Effects of Calcium and Nitrogen Fertilizers, Fungicides, and Tillage Practices on Incidence of *Sclerotium rolfsii* on Processing Carrots

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ABSTRACT

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Incidence of root rot caused by *Sclerotium rolfsii* on processing carrots in North Carolina and Georgia was reduced in 1983 and 1984 by deep plowing infested fields before planting compared with disking. Reduction in disease incidence after plowing was attributed to burial of sclerotia at depths where germination and infection were prevented. Three applications to deep-plowed plots of calcium nitrate or urea at 112 kg of calcium or nitrogen per hectare, respectively, ammonium bicarbonate (NH_4HCO_3) at 84 kg of nitrogen per hectare, or PCNB at 56 kg/ha reduced the percentage of dead plants at the end of the growing season to less than 5%; on untreated plots, disease incidence was 16.8%. On disked plots, only PCNB provided a similar level of control. Calcium levels in carrots receiving calcium nitrate or calcium sulfate were significantly ($P \leq 0.05$) higher than in carrots from unfertilized plots. Application of ammonium bicarbonate, urea, or PCNB to soil reduced germination of sclerotia and the extent to which mycelia grew to infect carrot tissue. Viability of sclerotia buried in field plots was significantly reduced by one application of ammonium bicarbonate compared with sclerotia in untreated plots. Combining deep plowing and applications of a calcium fertilizer and ammonium bicarbonate provides effective and economical control of *S. rolfsii* on processing carrots.

Additional key words: cultural control, southern blight

Sclerotium root rot, caused by *Sclerotium rolfsii* Sacc., is a major factor limiting the production of processing carrots (*Daucus carota* L.) in North Carolina and Georgia. Low levels of inoculum can result in high percentages of dead plants, because plant-to-plant spread of the pathogen within one growing season is extensive (26). Fields with more than 5% diseased plants are generally unacceptable for harvest. One possible approach to minimize losses caused by *S. rolfsii* on carrot is to avoid planting in fields that contain high levels of inoculum. Sampling and extraction procedures to identify potential areas have been described (25).

Attempts to control southern blight or stem rot with chemicals applied to sugar beet (2,16), peanut (9), carrot (12), and golf greens (20,21) have met with varied success. Carboxin, furmecyclox, and PCNB were the most effective fungicides (2,9,12,16,20,21). Soil fumigation (3,8,10,13,15) and application of nitrogen fertilizers (4,14,20,28) may also reduce disease incidence, whereas deep plowing and modified cultural practices (3,11,12) gave some level of disease control on other crops. One major consideration in developing an effective strategy to control *S. rolfsii* on processing carrots is cost, because carrot is not a high-value cash crop and profits are marginal. High costs incurred in using certain effective fumigants (15) or fungicides (12) could be prohibitive commercially.

The objective of this study was to determine the efficacy of calcium and nitrogen fertilizers and selected fungicides, used in combination with deep plowing or disking tillage practices, for control of root rot of processing carrots caused by *S. rolfsii*. Results of laboratory and field studies conducted to determine the modes of action of the most effective treatments are presented.

MATERIALS AND METHODS

Experimental plots. Two locations, one at Maxton, NC (field A), and the other at the Campbell Institute for Research and Technology Farm at Cairo, GA (field B), both with previous incidence of root rot on carrot caused by *S. rolfsii*, were selected for trials during the 1983 and 1984 growing seasons. Field A soil was a fine sandy loam (sand/silt/clay ratio of 65:19:16), pH 6.4, and organic matter content about 2%; field B soil was a coarse sandy loam (sand/silt/clay ratio of 76:18:6), pH 6.1, and organic matter content about 1%. The mean inoculum densities in fields A and B, determined in March 1983 before planting, were 5.4 and 5.9 sclerotia per 300 cm^3 of soil, respectively (25). In both years of this study, half of each field was deep-plowed with a moldboard plow equipped with extensions (trash covers) that turned under and buried surface residues and the upper 10–15 cm of soil to a depth of 25–30 cm. The other half of the field was disked 10–15 cm deep with a conventional disk. Tilling was done in March or April, depending on location, before planting. Immediately before and after plowing or disking field A in 1983, eight soil samples (each 600 cm^3) were taken from each half of the field with a 10.2-cm-diameter probe inserted 7.5 cm deep and assayed for sclerotia by a wet-sieving procedure (26). Samples were taken at 7.5-m intervals along the direction of tillage from about the same location before and after the tillage was conducted.

