Effect of Soil Temperature and Soil Amendments on Thielaviopsis Root Rot of Sesame

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ABSTRACT

Soil amended with alfalfa hay, corn stover, and cabbage tissue substantially reduced red root of sesame caused by *Thielaviopsis basicola* in greenhouse experiments. In the field, alfalfa hay and corn stover provided no significant control. In a crop rotation study, no significant control was obtained when sesame followed oat, corn, or cabbage. In the greenhouse at a temp of 15 C, alfalfa hay provided no control, whereas at 20 and 25 C, alfalfa hay provided substantial control. At 30 and 35 C, red root was controlled by temperature alone. When the soil temperature was cycled 10 hours at 25 C and 14 hours at 30 C, disease severity was significantly less than that at constant 25 C, and similar to that at constant 30 C. Maximum germination of chlamydospores of *T. basicola* in soil was obtained at 25 C, with percentage of germination declining rapidly to zero at 35 C. Use of clear plastic mulch in the field to raise the soil temperature provided significant control of red root 7 weeks after planting, but not 12 weeks after planting. Phytopathology 61:93-97.

Thielaviopsis basicola (Berk. & Br.) Ferr. causes a root rot of cotton, bean, poinsettia, tobacco, and numerous other economic crops. On sesame (*Sesamum indicum* L.), *T. basicola* causes a red rot to develop on the roots and lower stems; hence, the name of the disease, "red root". In the field, reddish-brown lesions occur occasionally on the upper stems, and sometimes these lesions cause the stems to crack. This disease has been reported (8) in commercial fields in Texas, and in an experimental field in Beltsville, Maryland.

Papavizas (5) recently reported that numerous organic materials, when added to soil, suppressed root rot of beans caused by *T. basicola.* Since a field naturally infested with the red root pathogen was available in Beltsville, the effect of edaphic factors and soil amendments on red root severity under both greenhouse and field conditions were determined.

A preliminary report of a portion of this investigation has been published (2).

Materials and Methods.—The soil used in all experiments was Hatboro loamy sand containing 4.5% organic matter, with a pH of 5.5 and a moisture-holding capacity (MHC) of 30%. It was obtained from a field in Beltsville, Md., naturally infested with *T. basicola,* and in which severe red root of sesame occurred in previous years (8). This field was used for all field studies.

In all greenhouse experiments, amendments were mixed with air-dried soil, and water was added to bring the moisture level of the soil to 50% MHC. Soil was then placed in No. 4½ plastic pots (1,000 g/pot) and incubated at the desired temp. In the soil-temp experiments, soil (1,000 g) was placed in glazed crocks (11.5 × 20 cm, 1,100 ml capacity) which in turn were placed in soil-temp tanks at the desired temp. Each treatment was replicated 4 times. The soil was incubated for 2 weeks then remixed, and six seeds of sesame Oro were planted in each container. Depending on the experiment, plants were allowed to grow for 43 to 66 days. At harvest, height of each plant and disease severity were determined. Disease severity ratings (0-4) were assigned as follows: 0 = no visible infection; 1 = slight discoloration of the roots; 2 = moderate discoloration and slight rotting of the roots; 3 = moderate rotting of the roots; and 4 = severe rotting of the roots. A disease severity index (DSI) was calculated by averaging the disease severity ratings of the four replications of each treatment.

The isolate of *T. basicola* used in laboratory experiments was isolated by Thomas & Papavizas (8) from diseased sesame plants, and is the same isolate used in a previous study on soil fungistasis (3). Suspensions of chlamydospores were obtained from 21-day-old agar cultures as previously described (3). Germination of chlamydospores in soil under various conditions was determined by using the buried filter method (1). Control of red root in the field in 1968 and 1969 was attempted by use of soil amendments, crop rotation, and manipulation of soil temp.

