Ecology and Control of Seedling Diseases of Crucifers

Donald R. Sumner

Assistant Professor, Department of Plant Pathology, University of Georgia, Coastal Plain Station, Tifton 31794.
Accepted for publication 3 December 1973.

ABSTRACT

Seedling diseases of cabbage (*Brassica oleracea* var. *capitata*), collard (*B. oleracea* var. *acephala*), turnip (*B. campestris* Ssp. *rapifera*), and mustard (*B. juncea* and *B. perviridis*) were studied in growth chambers and in experimental fields. Night-day temp cycles of 10-21 and 21-32 C with a 12-h photoperiod were used in growth chambers. The fungi most commonly associated with roots and hypocotyls of seedlings from commercial fields were *Fusarium oxysporum, Rhizoctonia solani, Pythium irregulare, F. solani, Phoma* spp., and *F. roseum,* in that order. The most virulent pathogen was *Rhizoctonia solani,* regardless of temp. At low temp *P. irregulare,* and at high temp *F. oxysporum, F. solani,* and *Sclerotium rolfsii,* caused significant reductions in stands. *Sclerotium bataticola* was not pathogenic. Collard, turnip, and mustard were less severely damaged than cabbage at high temp in both infested and noninfested soils. Chloroneb completely controlled *Rhizoctonia solani* and increased plant stands in growth chambers, but not in field tests. Benomyl, thiabendazole, and *p*-(dimethylamino)benzenediazo sodium sulfonate reduced stands, and the latter two were phytotoxic to cabbage and turnip. All crucifers were more vigorous, less chlorotic and spindly, and had greater root growth at 10-21 than at 21-32 C.
Phytopathology 64:692-697.

Crucifers are grown year-round in Georgia, both for fresh market and processing. Mustard (*Brassica juncea* Coss. and *B. perviridis* Bailey) and collard (*B. oleracea* var. *acephala* DC.) are grown for leafy greens, turnip [*B. campestris* Ssp. *rapifera* (Metzg.) Sinsk.] for leafy greens and roots, and cabbage (*B. oleracea* var. *capitata* L.) for transplants and heads. Cabbage is direct-seeded for transplant production in late summer and early fall when soil temp maxima 1 cm deep are 30-45 C. Frequent sprinkler irrigation is used to reduce surface soil temp to 30-39 C, and to prevent soil from drying around germinating seed. Turnip, collard, and cabbage are planted from late summer through early spring. Thus, soil temp may vary from below freezing up to 45 C. Damping-off and root decay are endemic in all growing areas, and occasionally fields are severely damaged (14). This study was undertaken to determine what fungi were involved in the root-disease complexes, and the effects of soil temp and soil fungicides on seedling diseases.

MATERIALS AND METHODS.—Seedlings were collected from grower fields and evaluated for root and hypocotyl discoloration from 1969 to 1973. Several cultivars of different crucifers were also planted in experimental plots at the Coastal Plain Station at various times and observed at different soil and ambient temp. Soil temp 1-2 cm deep were continuously monitored with

TABLE 1. Root and hypocotyl discoloration and fungi isolated from crucifer seedlings planted in field soil with plants cultured in growth chambers.

Soil[a]	Dis.[b] (%)	% Plants yielding				Temp[c] (C)	Stand[d] (%)
		Pythium spp.	*Fusarium*		*Rhizoctonia solani*		
			oxysporum	*solani*			
TLS - 1970	50.0	38.0	0.0	0.0	0.0	15.5-32.0	
TLS - 1970	9.8	81.7	0.0	0.0	1.4	10.0-21.0	70.0
TLS - 1970	82.4	31.8	11.8	0.0	3.5	21.0-32.0	39.0
Worth County - 1970	2.7	39.2	21.6	13.5	14.9	10.0-21.0	74.0
Worth County - 1970	22.7	10.6	28.7	0.0	6.1	21.0-32.0	62.0
TLS, DLS, FLS - 1971[e]	15.5	18.4	2.3	0.0	0.6	10.0-21.0	69.6
TLS, DLS, FLS - 1971	8.3	24.4	17.3	9.5	8.9	21.0-32.0	67.2

