Seedling Diseases of Vegetables in Conservation Tillage with Soil Fungicides and Fluid Drilling

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ABSTRACT

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Germinated and nongerminated seed of okra, cucumber, cowpea, and tomato were planted with fluid drilling into mowed, disked, or moldboard-plowed rye on Bonifay sand and Tifton loamy sand in March, April, or May in 1985 and 1986. In each plot, adjacent rows of each crop were either drenched with metalaxyl + pencycuron or not treated, and all plots were irrigated immediately after planting. Average plant stands were increased 13 and 20% in the fungicide treatment compared with nontreated soil in March and April 1985, respectively. However, even without fungicide treatment, plant stands in April were 91% greater than in March. In 1986, plant stands were increased an average of 28% with the fungicide treatment, but plant stands were similar in nontreated soil in April and May. The fungicide treatment significantly reduced populations of *Rhizoctonia solani* AG-4 in soil and reduced root disease severity in one planting of cowpea. Moldboard plowing increased plant stand in one planting of cowpea but not in okra or cucumber. There were no differences in root disease severity among tillage treatments in any crops. Plant stand and root disease severity were similar with both nongerminated and germinated seed treatments.

Conservation tillage is defined as "any tillage and planting system that retains at least 30% residue cover on the soil surface after planting" (10). The practice has been emphasized in recent years to reduce soil erosion, but vegetable growers prefer a smooth, even seedbed free from crop residues to ensure a more uniform stand and fewer crop losses from root diseases (20). Some seeds, if germinated before sowing, emerge faster and establish stands earlier in the field when planted with fluid drilling, especially with adverse climatic conditions (3,14). Most research with gel seeding or fluid drilling has been done in plowed, level seedbeds. Research was initiated at the Georgia Coastal Plain Station in 1983 on seeding germinated vegetable seeds in conservation tillage (7).

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Root diseases frequently reduce stand and stunt growth in vegetables in the Georgia coastal plain. *Rhizoctonia solani* Kühn, AG-4 and AG-2 type 2, *Pythium irregulare* Buis., *P. aphanidermatum* (Edson) Fitzp., *P. myriotylum* Drechs., and other fungi are pathogenic on seedlings of many vegetables (11,17–20). This research was conducted to determine if seedling diseases in vegetables could be controlled with fluid drilling and soil fungicides in conservation tillage.

MATERIALS AND METHODS

Experiments were conducted on two soils, Bonifay sand (loamy, siliceous, Thermic, grossarenic Plinthic Paleudult) and Tifton loamy sand (fine loamy, siliceous, Thermic Plinthic Paleudult). Two plantings were made on both soils each year, 25–27 March and 15–19 April in 1985 and 8–9 April and 8–9 May in 1986. Experiments were run using split-split-plot designs with four replications. Fields were planted in rye (*Secale cereale* L.) in the fall of the preceding year, and tillage practices were whole plots (49 × 2 m) of two rows spaced 91 cm apart. Three weeks before planting, rye was killed with the herbicide glyphosate, and tillage practices were established 2 wk later. In the first year, the rye was mowed and treatments were disk harrowing or no-till. In the second year, the rye was mowed and treatments were 1) conventional tillage with a moldboard turning plow (25–30 cm deep) followed by rototilling, 2) disk harrowing, or 3) no-till. Plowing was done 8–10 days and disk harrowing 2–3 days before planting. Fertilizer (15, 30, and 15 kg/ha of N, P, and K, respectively) was broadcast after tillage treatments were established.

Subplots (12.2 × 2 m) were crops of tomato (*Lycopersicon esculentum* Mill. 'ARC'), cucumber (*Cucumis sativus* L. hybrid Peto Triplenoch, 88%, and Pollinator, 12%), cowpea (*Vigna unguiculata* (L.) Walp. 'Mississippi Silver'), and okra (*Abelmoschus esculentus* (L.) Moench 'Clemson Spineless') the first year and cucumber, cowpea, and okra the second year. Sub-subplots were seed treatments, nongerminated and germinated seed (two rows 6.1 m long), and sub-sub-subplots were two soil treatments, treated and not treated with fungicides (one row 6.1 m long). The fungicide treatment was a combination of metalaxyl (34 mg a.i./m of row) and pencycuron (278 mg a.i./m of row) applied as a drench in 328 ml of water per meter of row. Metalaxyl is effective against *Pythium* spp. and pencycuron against *R. solani* and related fungi (15). The fungicides were applied by hand with a sprinkler can in a band 20 cm wide over the row after planting, and the experiments were irrigated immediately with 1.5 cm water through overhead sprinklers. Herbicides used were ethalfluralin (0.84 kg a.i./ha) on cucumber, diphenamid (4.48 kg a.i./ha) on tomato, and metolachlor (2.24 kg a.i./ha) on okra and cowpea.