Results.—*Effect of various organic amendments on the severity of red root of sesame.*—Various organic amendments, some of which are listed in Table 1, were added to soil at rates varying from 0.1 to 1.0% (w/w), and sesame seeds were planted after a 2-week incubation period. The plants were grown in a growth chamber in which the soil temp was maintained at 20-25 C.

Alfalfa hay, corn stover, and cabbage tissue markedly reduced the severity of red root when used at the proper concn (Table 1). With a few exceptions, there was an inverse relationship between red root severity and plant height. Materials such as chestnut tannin, barley straw, and corn stover at concn of 1.0, 0.5, and 0.25% caused varying degrees of stunting and chlorosis of the plants.

The effect of fresh alfalfa tissue on disease severity was compared to that of dried alfalfa hay. Since fresh alfalfa contains about 80% water, it was added to infested soil at the rate of 5%, while dried alfalfa hay was added to soil at the rate of 1%. At the completion of the experiment, plants grown in control (nonamended) soil had a DSI of 2.5, while those grown in

TABLE 1. Effect of various soil amendments on red root severity and plant height of sesame

Treatment	Concn	Disease severity index[a]	Plant height
	%		cm
Alfalfa hay	1.00	1.0 A[c]	24.0
	0.50	1.0 A	22.3
Cabbage tissue	0.50	1.0 A	22.6
	0.25	1.0 A	22.6
Corn stover	1.00	1.0 A	4.7
Alfalfa hay	0.25	1.2 AB	16.3
Corn stover	0.50	1.5 AB	7.6
Alfalfa hay	0.13	2.0 B	14.7
Cabbage tissue	0.13	2.0 B	17.2
Corn stover	0.25	2.0 B	12.0
	0.13	2.0 B	13.9
Chestnut tannin	0.13	2.0 B	10.1
Barley straw	0.50	2.0 B	4.5
Chestnut tannin	0.25	3.0 C	6.7
Barley straw	0.25	3.0 C	7.4
	0.13	3.0 C	9.7
Wheat straw	0.13	3.2 CD	10.6
Control		3.2 CD	10.1
PCNB[b]	0.01	4.0 D	7.2

[a] Disease severity index: 0 = no visible infection; 4 = severe rotting of the roots.

[b] Pentachloronitrobenzene.

[c] Mean values not followed by the same letter indicate a significant difference at the 5% level as determined by Duncan's multiple range test.

soil amended with fresh alfalfa and dried alfalfa hay had a DSI of 1.7 and 1.3, respectively.

In a similar experiment, the effect of alfalfa hay on disease severity was compared to the effect of dried alfalfa roots. Alfalfa hay and alfalfa roots were added to soil at the rate of 1%. At the completion of the experiment, plants grown in control soil had a DSI of 3.0, while plants grown in soil amended with alfalfa hay and alfalfa roots had a DSI of 0.6 and 2.9, respectively.

Effect of temp on red root severity and control with alfalfa hay.—Nonamended soil and soil amended with alfalfa hay at the rate of 0.5 and 1.0% were prepared and incubated at various temp for 2 weeks prior to planting. The results (Fig. 1) indicated that plants grown in the control soil at 15 C exhibited moderate discoloration and slight rotting of the roots. When sesame was grown in control soil at 20 or 25 C, however, the roots exhibited moderate to severe rotting. Roots of sesame grown in soil at 30 C suffered only slight discoloration, while those grown in soil at 35 C had no visible symptoms. When sesame was grown in infested soil amended with alfalfa at the rate of 0.5% at 15 C, the DSI was slightly greater than that in the control soil. At 20, 25, and 30 C, only slight discoloration of the roots occurred. At 30 and 35 C, disease severity in alfalfa-amended soil was similar to that in the control soil. Similar results were obtained when the soil was amended with alfalfa hay at the rate of 1.0%.