[a]TLS = Tifton loamy sand; DLS = Dothan loamy sand; FLS = FuQuay loamy sand, all at the Coastal Plain Station.
[b]Percentage of seedlings with >10% discoloration on hypocotyls and roots.
[c]Night-day range in temperatures, ± 2 C.
[d](Number of plants ÷ number of seeds planted) × 100.
[e]Three replications on TLS and one each on DLS and FLS.

a Tempscribe® recorder. Air temp information was provided by the National Weather Service at the Coastal Plain Station. Crucifers were also planted in artificially-infested Tifton, FuQuay, or Dothan loamy sand, methyl-bromide-treated or autoclaved, or naturally infested soil, and grown in environmental chambers for 14-28 days. A 12-h photoperiod of both fluorescent and incandescent light (ca. 17,000 lux) was alternated with 12 h of darkness. Temperature cycles of 10-21 ± 1 C to 21-32 ± 1 C night-day were used. Soil moisture was maintained between one-half of the available moisture holding capacity and the normal moisture holding capacity.

Cultivars used in one or more experiments were 'Market Prize' (MPC), 'Market Topper,' and 'Rio Verde' (RVC) cabbage; 'Purple Top White Globe' (PTWG) and 'Shogoin' (ST) turnip; 'Southern Giant Curled' (SGCM) and 'Tendergreen' mustard; and 'Georgia' (GC) and 'Vates' (VC) collards.

Plants were periodically evaluated for root and hypocotyl discoloration 7-28 days after planting. Isolations were made from excised hypocotyl and root tissue sections 1-2 cm long and 0.2-1.0 mm in diam. Tissues were washed 0.5-2.0 h in running tap water at ca. 5-20 C, aseptically blotted dry on sterile filter paper, and incubated on water agar. Surface disinfestation was rarely used. Fungi that grew from the interior or surface of the tissues were transferred to other media and identified. Several fungi recovered from roots were grown on 3% cornmeal-sand (w/w) (CMS) for 7-14 days. Soil was then infested with CMS fungal cultures 1:50 to 1:140 (v/v). Crucifers were grown in each infested soil at different temp to determine pathogenicity and virulence of the fungi.

The following soil fungicides were tested at recommended experimental rates in both field and growth chamber experiments: chloroneb (Demosan), benomyl (Benlate), chloroneb plus benomyl, thiabendazole (Mertect), and *p*-(dimethylamino)benzenediazo sodium sulfonate (Dexon). Fungicides in 50-100 ml of water/30 cm of row were drenched over seed in the row just before covering, or both before and after covering.

In all experiments, seeds were planted 5-15 mm deep and 5-10 mm apart in the row. In most experiments, seeds were from commercial lots treated with thiram (1 g/1,400 g seed). Split-plot experiments in a randomized complete block design with three or four replications were used in most tests. Stylet-bearing nematodes were either absent, or present at only very low population levels, in all soils used.

RESULTS.—*Fungi associated with discolored seedlings.*—Isolations were made from hypocotyls and primary roots of ca. 850 crucifer seedlings from farm fields. The fungi most commonly isolated and the percentage of roots yielding each were: *Fusarium oxysporum* Schlecht, 22.2; *Rhizoctonia solani* Kuehn, 11.2; *Pythium irregulare* Buis. and other *Pythium* spp., 7.3; *F. solani* (Mart.) Appel & Wor., 7.3; *Phoma* spp., 5.3; and *F. roseum* (Lk.) em. Snyd. & Hansen, 1.7.

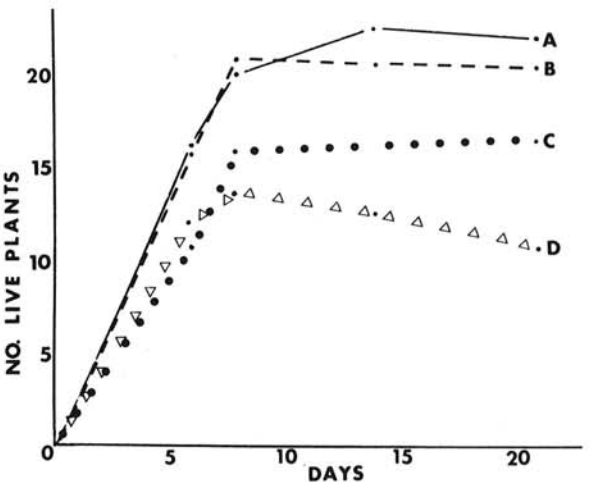

Fig. 1. Effect of temp on avg stand size of crucifer seedlings (collard, cabbage, turnip, and mustard) in Tifton loamy sand. Seedlings grown in noninfested soil at (A) 10-18 C, and (B) 15-35 C air temp, or field soil at (C) 10-18 C, and (D) 15-35 C.