Carrots (cultivar Camden) were seeded in a 5-cm-wide band (12–15 seeds per 30.5 cm of row) on raised beds (10 cm high × 1.9 m wide). Three rows on 0.5-m centers were planted in each bed. The average stand per 30.5 cm of row was determined 6 wk after planting by counting plants within all rows in 12 7.6-m-long bed sections in each half of the field. Trifluralin (Treflan 4E, 1.8–2.4 L/ha preplant) and linuron (Lorox 50W, 1.1–2.3 kg a.i./ha postplant) were used for weed control. Insects were controlled with carbaryl (Sevin 80W, 0.85 kg a.i./ha), and chlorothalonil and mancozeb were applied at label rates to control foliar fungal pathogens. Fertilizer (10-20-20, 570 kg/ha) was applied preplant, and nitrogen (45 kg/ha) was applied 6–8 wk after planting. Irrigations were made

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through overhead sprinklers once every 4–5 days or as required to supplement rainfall. Cultivations were made three times during the season. Disease incidence (expressed as percentage of plants dead) was assessed by measuring the length of row in each plot that contained dead plants (Fig. 1A) and expressing the summed value as a percentage of the total length of row in the plot. All rows in each plot were included in the disease assessment.

1983 Study. Plantings in North Carolina and Georgia were made on 15 and 22 April, respectively. Four calcium fertilizers, four nitrogen compounds, and three fungicides were evaluated at Maxton (Table 1), and two calcium and three nitrogen compounds were evaluated at Cairo (Table 2). Fertilizers were applied to provide 112 kg of calcium or nitrogen per hectare, except ammonium bicarbonate (NH_4HCO_3), which was applied at a rate of 84 kg of nitrogen per hectare. Chlorothalonil (Bravo 500 F), PCNB (used as granular FF-II containing 15.4% PCNB and 14% nitrogen), and triphenyltin hydroxide (TPTH) (Duter, 1.875 F) were applied at rates of 0.5, 56, and 2.2 kg a.i./ha, respectively. Each material was applied three times during the season: on 7 and 28 June and on 19 July. The fertilizers and FF-II were broadcast over the beds in each plot. Fungicides were applied through two drop nozzles in a 30.5-cm-wide band over each row with a hand-held boom and a CO_2-pressurized backpack sprayer (at 550 kPa) in 935 L of water per hectare. Treatments within each half (deep-plowed or disked) of the field were randomized in a complete block design with four replicates per treatment. Plots measured 7.6 × 5.6 m and comprised three beds, each with three rows. One-meter-wide alleys separated adjoining plots. Disease assessments were made on 13 July and 9 August; the experiment ended on 15 September.

Calcium levels in a sample of 10 roots from untreated plots at Maxton, NC, and from plots receiving three applications of calcium nitrate or calcium sulfate were determined by atomic absorption spectrophotometry (1). Root samples were sectioned to separate outer periderm and pericyclic parenchyma from inner