Since moderate to severe disease was obtained at 20 and 25 C, and since slight disease occurred at 30 C in the control soil, an experiment was performed in

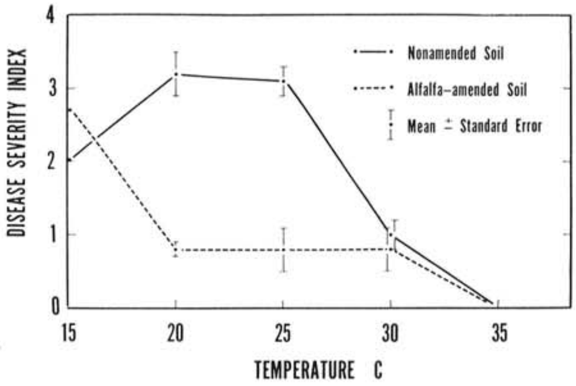

Fig. 1. Effect of soil temp on red root (*Thielaviopsis basicola*) severity of sesame and its control in soil amended with alfalfa hay at the rate of 0.5%.

which the disease severity was determined when the soil temp was cycled between 25 and 30 C. Plants were grown in nonamended soil under three temp conditions: in crocks in a temp tank at a constant 25 C; in crocks in a temp tank at a constant 30 C; and in pots in a growth chamber in which there was a 14-hr day length with a soil temp of 30-32 C and a 10-hr night period with a soil temp of 22-24 C. At the completion of the experiment, plants grown at a constant soil temp of 25 C had a DSI of 3.2, whereas those grown at constant soil temp of 30 C or those in which the soil temperature was cycled had a DSI of 0.8 and 0.9, respectively.

Effect of soil pH on red root severity of sesame and its control by alfalfa hay.—The soil was adjusted from pH 5.5 to 6.5 and 7.5 with lime. Several weeks after adding the lime, each soil was either left nonamended or amended with alfalfa hay at the rate of 0.5 or 1.0%. Sesame was planted 2 weeks after the soil was amended.

Soil pH had no significant effect on red root severity in the nonamended soils. Soils amended with alfalfa hay at both rates significantly (at the 1% level) reduced red root severity to essentially the same degree at each soil pH tested.

Effect of soil temp on germination of chlamydospores of T. basicola.—Soil was amended with alfalfa hay at the rate of 1%. At the time of amending the soil, membrane filters on which chlamydospores of *T. basicola* had previously been placed were buried in the soil. Soil containing the filters were incubated at 20, 25, 30, and 35 C. At various intervals thereafter, membrane filters were removed from the soil, and percentage germination of the chlamydospores was determined.

Chlamydospores began to germinate in the amended soil after an incubation period of 4-8 hr at 20, 25, and 30 C. After 12 hr of incubation at 20, 25, and 30 C, there was 46, 65, and 28% germination, respectively. After a 24-hr incubation period, considerable lysis of the germ tubes of chlamydospores incubated at 25 and 30 C occurred. No germination of chlamydospores occurred at 35 C within 24 hr.

Field studies. Effect of various soil amendments.—

TABLE 2. Effect of various soil amendments on the severity of red root of sesame in the field

Treatment	Rate (ppm)	Disease severity index (0-4)[a]	
		7 weeks	12 weeks
Benomyl[b]	500	0.13 A[c]	0.33 A
Chestnut tannin	5,000	0.60 B	0.93 B
Oat straw	5,000	0.40 AB	1.57 C
Benomyl[b]	50	0.70 BC	1.80 CD
Alfalfa hay	5,000	1.07 CD	2.17 DE
Control		1.23 D	2.33 DE
Alfalfa hay	10,000	0.93 CD	2.37 E
Corn stover	5,000	0.97 CD	2.50 E

[a] Disease severity index: 0 = no visible infection; 4 = severe rotting of the roots.
[b] Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate.
[c] Mean values not followed by the same letter indicate a significant difference at the 5% level as determined by Duncan's multiple range test.