TABLE 2. Percentage of 13-day-old plants with <50% root or hypocotyl discoloration in four crucifers grown at two temp regimes in autoclaved soil infested with several fungi[a]

Fungus	'Vates' collard		'Purple Top White Globe' turnip		'Southern Giant Curled' mustard		'Market Prize' cabbage	
	Temp							
	L[b]	H	L	H	L	H	L	H
Rhizoctonia solani	10	0	0	0	2	0	2	0
Pythium irregulare	58	46	28	24	38	30	12	18
Fusarium solani	78	76	76	44	82	90	72	54
Fusarium oxysporum	82	20	48	8	62	0	66	10
Sclerotium bataticola	96	50	76	68	84	82	58	60
None	50	42	80	64	92	72	84	70

[a]Based on 50 seeds of each crucifer planted at each temp.
[b]L = 10-21 ± 1 C, night-day; H = 21-32 ± 1 C, night-day.

Occasionally roots also yielded *Sclerotium bataticola* Taub. and other *Fusarium* spp.

The same fungi were associated with roots of crucifer seedlings planted in field soils and cultured at different temp in growth chambers (Table 1). Neither root, nor hypocotyl, discoloration was noted until 10-14 days after planting. In one field soil, plants were removed 7, 14, and 20 days after planting; and 0, 8, and 36% of the plants showed discoloration, respectively. *Pythium irregulare* was recovered from 0, 4, and 24% of these roots; and *Fusarium* spp. from 7, 1, and 9%, respectively, from those plants. *Rhizoctonia solani* was not isolated from the seedlings. In another experiment, however, *Rhizoctonia solani* was isolated from seedlings grown in a field soil previously amended with residue from a cotton ginning operation. Plant stands were markedly reduced in a separate naturally infested field soil, but not in a similar noninfested soil at growth chamber day/night temp of both 10-18 and 15-35 C (Fig. 1).

TABLE 3. Effect of fungi on growth and root and hypocotyl discoloration in four crucifers grown in infested, autoclaved soil

Treatments	Number of live plants after (days)		Hypocotyl discoloration after 13 days
	6	13	%[x]
Crucifer			
VC[y]	12.3 b[z]	13.0 b	30.8 b
PTWG	12.3 b	13.7 b	44.7 a
SGCM	15.8 b	16.2 a	48.2 a
MPC	7.0 a	12.2 c	39.1 ab
Fungi			
Fusarium solani	15.5 a	19.0 a	24.0 c
Fusarium oxysporum	2.2 c	9.6 b	58.8 b
Pythium irregulare	12.8 b	10.1 b	79.8 ab
Sclerotium bataticola	15.1 a	18.3 a	16.2 c
Rhizoctonia solani	2.1 c	1.1 c	88.0 a
None	14.8 ab	17.4 a	17.5 c

[x]Percentage emerged plants with more than 2% root and hypocotyl discoloration.
[y]VC = 'Vates' collard; PTWG = 'Purple Top White Globe' turnip; SGCM = 'Southern Giant Curled' mustard; and MPC = 'Market Prize' cabbage.
[z]Numbers followed by the same letter are not significantly different according to Duncan's multiple range test; $P = 0.05$.

Symptoms.—Initial symptoms varied from brown to a gray, water-soaked discoloration at the juncture of the hypocotyl and primary root to black or brown superficial streaks and lesions on the hypocotyl. Microscopic observations indicated that only the cortical parenchyma cells were collapsed in plants with superficial discoloration. In older plants, severely damaged hypocotyls were usually girdled by a lesion or covered with sunken pits. Frequently, the entire hypocotyl was shriveled and brown, or flaccid and water-soaked gray in wilted plants. Seedlings grown in field soils were separated according to symptoms, and isolations were made from several plants of each. No fungus was consistently recovered from a particular type of lesion. Nevertheless, black streaks and water-soaking were seen only when autoclaved soil was artificially infested wtih *Fusarium oxysporum* and *Pythium irregulare*.