Planting was with a fluid drill mounted on a Buffalo conservation tillage seeder frame (6). The gel was prepared by mixing magnesium silicate (Laponite 508 gel powder, Laporte North America, Hackensack, NJ) with tap water, 1.75:100, w/w; for tomato, the ratio was 1.5:100. The amount of gel used for seeding was 0.5 g per seed for tomato, 6 g per seed for cucumber and okra, and 8 g per seed for cowpea. All seed were sown in continuous rows 2.5 cm deep, 13/m; for tomato, 78 seed/m were sown. Soil temperatures 5 cm deep were taken from Coastal Plain Station records from the meteorology station approximately 100 m from the plantings on Tifton loamy sand in 1985 and 1986. Also, in 1986 the sensor of a maximum/minimum soil thermometer was buried 2 cm deep laterally adjacent to the row in a plot of cowpea on Tifton loamy sand from 9 April until 26 May.

Cowpea and okra seedlings were removed at random in all experiments 2–3 wk after planting (2–20 each from fungicide treated and nontreated plots) in 1986, and from cowpea in the March 1985 planting on Tifton loamy sand. Seedlings were washed in running tap water, and 0.5- to 1.0-cm sections of roots and hypocotyls were excised. Tissues were surface-disinfested 15–30 sec in 70% ethanol, blotted dry on sterile filter paper, and incubated on water agar at 20–27 C. Hyphal tips were transferred to potato-dextrose agar (PDA), grown 10–14 days at 20–27 C, and identified to genus and species.

In 1985, plant stands were recorded in all crops, but seedlings were not rated for symptoms of root disease. To obtain detailed data on the effect of fungicide treatments on symptoms of root diseases, in 1986 cowpea and okra plants were removed from 1 or 2 m of row 2–3 wk after planting and rated for root and hypocotyl disease severity on a 1–5 scale, where 1 = < 2, 2 = 2–10, 3 = 11–50, and 4 = > 50% root and hypocotyl discoloration and decay, 5 = dead plant. Cucumber plants were not rated because diseased seedlings usually died before they were 2–3 wk old, and remaining plants did not show symptoms of root disease. Fresh weights of okra and cucumber plants from two experiments were recorded as additional data 4–5 wk after planting, when root and hypocotyl disease severity was not recorded in 1986. Experiments were terminated 6 wk after planting, and pods or fruits were not harvested in any experiments. In all experiments, data were analyzed by least squares analysis and means were separated using standard errors. Soil was sampled (10 cores, 5 cm deep, 2.5 cm diameter) 8 and 16 days after treatment with fungicides in 1986 and assayed for *R. solani* and other basidiomycetes on TAB medium (16) with a multiple pellet soil sampler (9) and for *Pythium* spp. on PARP medium (12).

RESULTS

For two wk after the March and April 1985 plantings, soil temperature ranges 5 cm deep were 11–17.5 and 16.5–22 C, respectively. Emergence was slow and stands were poor in all crops during the first planting because of the cool soil temperatures. With fungicide treatment, average plant stands of all crops were increased 13% over controls (6.1 vs. 5.4 plants/2 m) in March and 20% (12.4 vs. 10.3 plants/2 m) in April. Stands were increased significantly by fungicides in four of 16 crop-soil-planting date combinations (Table 1). Without fungicide treatment, delaying planting from March until April increased stands 92% (5.4 vs. 10.3 plants/2 m). In Georgia, tomato is planted in March to produce transplants and the other crops are planted in both March and April. There were no significant differences in plant stands between disk harrowing and no-till. There were no tillage × fungicide treatment interactions and only two seed treatment × fungicide treatment interactions. Fungicide treatment of the first planting of cowpea on Tifton loamy sand significantly increased plant stand in nongerminated seed (4.2 vs. 1.1/m) but not in germinated seed (0.9 vs. 0.5/m), compared with the control. In the second planting of tomato in Bonifay sand, the fungicide treatment significantly decreased

Table 1. Plants per meter of row in four vegetable crops treated or not treated with fungicides and planted in two soils in March and April 1985[x]

		Planted 27–30 March		Planted 15–19 April	
Crop	**Treatments**	**Bonifay sand**	**Tifton loamy sand**	**Bonifay sand**	**Tifton loamy sand**
Cowpea	Fungicides[y]	3.4	2.5 a[z]	8.0 a	6.1
	Control	2.2	0.8 b	5.5 b	4.9
Cucumber	Fungicides	2.2	4.8 a	9.3	9.7
	Control	2.5	2.8 b	8.4	9.6
Okra	Fungicides	1.2	1.7	4.6	7.2 a
	Control	1.4	0.5	3.9	3.4 b
Tomato	Fungicides	5.8	2.9	1.1	3.7
	Control	8.7	3.2	1.7	4.9

[x] Averages of plants in both disk-harrowed and no-till plots with germinated and nongerminated seed.
[y] Metalaxyl + pencycuron as a soil drench over the row immediately after planting.
[z] Numbers followed by different letters are significantly different according to a least square analysis using standard errors ($P = 0.05$). No letter indicates no significant difference.