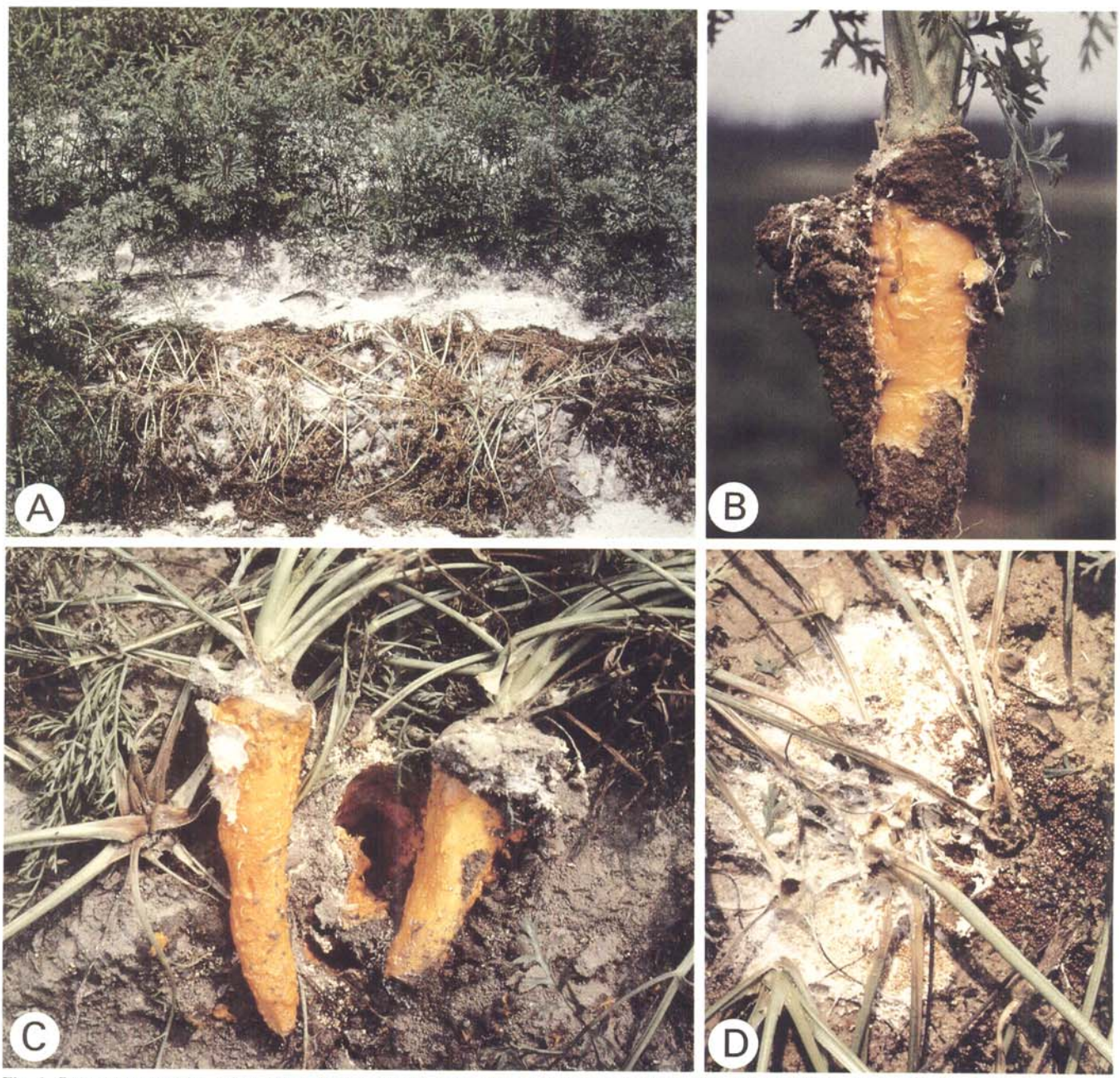

Fig. 1. Root rot caused by *Sclerotium rolfsii* on carrots grown for processing at Maxton, NC. **(A)** Disease focus resulting from lateral spread of mycelium of the pathogen from plant to plant. **(B)** Initial symptom of soft rotting after infection at the root crown by mycelium growing through soil. **(C)** Advanced stage of infection, showing tissue maceration. **(D)** Abundant mycelial growth and sclerotial formation at the soil surface within the plant canopy, showing fanlike growth and secondary spread to adjacent plants.

phloem parenchyma, or whole unsectioned root pieces were used. Three replicate 0.5-g (oven-dry weight) samples were ashed overnight at 550 C in a muffle furnace, dissolved in 3 ml of concentrated HCl, and diluted with distilled water to 50 ml. Samples were analyzed on a Perkin-Elmer atomic absorption spectrophotometer after further dilution with 0.5% lanthanum to provide a working range of (0.5–5 μg/ml calcium. Calcium levels in tissues were determined from a standard curve and expressed as a percentage of tissue dry weight.

1984 Study. Plantings in North Carolina and Georgia were made on 22 and 12 April, respectively. At both locations, treatments comprised ammonium bicarbonate and calcium sulfate, applied singly or in combination, to each half (deep-plowed or disked) of the field. Each treatment was replicated four times; plots were 128 m^2. Calcium sulfate (gypsum, 64.9%) was broadcast on 7 June at 1,120 kg/ha; ammonium bicarbonate was applied on 28 June and 25 July at 84 kg of nitrogen per hectare. Disease evaluations were made on 9 August, and the experiment ended on 15 September.

To determine the influence of ammonium bicarbonate on sclerotial viability, batches of 50 nondried sclerotia from laboratory-grown oat cultures of *S. rolfsii* (17) were sealed in Saran cloth bags (4×4 cm) (Chicopee Mfg. Co., Cornella, GA; 144 openings per square centimeter) and buried 1 cm below the soil surface on 27 June at two sites in field A. Four replicate bags were recovered from each site on 25 July and 28 August (after one or two applications of ammonium bicarbonate), and the sclerotia were surface-disinfested in 0.5% NaClO and plated onto 1.5% Bacto water agar. Percent viability after 72 hr of incubation at 28 C was compared with viability of sclerotia recovered from untreated plots.