Pathogenisis in autoclaved soil.—Cultures were grown on cornmeal sand (3:100, w/w) for 10-13 days. Inoculum thus prepared was mixed 1:49 (v/v) with an autoclaved mixture of Tifton loamy sand (TLS):vermiculite (3:1, v/v) and placed in 20×20×5 cm aluminum pans. The soil was incubated 4 days at 21-25 C, then one row of 25 seeds each of VC, PTWG, SGCM, and MPC was planted. Two pans of each treatment were placed in each of two growth chambers at night-day temp cycles of 10-21 or 21-32 ± 1 C. Plants were grown 13-15 days and evaluated for root and hypocotyl discoloration.

As shown in Table 2, *Rhizoctonia solani* was the most virulent pathogen at both temp cycles, followed in severity by *Pythium irregulare* and *F. oxysporum*. *Fusarium solani* was pathogenic at high temp on turnip but avirulent on the other hosts. *Fusarium oxysporum* was also far more destructive at high temp, as there was an

average of only a 12% stand at the high, compared to 64% at low temp 13 days after planting. *Sclerotium bataticola* was not pathogenic.

Stands were significantly reduced by *R. solani, P. irregulare,* and *F. oxysporum* (Table 3); and there was significantly less discoloratoin in VC than in SGCM and PTWG. Root decay was significantly greater at 21-32 than at 10-21 C, but stands were not significantly different.

Fungi-crucifer interactions were significant. The number of seedlings with <10% discoloration was not reduced by *F. oxysporum* or *P. irregulare* in VC, but was reduced in the other crucifers, and *F. solani* only increased the number of seedlings with >10% discoloration in PTWG. However, there were no significant interactions in the percentage of emerged plants with root and hypocotyl discoloration.

All crucifers were more vigorous, less chlorotic or spindly, and had greater root proliferation at low, rather than at high, temp.

Pathogenisis in methyl-bromide treated soil.—Dothan loamy sand fumigated with methyl-bromide was infested wtih CMS inoculum of several fungi (1:140, v/v). Controls were infested with sterile CMS. Plants were grown for 19-21 days in growth chambers at diurnal temp cycles of: (i) 10-21 C (low); (ii) 10-21 C for 3 days, 21-32 C for 3 days, then 10-21 C for 15 days; and (iii) 21-32 C (high). All seedlings were evaluated for root and hypocotyl discoloration, and isolations were made from 6-10 randomly selected seedlings from each treatment at the continuous low- and high-temp cycles.

Pythium irregulare was frequently isolated from the control seedlings grown at 10-21 C, and stands were significantly lower than in infested soils. In contrast, at 21-32 C, stands were significantly greater in the control soils than in soils infested with *F. solani* and *Sclerotium rolfsii* (Fig. 2).

At alternating low-high-low temp cycles, the control was not significantly different from soil infested with *P. irregulare,* but stands were significantly lower than in the other infested soils. There were fewer live plants in soils infested with *S. rolfsii* than in any of the other treatments. Isolates of *Rhizoctonia solani, F. oxysporum, F. roseum,* and *Phoma* sp. were nonpathogenic at all temp.

Stands were greatest at constant 10-21 C and poorest at constant 21-32 C. There was significantly more root and hypocotyl discoloration in collard at 10-21 C and at the alternating temp than in any of the other crucifers. At 10-21 C, turnip had significantly less discoloration than any of the other crucifers, but was not significantly different from mustard at the other two temp cycles. The mustard had significantly less discoloration than cabbage at 21-32 C but not at the lower temp. Cabbage was damaged significantly less than collard at the two lower temp cycles but not at the 21-32 C cycle. There were no significant crucifer-fungi interactions.