Table 2. Plant stands and root and hypocotyl disease severity in cowpea with tillage, seed, and fungicide treatments in 1986

	Planted 8–9 April				Planted 8–9 May			
	Bonifay sand		Tifton loamy sand		Bonifay sand		Tifton loamy sand	
Treatments	**Plants per meter**	**RHDI[x]**	**Plants per meter**	**RHDI**	**Plants per meter**	**RHDI**	**Plants per meter**	**RHDI**
Tillage								
Moldboard plow	8.0	4.0	4.5	2.9	4.6 a[y]	4.1	5.3	1.9
Disk harrow	5.8	4.0	4.5	3.1	2.8 b	3.9	3.9	2.7
No-till	7.2	4.3	4.0	2.8	3.0 b	3.9	2.3	2.8
Seed								
Nongerminated	...[z]	...	...	...	3.1 b	4.1	5.5 a	2.4
Germinated	...	...	...	...	3.8 a	3.9	2.2 b	2.6
Fungicides								
Pencycuron + metalaxyl	8.0	4.0	5.9 a	2.7	4.5 a	4.0	3.7	2.2 a
None	6.0	4.2	2.8 b	3.2	2.5 b	4.0	4.0	2.8 b

[x] Root and hypocotyl disease index: 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay, 5 = dead plant.
[y] Numbers within columns of tillage, seed, or fungicide treatments followed by different letters are significantly different according to least squares analysis ($P = 0.05$). No letter indicates no significant difference.
[z] Plants were collected only in plots planted to nongerminated seed in April.

Table 3. Plant stands, foliage weight, and root and hypocotyl disease severity in okra with tillage, seed, and fungicide treatments in 1986

	Planted 9 April			Planted 8–9 May			
	Bonifay sand	Tifton loamy sand		Bonifay sand		Tifton loamy sand	
Treatments	Plants per meter	Plants per meter	Foliage fresh wt (g)[w]	Plants per meter	RHDI[x]	Plants per meter	RHDI
Tillage							
Moldboard plow	4.8	6.5	20.2	6.9	3.5	7.1	3.6
Disk harrow	4.8	8.2	25.7	5.6	3.6	4.9	4.0
No-till	3.5	6.3	17.6	5.6	3.3	3.2	3.9
Seed							
Nongerminated	...	...	...[y]	6.5	3.6 a[z]	5.1	3.8
Germinated	...	...	...	5.5	3.4 b	5.1	3.9
Fungicides							
Pencycuron + metalaxyl	4.4	8.4	24.7	6.4	3.5	5.5	3.9
None	4.3	5.6	17.7	5.6	3.5	4.5	3.8

[w] Two meters of row 5 wk after planting.
[x] Root and hypocotyl disease index: 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and decay, 5 = dead plant. Index taken 14 and 21 days after planting in Tifton loamy sand and Bonifay sand, respectively.
[y] Plants were collected only from plots planted with nongerminated seed on Tifton loamy sand in April.
[z] Numbers within seed treatments followed by different letters are significantly different according to least squares analysis ($P = 0.05$). No letter indicates no significant difference.

plant stand in nongerminated seed (1.5 vs. 3.3/m), whereas in germinated seed, plants were almost nonexistent with or without fungicide treatment (0.7 vs. 0.1/m).

In 1986, fungicide treatments increased plant stands significantly in cowpea in two of four plantings and reduced root and hypocotyl disease severity significantly in one planting (Table 2). Fungicide treatment did not increase stands or reduce root and hypocotyl disease severity in okra (Table 3). In cucumber, stands were increased significantly by fungicide treatment in two of four plantings, but there were no differences in fresh foliage weights 26 days after the second planting (Table 4). With fungicide treatment, plant stands (average of all crops) were increased an average of 15 and 40% over controls in Bonifay sand and Tifton loamy sand, respectively. During the two wk after the April and May plantings, soil temperature minima 2 cm deep was 9 and 15 C, respectively. Average plant stands were similar in April and May plantings in controls (8.8 vs. 9.6 plants/2 m, respectively).

