianum (B)		OD	13.0 ab	4418 d
Control			13.5 ab	4909 bcd
T. harzianum (B)+ carboxin 4G	1.12	EP	14.0 ab	4577 bcd
T. harzianum (T+L)		EP	14.3 ab	4574 cd
T. harzianum (B)+ carboxin 4G	1.12	OD	14.5 ab	4678 bcd
T. harzianum (A)		OD	14.5 ab	4636 bcd
T. harzianum (T+L)		OD	15.8 b	4454 d

[1] *Trichoderma harzianum* (1970-3A, ATCC 24274) formulations were: A = Abbot Laboratories USA; B = Binab Laboratories Sweden; and T+L = Tate and Lyle Laboratories England.

[2] All *T. harzianum* formulations applied at 336 kg/ha.

[3] Treatments applied on demand (OD) when disease first appeared on July 25, at early pegging (EP) on June 29. Peanuts were planted May 1 and harvested September 20.

[4] Numbers of disease loci recorded at digging.

[5] Means followed by common letters within columns are not significantly different at P=0.05 according to Waller-Duncan K-Ratio Test. Correlation coefficient for numbers of disease loci versus yield was -0.83 at P=0.02.

plots treated with *T. harzianum* (B) plus PCNB applied on demand produced greater yeilds than the control. None of the other formulations of *Trichoderma* spp. applied alone or in combination with PCNB or carboxin increased yield. *Trichoderma* sp. CPES or *T. harzianum* (A) mixed with wheat middlings were also ineffective in increasing yield over the control (data not shown).

Fungicide Treatments

Carboxin was evaluated during 1979-81 in the same location. Carboxin 4G at 1.12 kg ai/ha applied on demand increased yield over the control in 1979 and 1980 (table 2, 3) but not in 1981 (data not shown). However, Carboxin 75W at 1.27 kg ai/ha and Carboxin 3F at 1.4 kg ai/ha applied on demand in 1979 and Carboxin 4G at 0.67 ai/

ha and Carboxin 3F at 0.84 kg ai/ha applied on demand in 1980 did not increase yields. Carboxin at 0.67 and 1.12 kg ai/ha applied three and five times on a two-week schedule did not increase yields. Carboxin did not decrease the numbers of disease loci, in 1979 at digging, in 1980 at 98 days post seeding, or at any period in 1981 (data not shown). However, in 1980, 114 days post seeding, plots treated with Carboxin at 1.12, and 0.67 kg ai/ha applied on demand, and Carboxin 4G at 1.12 kg ai/ha applied three times at two week intervals reduced disease loci and Carboxin 4G at 1.12 kg ai/ha on demand reduced disease at digging, 144 days post seeding. Also, PCNB 10G at 11.2 kg ai/ha applied at pegging in 1979 (Table 2) and PCNB + fensulfothion 10-3G 11.2 + 3.35 kg ai/ha applied at pegging in 1980 (Table 3). increased yields and reduced disease loci. Daminozide 85W did not reduce disease or increase yield.

PCNB alone at 11.2 kg ai/ha and in combinations with ethoprop at 3.36 kg ai/ha when applied at either early pegging or on demand increased peanut yields in 1979 (Table 4). All of these treatments, except PCNB 10G at 11.2 kg ai/ha applied on demand, decreased disease incidence. Ethoprop 10G at 3.36 kg ai/ha applied at pegging also increased yields, but did not reduce numbers of disease loci.

In 1981, PCNB + ethoprop 10-3G at 11.2 + 3.4 kg ai/ha, PCNB + fensulfothion 10-3G at 11.2 + 3.4 kg ai/ha and PCNB + aldicarb 17.0 - 2.5G at 1.7 + 11.2 kg ai/ha applied at pegging increased yields (Table 5). Disease incidence for the PCNB + ethoprop and PCNB + fensulfothion treatments were less than for control 128 days after planting. Also, the disease incidence for ethoprop 10G at 3.4 kg ai/ha applied three times, at pegging and two and four weeks later, was less than for control. Plots

Table 2. Effects of PCNB and carboxin on southern stem rot incidence and peanut yields, 1979.

Treatment and formulation	Rate (kg ai/ha)	Application time[1]	Disease loci[2] (no/15.2 m row)[3]	Yield (kg/ha)
PCNB 10G	11.2	EP	8.9 a	5855 a
Carboxin 4G	1.12	OD	13.1 ab	5108 b
Carboxin 75W	1.27	OD	13.6 ab	4807 bc
Carboxin 3F	1.4	OD	14.8 b	4736 bc
Control	-0-	--	17.6 b	4461 c

[1]Treatment applied at early pegging (EP) on June 29 and on demand (OD) July 24-25. Peanuts were planted May 1 and harvested September 20.