Pathogenisis in field soil.—Dothan loamy sand was collected from a field that was alternately planted to rye in the winter and fallow during the summer for 2 yr. The soil was stored outside for 5 mo, then passed through a sieve with 5-7 mm openings, mixed with 12, 24, and 36 mg/liter N, P_2O_5, and K_2O, respectively, and stored at normal moisture capacity of 6-8% for 7 wk. The soil was then passed through a sieve with 3-mm openings to remove particles of remaining organic matter and amended with 10- to 11-day-old CMS cultures (1:70, v/v). Two isolates of *F. oxysporum,* three of *F. solani,* two of *P. irregulare,* two of *Phoma* spp., three of *Rhizoctonia solani,* and one each of *P. myriotylum, F. roseum,* and *S. rolfsii* were used.

Amended soil was placed in 11.5 × 11.5 × 5.5 cm trays and planted with one row each of RVC, GC, and ST. Plants were grown at each of three temp cycles: (i) 10-21 C (low); (ii) 21-32 C for 26-53 h then 10-21 C; and (iii) 21-32 C (high). The number of live seedlings was recorded 6-7 and 13-14 days after planting, but root and hypocotyl discoloration was not evaluated.

Exposing the seeds to 21-32 C for 26-53 h immediately after planting did not reduce stands, as compared to the 10-21 C cycle. However, stands were reduced 12, 14, and 28%, respectively, in ST, GC, and RVC at the high- as compared to the low-temp cycle. There were no significant crucifer-fungi interactions. The only fungi that significantly reduced stands were three isolates of *Rhizoctonia solani.* As indicated in Fig. 3, two isolates caused severe stand losses at all temp while the third caused significant losses only at high temp. The latter isolate was recovered from a cabbage plant in a field where seedlings were severely damaged in early planting at high temp in August and September. When the grower made later plantings at lower temp in adjacent fields, few plants were killed.

Soil fungicides.—When plants were removed from infested autoclaved soil as previously described, the soil from each treatment in each growth chamber was mixed and returned to the original pans. Four rows ca. 1 cm deep and 20 cm long were made in each pan. Each row was drenched either with: chloroneb, 13 mg; thiabendazole (TBZ), 30 mg; *p*-(dimethylamino)benzenediazo sodium

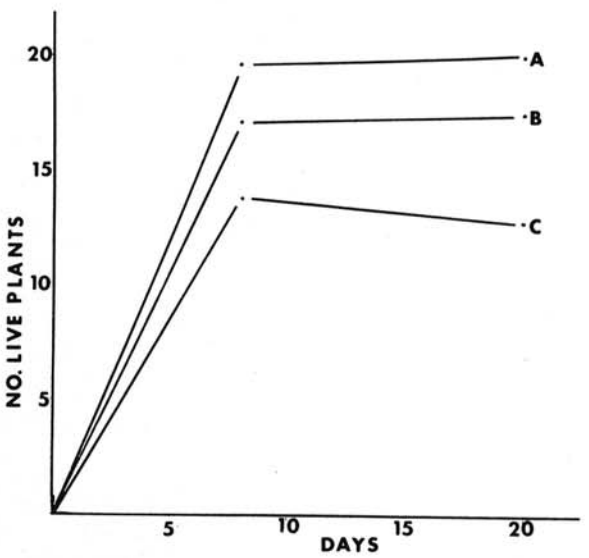

Fig. 2. Average number of live crucifer seedlings (collard, cabbage, turnip, and mustard) grown at 21-32 C in Dothan loamy sand treated with methyl-bromide and (A) noninfested, or infested with (B) *Fusarium solani* or (C) *Sclerotium rolfsii.*