Moldboard plowing increased plant stand compared with disk harrowing and no-till in one planting of cowpea (Table 2). Tillage treatments had no significant influence on plant stand in okra or cucumber, on root and hypocotyl disease severity in cowpea or okra, or on foliage weight in okra or cucumber (Tables 2–4). Root and hypocotyl disease severity was increased slightly with nongerminated compared with germinated seed in one planting of okra (Table 3), but there were no differences between seed treatments in cowpea and cucumber. Germinating seed before planting increased stand in one planting of cowpea but decreased stand in another (Table 2) and had no significant influence on plant stand in okra and cucumber (Tables 3 and 4). Interactions among tillage, fungicide, and seed treatments were usually not significant ($P = 0.05$). In one planting of cowpea, however, fungicides reduced root disease severity in disk harrowed and no-till treatments; with moldboard plowing, root disease severity was low and the fungicide had no significant benefit.

The fungi isolated most frequently from cowpea and okra seedlings (106 seedlings total, 1985 and 1986) were *Fusarium oxysporum* Schlecht. (39%), *F. solani* (Mart.) Appel & Wr. (9%), *Pythium* spp. (2%), *Macrophomina phaseolina* (Tassi) Goid. (2%), *R. solani* AG-4 (1%), and *Sclerotium rolfsii* Sacc. (1%). In soil collected 15 days after treatment in 1986, populations of *R. solani* AG-4 in Tifton loamy sand were reduced by 90% in the fungicide treatment compared with the control (Table 5). Except for *Laetisaria arvalis* Burdsall, populations of other basidiomycetes were usually low (<5 cfu/100 g of oven-dried soil) and were not

Table 4. Plant stands and foliage weight in cucumber planted 8–9 May with tillage, seed, and fungicide treatments in 1986

	Bonifay sand		Tifton loamy sand	
Treatments	Plants per 2 m	Foliage fresh wt (g)[y]	Plants per 2 m	Foliage fresh wt (g)
Tillage				
Moldboard plow	14.8	101	5.1	18.2
Disk harrow	12.4	67	4.2	19.6
No-till	12.7	64	3.9	19.7
Seed				
Nongerminated	12.7	77	3.4	14.1
Germinated	13.8	78	5.5	24.3
Fungicides				
Pencycuron + metalaxyl	14.9 a[z]	86	5.3	23.5
None	11.5 b	68	3.4	14.6

[y] Two meters of row 4 wk after planting. Data were not taken on the April plantings.
[z] Numbers followed by different letters within fungicide treatments are significantly different according to least squares analysis ($P = 0.05$). No letter indicates no significant difference.

Table 5. Mean population densities of *Rhizoctonia solani* and other basidiomycetes in soil planted to cowpea with tillage and fungicide treatments in 1986[y]

	Bonifay sand			Tifton loamy sand		
Treatments	*R. solani* AG-4	*R. zeae*	*Laetisaria arvalis*	*R. solani* AG-4	*R. zeae*	*Laetisaria arvalis*
Tillage						
Moldboard plow	0	5	6	3	2	0
Disk harrow	1	7	12	11	3	2
No-till	1	6	15	4	2	2
Fungicides						
Pencycuron + metalaxyl	1	6	12	1 b[z]	3	0
None	1	6	9	10 a	1	3

[y] Colony-forming units per 100 g of oven-dried soil 8 and 15 days after fungicide treatment in Bonifay sand and Tifton loamy sand, respectively. Densities are means of four replications of tillage treatments and 12 replications of fungicide treatments.
[z] Numbers followed by different letters within fungicide treatments are significantly different according to least squares analysis ($P = 0.05$). No letter indicates no significant difference.

influenced significantly by the fungicide treatment. The fungicide treatment did not have a significant effect on populations of *R. solani* AG-4 or other basidiomycetes in Bonifay sand (Table 4). Colonies of *Pythium* spp. were detected rarely in soil dilutions, and there were no differences among treatments. Tillage treatments did not significantly influence populations of *R. solani* AG-4 and other basidiomycetes, and there was no interaction between tillage and soil treatment.

DISCUSSION

This research indicates that seedling diseases may limit vegetable production in conservation tillage with fluid drilling and that soil fungicides to control *R. solani* and *Pythium* spp. will ensure more uniform plant stands. However, fungicides did not overcome the deleterious effect of low soil temperatures in early spring plantings, and delaying planting increased emergence (7). Growers prefer to plant early to harvest when market prices are more favorable, but we could not produce acceptable plant stands of okra, cowpea, and cucumber in March compared with April and May plantings with conservation tillage.

Others have added biological control agents (2) and fungicides (4,5, 8,13,21) to gels in fluid drilling, and it may be possible to add systemic fungicides to gel that would protect seedlings from preemergence and postemergence damping-off in conservation tillage. All of our research on conservation tillage was done by planting into winter rye residues. Residues from rye and other small grains may be beneficial in lowering populations of soilborne fungi pathogenic to vegetables compared with peanut or corn residues (1,19,20). Additional research is needed to determine if fluid drilling with gel and soil fungicides or biological control agents can produce satisfactory stands of vegetables in conservation tillage.

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