[2]Numbers of disease loci recorded at digging.

[3]Means followed by common letters within columns are not significantly different at (P=0.05) by the Waller-Duncan K-Ratio T Test. Correlation coefficient for numbers of disease loci versus yield was -0.84 at P=0.02.

Table 3. Southern stem rot disease loci and yield of peanuts treated with carboxin, PCNB + fensulfothion and daminozide, 1980.

Treatments and formulation	Rate (kg ai/ha)	Application time	Disease loci (no/15.2 m row)[6] 98 days[7]	114 days	144 days	Yield (kg/ha)
Carboxin 4G	1.12	on demand[1]	2.0 b	3.0 d	14.4 c	3902 a
PCNB + fensulfothion 10-3G	11.2+3.36	peg[2]	5.2 ab	6.2 a-d	18.4 bc	3887 a
Carboxin 4G	0.67	on demand[1]	3.9 ab	5.1 cd	18.9 abc	3782 ab
Carboxin 4G	1.12	1st disease ++ 2 wk[3]	3.0 ab	4.9 cd	19.5 abc	3669 ab
Carboxin 4G	1.12	2 wk schedule[4]	3.5 ab	5.8 bcd	21.8 ab	3593 abc
Carboxin 4G	0.67	2 wk schedule[4]	5.5 ab	7.1 abc	22.5 ab	3568 abc
Carboxin 4G	0.67	1st disease ++ 2 wk[3]	4.9 ab	6.0 bcd	20.2 abc	3539 abc
Control	--	--	4.5 ab	8.5 ab	25.5 a	3321 bc
Carboxin 3F	0.84	on demand[1]	3.6 ab	5.4 bcd	19.9 abc	3132 c
Daminozide 85W	0.95+0.48	53 da. + 70 da.[5]	5.9 a	9.2 a	23.6 ab	3078 c

[1]Applications made 59 days, 84 days, 95 days, 105 days, 112 days, and 126 days after seeding at rates indicated for each application.

[2]Application made 59 days after seeding.

[3]Applications made 59 days, 77 days, and 91 days after seeding.

[4]Applications made 77 days, 91 days, 105 days, 112 days, and 126 days after seeding.

[5]Applications made 53 days and 70 days after seeding.

[6]Means followed by common letters are not significantly different according to Duncan's multiple range test, P=0.05. Correlation coefficients for numbers of disease loci at 98, 114 days and 144 days post seeding versus yield were -0.57, -0.71 and -0.77, respectively at P=0.02.

[7]Days after seeding.

Table 4. Effects of PCNB and ethoprop on southern stem rot incidence and peanut yields, 1979.

Treatment and formulation	Rate (kg ai/ha)	Application[1] time	Disease loci[2,3] (no/15.2 m row)	Yield (kg/ha)
PCNB 10G + ethoprop 10G	11.2 + 3.4	OD	6.5 a	5883 a
PCNB 10G + ethoprop 10G	11.2 + 3.4	EP	5.7 a	5776 a
PCNB 10G	11.2	EP	7.2 ab	5689 a
PCNB 10G	11.2	OD	11.7 bc	5427 ab
Ethoprop 10G	3.4	EP	12.0 c	5224 b
Ethoprop 10G	3.4	OD	16.7 d	4630 c
Control	-0-	--	14.8 cd	4617 c

[1]Treatments applied at early pegging (EP) on June 29 and on demand (OD) at first disease on July 25. Peanuts were planted May 1 and harvested September 20.

[2]Numbers of disease loci recorded at digging.

[3]Means followed by common letters within columns are not significantly different at (P=0.05) by the Waller-Duncan K Ratio T Test. Correlation coefficient for number of disease loci versus yield was -0.79 at P=0.02.

treated with EDB had higher numbers of disease loci than the control at digging, but did not decrease yield. In another test, PCNB (11.2 kg ai/ha) carboxin (1.4 kg ai/ha) aldicarb (2.2 kg ai/ha) and phenamiphos (2.2 kg ai/ha) were tested alone and as fungicide-nematicide combinations. None of the treatments decreased disease or increase yield over the control (data not shown).

Correlation coefficients for numbers of disease loci versus yield were negatively related Tables 1-5). The absolute value of the correlation coefficients increased as the time of disease evaluation approached harvest.