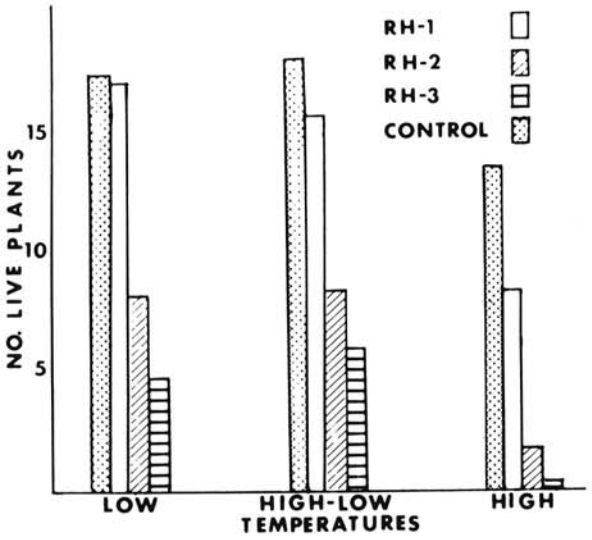

Fig. 3. Average number of 14-day-old collard, cabbage, and turnip seedlings grown at three temp cycles in Dothan loamy sand field soil artificially infested with three isolates of *Rhizoctonia solani* and noninfested. Low = 10-23 C, 14 days; High-Low = 21-32 C for 1-2 days, then 10-23 C for 12-13 days, and High = 21-32 C for 14 days.

sulfonate (DBSS), 13 mg; or no fungicide in 10 ml of water. An additional 20-30 ml of water/row was added to further infiltrate the fungicide. Twenty-five seeds/row of PTWG turnip were immediately planted, and the pans moved to growth chambers at 10-21 or 21-32 C. After 11-12 days, the plants were evaluated. The greatest seedling damage was again caused by *Rhizoctonia solani,* but chloroneb completely controlled the fungus at both temp cycles. Chloroneb also controlled *Pythium irregulare* at low, but not at high temp. Emergence was reduced by DBSS, and TBZ was phytotoxic.

In a second experiment with Tifton, FuQuay, and Dothan loamy sand field soils, a mixture of 32.5 mg of chloroneb and 25 mg of benomyl/kg of soil was incorporated into half of the soil, and the other half was not treated. MPC and ST were planted and grown at 10-21 or 21-32 C for 18-21 days. Root diseases were not severe; the stands of live MPC plants at low and high temp were 59 and 46% in nontreated soil, and 60 and 53% in treated soil, respectively. In ST, the stands were 80 and 77 vs. 83 and 89%, respectively. In addition to slightly increasing stands, chloroneb + benomyl decreased the percentage of plants which yielded cultures of *Rhizoctonia solani* from 8.9 to 2.1, *F. oxysporum* from 17.3 to 2.1, and *F. solani* from 9.5 to 1.0 at high temp. Approximately 24% of the plants in both soils yielded cultures of *Pythium* spp.

At low temp, very few cultures of *Rhizoctonia solani, F. oxysporum,* or *F. solani* were isolated from seedlings; but 18% of the plants grown in nontreated soils yielded *Pythium* spp., compared to 5% in the treated soil. More cultures of each fungus were isolated from plants grown at high than at low temp in both treated and nontreated soils.

In another study with DLS artificially-infested with *Rhizoctonia solani* and treated with chloroneb, stands were increased 20 and 72% in ST and MPC, respectively. Increases averaged 56% at 13-26 C, and 74% at 20-33 C.

Field studies.—Cabbage was direct-seeded for transplant production from August through November by a commercial grower in 1971. The fields were periodically observed from 14 September to 1 December, and isolations were made from severely damaged plants 14 September, and 21 and 28 October. A small plot in one field was used for a fungicide test 7 October. Rows were 3.05 m long and 20 cm apart. Immediately after planting, rows were drenched with 135, 271, or 541 mg of chloroneb in 35 ml of water per 3.05 m of row. Nontreated guard rows were left on both sides of the treated rows. The field was sprinkler-irrigated the following day and each day thereafter as needed.

Diurnal air temp ranged from 7-21 C to 20-29 C during the following 2 wk. Only 2% of the seedlings died in the controls, compared to 25-50% noted in the field in August and September when air temp were 20-36 C. When plants were 54 days old, they were evaluated for root and hypocotyl damage. Only an average of 9.3% of the plants treated with chloroneb showed >10% root and hypocotyl discoloration as compared to 15.6% in the controls. Nevertheless, the average number of live plants available for transplanting was reduced by chloroneb from 206 to 125/meter of row.