In 1968, a soil amendment study was initiated in which various amt of selected amendments and a fungicide were incorporated into the soil with a rototiller. Each plot was 0.6 m wide and 6.1 m long, and each treatment was replicated 3 times in a randomized complete block design. The amendments were applied on 14 May, and the fungicide, methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl), was applied at the time of planting, 6 June. Plant height, disease severity, and seed yield were determined at the time of harvest in October. In 1969, the same treatments were applied a second time to their respective plots, except that oat straw was substituted for wheat straw. The amendments were applied on 1 May, and benomyl was applied on 27 May. Sesame was planted on 5 June. Plant height, plant wt, and disease severity were recorded for each plant in July (7 weeks after planting) and August (12 weeks after planting). The 1969 results on the effectiveness of the various amendments on red root severity showed (Table 2) that benomyl, chestnut tannin, and oat straw significantly reduced red root severity, as compared to that of the control. Results (not shown) from the 1968 test indicated that only benomyl at the rate of 500 ppm was effective in suppressing red root. Data on the effect of the various amendments on growth of sesame (Table 3) indicate that alfalfa hay, applied at the rate of 1%, increased both plant height and plant wt at both harvest dates. Although benomyl at 500 ppm, chestnut tannin, and oat straw reduced red root severity, there was no significant increase in plant height or plant wt when these materials were added to the soil. Chestnut tannin and corn stover were less phytotoxic in the field than when used in greenhouse experiments. Chestnut tannin was observed to have some herbicidal properties under field conditions.

Effect of crop rotation.—A crop rotation study was initiated in 1968 in which corn (*Zea mays* L. 'Eureka Ensilage'), cabbage (*Brassica oleracea* var. *capitata* L. 'Merion Market'), and oat (*Avena sativa* L. 'Garry') were grown on 16.8- × 4.6-m plots with three replications arranged in a randomized complete block design. One plot in each replication remained fallow. The crops were planted in late May and early June 1968. The oat and cabbage tissue were mowed and rototilled into the plots in late August and early September, respectively. The corn stalks were allowed to stand over winter, then mowed and rototilled into the plots in late April 1969. Sesame was planted in June 1969. When sesame followed oat, corn, or cabbage, disease severity was similar to that of plants grown in a field which was fallow the previous year. Seven weeks after planting, however, sesame plants grown in plots following oats were taller and heavier than those following either cabbage or fallow.

Effect of plastic mulch.—Manipulation of soil temp by the use of plastic mulch was evaluated during the summer of 1969 for the control of red root. Clear plastic (4 ml), black plastic (1.5 mil), and no plastic (control) were replicated 4 times in a randomized complete block design on each of two plots. The plastic strips (46-51 cm wide) were laid immediately after planting on either side of the 4.6-m rows in June 1969. Plants were harvested in July (7 weeks after planting) from the first plot and in August (12 weeks after planting) on the second plot. Plant height, plant wt, and disease severity were recorded for each plant in each treatment. The soil temp under the clear plastic mulch during the day was usually 7-10 C higher than in soil with no plastic mulch. Clear plastic mulch caused the plants to be less severely diseased, taller, and heavier than plants grown without plastic mulch 7 weeks after planting (Table 4). But 12 weeks after

TABLE 3. Effect of various soil amendments on the growth of sesame in the field

Treatment	Rate (ppm)	Mean plant height (cm)		Mean plant wt (g)	
		7 weeks	12 weeks	7 weeks	12 weeks
Alfalfa hay	10,000	42.2 A[b]	119.9 A	158 A	601
Alfalfa hay	5,000	39.3 AB	109.3 AB	86 B	344 B
Corn stover	5,000	32.7 BC	94.7 ABC	69 BC	210 B
Chestnut tannin	5,000	27.5 C	101.2 ABC	67 BC	282 B
Benomyl[a]	500	25.6 C	105.8 ABC	56 BC	317 B
Oat straw	5,000	21.7 C	93.5 ABC	50 BC	311 B
Control		26.4 C	89.5 BC	64 BC	278 B
Benomyl[a]	50	23.6 C	78.6 C	36 C	118 B

[a] Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate.
[b] Mean values not followed by the same letter indicates a significant difference at the 5% level as determined by Duncan's multiple range test.