Discussion

No isolate of *T. harzianum* alone reduced the number of disease loci or increased yields. The disease reduction obtained by *T. harzianum* (B) + PCNB was probably due to PCNB since *T. harzianum* alone did not reduce disease. In view of the fact that *T. harzianum* (CPES) was effective in controlling *S. rolfsii* on tomatoes in the field (17) and *T. harzianum* (CPES) was antagonistic to *S. rolfsii* and *R. solani* in vitro (4), we suspect that the negative results obtained in these tests can be attributed to at least two factors. First, *S. rolfsii* in peanuts is active for a long period of time while *T. harzianum* was probably active for only 3-8 days which is not long enough for adequate control of the disease. *T. harzianum* probably became inactive soon after the food base supplied in the inoculum was exhausted. Secondly, *T. harzianum* is sensitive to foliar fungicides applied to peanut while *S. rolfsii* is relatively tolerant. To be highly effective a biocontrol agent must have a relatively long residual life and be tolerant to the fungicides used to control other diseases.

A high percentage of treatments containing PCNB alone or PCNB plus an insecticide nematicide reduced disease and/or increased yields. Nine of twelve treatments increased yields ($P = 0.05$). Average yields for the twelve treatments and controls were: treatments

Table 5. Southern stem rot disease loci and yield of peanuts treated with fungicides and nematicide/insecticides, 1981.

Treatment and formulation	Rate (kg ai/ha)	Application[1] time & method	Disease loci (no/15.2 m row)[2] 87 days[3]	128 days	144 days	Yield (kg/ha)
PCNB + Ethoprop 10-3G	11.2+3.4	Peg	0.5 a	2.0 cd	6.3 bc	4190 a
PCNB + fensulfothion 10-3G	11.2+3.4	Peg	0.3 a	1.5 d	5.0 c	3954 a
PCNB + aldicarb 17-2.5G	1.7+11.2	Peg	0.5 a	3.3 bc	4.8 c	3816 a
Ethoprop 10G	3.4	Peg+2wk+2wk	0.5 a	1.3 d	10.8 b	3410 b
Aldicarb 15G + PCNB + aldicarb 17-2.5G	1.17+(11.2+1.7)	Plant + peg	0.8 a	5.0 a	10.8 b'	3345 b
Control	--	--	0.3 a	4.0 ab	8.8 bc	3167 b
EDB 90	31.5	CI	1.0 a	4.8 ab	15.5 a	3077 b

[1]Peg = at pegging, 52 days after seeding; Peg + 2 wk + 2 wk = at pegging, 52, 71 and 92 days after seeding; plant = at planting May 5; and CI = chisel injected before planting. EDB 90 applied to only one treatment at planting; others were not treated with EDB 90.

[2]Means followed by common letters are not significantly different according to Duncan's multiple range test, P= 0.05. Correlation coefficients for numbers of disease loci recorded 87, 128 and 144 days post seeding versus yield were -0.23, -0.69, and -0.69, respectively, at P=0.02.

[3]Days after seeding.

4880 kg/ha; controls 4090 kg/ha or an increase of 790 kg/ha. Disease was reduced ($P = 0.05$) by five of the twelve treatments. Average numbers of disease loci (no./15.2 m rows at digging) for treatments and controls were: treatments 7.8; control 12.3 or a decrease in disease of 36%.

Although carboxin is very active *in vitro* against *S. rolfsii* it was only effective in the field at high rates when applied several times. Carboxin decreased disease and increased yield only where 1.12 kg ai/ha was applied six times at two-week intervals beginning at the first appearance of disease. Lower rates or fewer applications reduced disease initially; however disease increased by the end of the season and yields were not increased. The ineffectiveness of carboxin and, perhaps other materials tested may be due to their short half-life in the soil under the existing conditions. *Sclerotium rolfsii* is a vigorous pathogen and in most years is active over a 100 day period.

In general, the absolute value of correlation coefficients for numbers of disease loci versus yields were higher at digging compared to disease evaluations versus yeild earlier in the season. This may be indicative of the continual progression of the disease during the season, or may reflect the relative ease of seeing disease loci when plants are dug and inverted compared to searching for disease loci among healthy plants.

Deep plowing and PCNB + fensulfothion or ethoprop are the standard recommended practices for reduction of *S. rolfsii* on peanut in Georgia (16); however, PCNB alone or in combination treatments provided a decrease in disease only about 40% of the time and increased yield 75% of the time. Therefore, additional research on chemical control of this disease is warranted.

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