Rhizoctonia solani was isolated from 12% of the 14-day-old and 41% of the 21-day-old nontreated seedlings in October, as compared to 74% from 7- to 35-day-old plants collected 14 September. Tissue from 42 plants sampled 14 September was incubated on pimaricin-streptomycin water agar (100 mg/ml each of pimaricin and streptomycin) to determine if *Pythium* spp. were also involved in the root disease. Only two roots yielded cultures of *Pythium* spp. No *Pythium* was recovered from seedlings collected in October. In contrast, *F. oxysporum* was isolated from 29-54% of the seedlings in October and only 6% on 14 September. None of the plants yielded cultures of *F. solani.* Thirty-five juvenile plants were collected 1 December from rows treated with 541 mg chloroneb/3.05 m of row, and isolations were made from each hypocotyl. The plants yielded no cultures of *Rhizoctonia solani,* but did yield 16, two, and four cultures of *F. oxysporum, F. solani,* and *Pythium* spp., respectively.

In another study in September and October, 1972 (15), soil fungicides also reduced stands of MPC. In an earlier test in August, 1970, stands of both ST and MPC were reduced by treatments with chloroneb, thiabendazole, and benomyl. Cabbage was also damaged by DBSS, but stands were improved from 37 to 43 plants per meter of row in turnip with DBSS.

DISCUSSION.—My research with controlled temp confirms the research of others (4, 5, 7, 8, 13, 16, 17) and shows that significant temp-pathogen interactions do occur in crucifer seedling diseases.

Rhizoctonia solani was the most virulent seedling pathogen on crucifers and was the least affected by temp. This corroborates the work of Gratz (4) who reported that the pathogen caused severe damage from 15-30 C. Nevertheless, I found some isolates that were more virulent than others at higher temp, and *R. solani* was

more frequently isolated from seedlings grown in the field at 20-35 C, than at 5-20 C. Conversely, Wellman (18) found that the optimum temp for bottom rot of cabbage heads was 25-27 C, and that no rot occurred at 32 C. The presence of plant debris also apparently influenced damage by *R. solani,* since the fungus was most frequently recovered from plants grown in fields recently amended with organic matter.

High soil temp are also known to increase *Fusarium* yellows of cabbage (16, 17), and seedling necrosis caused by *F. oxysporum* was significantly greater at higher temp in these experiments. However, I made no attempt to determine whether the isolates used would cause yellows. Some isolates of *F. solani* significantly reduced stands at high temp, although the fungus has not been reported to cause seedling diseases of crucifers. In addition, *Sclerotium rolfsii* caused significant seedling death at high temp; and cabbage, turnip, and mustard are known to be susceptible hosts (3).

The most common phycomycete isolated from seedlings was *Pythium irregulare,* and the fungus was most virulent at low temp. An isolate of the *P. debaryanum* group was reported to be more virulent on swede in autoclaved soil at 0-15 C than at either 5-20 or 15-30 C (5). Also, *P. intermedium* d By was the only one of numerous fungi isolated from *Brassica nigra* L. Koch grown in nonsterile soil at 13-26 C that was pathogenic (9). High-temp pythia, such as *P. aphanidermatum* (Edson) Fitz. and *P. myriotylum* Drechs, cause severe damping-off in numerous crops in the coastal plain (10). However, my research indicates they cause only a slight reduction in stands of crucifers.

In the coastal plain of Georgia, cabbage is direct-seeded for transplant production from late July to October and again in February and March. Air temp maxima are commonly 29-37 C in the late summer, but only 7-25 C in the late winter. Turnips and mustard are direct-seeded during the same periods for leafy greens production. Collard is primarily seeded only in the late fall for production of winter leafy greens. During the late summer plantings, soil temp daily maxima 1-2 cm deep are commonly 30-39 C, even with daily sprinkler irrigation (15). In contrast, daily maxima in February and March, 1973, ranged from 3-30 C, and usually were 15-26 C. Thus, the temp are much more favorable for damage by soil-borne pathogens in the fall crop. Observations on grower fields and in research plots 1969-1973 indicate that seedling diseases are severe (especially on cabbage) in the late summer, but are negligible in the late winter plantings.

Cabbage is known to be sensitive to temp over 25 C (11), and 15-30 C caused elongation and etiolation in swede (5). In contrast, collard thrived well at soil temp of 18-29 and air temp of 21-40 C, with maximum growth at soil temp of 24 C (1). Turnip leaf growth was best at soil temp of 24-29, while root growth was best at 13-24 when air temp were 21-40 C (2). I found that turnip, mustard, and collard were less sensitive than cabbage seedlings to high temp in sterile soil.