TABLE 4. Effect of plastic mulch on growth of sesame and red root development in the field

	Mean values					
	Disease severity index (0-4)[a]		Plant height (cm)		Plant wt (g)	
Treatment	7 weeks	12 weeks	7 weeks	12 weeks	7 weeks	12 weeks
Clear plastic	1.04 A[b]	1.20 A	56.9 A	119.4 A	240 A	527 A
Black plastic	1.69 B	1.48 A	54.3 A	123.7 A	125 B	473 A
No plastic	1.76 B	1.55 A	45.5 B	115.6 A	101 B	421 A

[a] Disease severity index: 0 = no visible infection; 4 = severe rotting of the roots.
[b] Mean values not followed by the same letter indicate a significant difference at the 5% level as determined by Duncan's multiple range test.

planting, the advantage of using plastic mulch was lost. Disease severity of plants grown under black plastic mulch was similar to that of plants grown without plastic mulch.

DISCUSSION.—Papavizas (5) recently reported that in the greenhouse numerous materials, including those listed in Table 1, provided control of *Thielaviopsis* root rot of snap beans. These materials were reported to reduce the inoculum density. In subsequent work, alfalfa hay and corn stover were shown to increase the level of fungistasis of the soil (3, 6). In the field, alfalfa was shown (7) to control *Thielaviopsis* root rot of snap beans. The results presented above indicate that alfalfa hay, cabbage tissue, or corn stover when incorporated into the soil at the rate of 0.5% or more will control red root in the greenhouse but not in the field. No adequate explanation can be offered for the differences in results obtained with these amendments.

Sesame plants grown in alfalfa-amended soil in the field appeared to be significantly healthier than plants grown in nonamended soil; they were taller, heavier, and greener. In the 1968 field test, however, the seed yield of plants grown in alfalfa-amended soil was not statistically greater than the yield of those grown in nonamended soil.

One purpose of evaluating dried plant tissues as soil amendments for the control of soil-borne diseases in greenhouse experiments is that of seeking a plant tissue that can be worked into a crop rotation scheme. Data in Table 1 suggest that a cabbage or corn rotation would provide some control of red root the following year. In order to give the corn tissue a better chance of succeeding, the corn stalks were not mowed and rototilled into the soil until 2 months before the planting of sesame in 1969. Although the three crop rotations reduced the disease severity on sesame the following year, there were no statistical differences.

Bateman & Dimock (4) reported that high soil temp decreased the severity of root rot caused by *T. basicola*. Results in Fig. 1 agree with their conclusions. The chlamydospore germination experiments suggest how temp controls red root. Maximum germination of chlamydospores occurred at 20 and 25 C, with substantially less germination at 30 C and none at 35 C. When the soil temp was cycled between 25 and 30 C, red-root severity was substantially less than at a constant 25 C, and similar to that at a constant 30. These results cannot be explained on the basis of percentage germination of the chlamydospores at the two temp, since 50 to 65% of the spores could germinate during the 10-hr 25-C night period. Thus, soil temp of 30 C or greater apparently caused the plant to become more resistant to infection and subsequent disease development. Bateman & Dimock (4) reported that *Thielaviopsis* root rot of poinsettia developed best at 17 C, and was severe at soil temp between 13 and 26 C. They also found that at 30 C, the highest soil temp tested, only a trace of root rot developed. In agar cultures, they found that the opt range for growth of *T. basicola* was 15 to 27 C, and that no growth occurred at or above 33 C. These results substantiate the chlamydospore germination data presented here.

Since sesame is favored by relatively high soil temp, raising the soil temp in the field by the use of plastic mulch, a practical control of *Thielaviopsis* root rot, seemed possible. Clear plastic strips, placed adjacent to the row at the time of planting, helped control the disease and the development of taller, heavier plants 7 weeks after planting (Table 4). But the advantage of plastic mulch was lost, statistically, 12 weeks after planting. No explanation of the unexpected results can be offered at this time.

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