This research shows that even though root-disease fungi differ in virulence on different crucifers, there is little evidence to indicate differential pathogenicity. Numerous strains of soil-borne pathogenic fungi exist in Georgia coastal plain soils, and more crucifer-fungi interactions could probably be elucidated with further tests.

Reducing root damage by soil fungi with selective fungicides did significantly increase stands in controlled environments, but not under field conditions (15). Fumigation with ethylene dibromide controlled *Meloidogyne incognita* and significantly increased yields in nonirrigated and reduced yields in irrigated plots at Tifton (6), but no data were taken on soil-borne fungi. In California, stands of cabbage were increased by fumigation with a 67% methybromide, 31.75% chloropicrin, and 1.25% gel mixture (12). More research is needed to help assure growers better stands under adverse environmental conditions.

LITERATURE CITED

1. DEL VALLE, C. G., and S. A. HARMON. 1967. Collard growth and mineral composition as influenced by soil temperature and two fertility levels. Proc. Am. Soc. Hortic. Sci. 91:347-352.
2. DEL VALLE, C. G., and S. A. HARMON. 1968. Turnip growth and mineral composition as influenced by soil temperature and two fertility levels. Proc. Am. Soc. Hortic. Sci. 92:578-582.
3. EPPS, W. M., J. C. PATTERSON, and I. E. FREEMAN. 1951. Physiology and parasitism of Sclerotium rolfsii. Phytopathology 41:245-255.
4. GRATZ, L. O. 1925. Wire stem of cabbage. N.Y. (Cornell) Agric. Exp. Stn. Mem. 85. 60 p.
5. GREEVES, T. N., and A. E. MUSKETT. 1936. A temperature study of Pythium attack on swede seedlings. Ann. Appl. Biol. 23:264-270.
6. HEGWOOD, D. A., and J. M. GOOD. 1961. Effect of soil fumigation, irrigation, and fertilizer application on turnip green production. Proc. Ass. Southern Agric. Workers 58:165 (Abstr.).
7. HEMMI, T. 1923. On the relation of temperature to the damping-off of garden-cress seedlings by Pythium debaryanum and Corticium vagum. Phytopathology 13:273-282.
8. LEACH, L. D. 1947. Growth rates of host and pathogen as factors determining the severity of preemergence damping-off. J. Agric. Res. 75:161-179.
9. LONG, P. G., and R. C. COOK. 1969. Fungal factors and density-induced mortality in plant species. Trans. Br. Myc. Soc. 52:49-55.
10. MC CARTER, S. M., and R. H. LITTRELL. 1970. Comparative pathogenicity of Pythium aphanidermatum and Pythium myriotylum to twelve plant species and intraspecific variation in virulence. Phytopathology 60:264-268.
11. NIEUWHOF, M. 1969. Cole crops: botany, cultivation, and utilization. Leonard Hill, London. 353 p.
12. RADEWALD, J. D., B. J. HALL, F. SHIBUYA, and J. NELSON. 1971. Results of preplant fumigation trial for the control of sugarbeet nematode on cabbage. Plant Dis. Rep. 55:841-845.
13. SCHULZ, F. A., and D. F. BATEMAN. 1969. Temperature response of seeds during the early phases of germination and its relation to injury by Rhizoctonia solani. Phytopathology 59:352-355.
14. SUMNER, D. R. 1971. Fungi associated with seedling rot in crucifers. Ga. Acad. Sci. 29:97-98 (Abstr.).
15. SUMNER, D. R. 1972. Seedling root-rot of cabbage. Fungicide-nematicide Tests 28:68. American Phytopathological Society, St. Paul, Minnesota.

16. TIMS, E. C. 1926. The influence of soil temperature and soil moisture on the development of yellows in cabbage seedlings. J. Agric. Res. 33:971-992.
17. TISDALE, W. B. 1923. Influence of soil temperature and soil moisture upon the Fusarium disease in cabbage seedlings. J. Agric. Res. 24:55-86.
18. WELLMAN, F. L. 1932. Rhizoctonia bottom-rot and head-rot of cabbage. J. Agric. Res. 45:461-469.