Influence of calcium and nitrogen compounds and fungicides on sclerotial germination and infection of carrot tissue in vitro. Air-dried, nonsterile soil from field A was sieved through a 14-mesh (1.18-mm) screen, and 30-cm^3 aliquots were placed in glass petri dishes (100×15 mm). The soil was moistened to approximately field capacity with sterile 20 mM solutions of ammonium bicarbonate, calcium nitrate, or urea, or with 10-μg/ml suspensions of chlorothalonil (Bravo 500F) or PCNB (Terraclor 75W) (about 10 ml of each per dish). Control dishes received sterile distilled water or autoclaved soil. After 24 hr of incubation at 25 C, air-dried sclerotia of isolates 1126 and 2672 of *S. rolfsii* originating from annual bluegrass-bentgrass golf greens (20) that were produced in 3-mo-old oat cultures (17) were placed on the moistened soil. Each dish received eight sclerotia placed 2 cm from a detached carrot leaf petiole. The number of germinating sclerotia and the percentage that produced mycelia that infected the leaf petiole were determined after 6 days of incubation at 28 C. Data presented are the means of five replicates; the experiment was repeated twice.

RESULTS

Disease symptoms. The first aboveground symptom resulting from infection of carrot roots by *S. rolfsii* was wilting of the foliage, which was rapidly followed by collapse and death of the plant. Extensive lateral secondary spread of mycelium from initial infection sites resulted in formation of disease foci (Fig. 1A). Infected roots had characteristic symptoms of soft rotting and tissue maceration (Fig. 1B,C), and signs of the pathogen (mycelium and sclerotia) were evident (Fig. 1B). Mycelial growth and sclerotial formation within the canopy were most extensive at the soil surface, and mycelia grew onto senescent leaves and infected the crowns of adjacent plants (Fig. 1D).

1983 Study. The average stands in fields A and B were 3.4 and 6.2 plants per 30.5 cm of row, respectively. Inoculum densities before and after deep plowing or disking field A are illustrated in Figure 2. Values represent the inoculum density at eight sampling sites along the direction of tillage. After deep plowing, inoculum levels in the upper 8 cm were reduced about 80% (Fig. 2). After disking, inoculum levels were reduced about 40%, and there was some movement of sclerotia in the direction of disking (Fig. 2).

The percentage of plants dead on 13 July in all plots at Maxton was generally lower on the half of the field that was deep-plowed (Table 1). Applications to deep-plowed plots of calcium carbonate, calcium hydroxide, ammonium nitrate, ammonium sulfate, or TPTH did not significantly ($P \geq 0.05$) reduce disease incidence compared with the untreated control. Applications of calcium nitrate, calcium sulfate, ammonium bicarbonate, urea, chlorothalonil, or PCNB reduced the percentage of dead plants to less than 2.5 (Table 1). On disked plots, only ammonium bicarbonate, chlorothalonil, and PCNB reduced disease incidence to less than 5%. On 9 August, percentages of plants dead were similar on deep-plowed and disked control plots. Disease incidence was lower than 5% only on deep-plowed plots treated with calcium nitrate, ammonium bicarbonate, urea, or PCNB (Table 1) or on disked plots treated with PCNB.

Table 1. Efficacy of calcium and nitrogen fertilizers and three fungicides for control of *Sclerotium rolfsii* on processing carrots grown at Maxton, NC, with two tillage practices

	Percentage of plants dead at two dates on deep-plowed or disked plots[b]			
	13 July		9 August	
Treatment[a]	Deep plow	Disk	Deep plow	Disk
None	6.3	12.4	16.8	18.4
Calcium carbonate	3.8	7.2	10.0	13.1
Calcium hydroxide	3.5	7.4	11.7	14.6
Calcium nitrate	1.6	7.4	3.9	11.2
Calcium sulfate	2.4	11.8	9.8	17.8
Ammonium bicarbonate	0.4	3.2	1.9	5.6
Ammonium nitrate	5.7	7.3	11.6	14.2
Ammonium sulfate	5.1	12.8	10.5	15.2
Urea	1.4	6.5	3.6	9.0
Chlorothalonil	1.0	3.1	5.5	9.6
TPTH	3.5	6.5	10.4	17.2
PCNB	0.0	1.7	0.8	3.3
LSD ($P = 0.05$)	3.1	5.2	5.1	6.2

[a] Materials were applied three times at 3-wk intervals starting on 7 June 1983 (53 days after seeding).
[b] Values represent the mean of four replicates; data were analyzed using Fisher's LSD test.

Table 2. Efficacy of calcium and nitrogen fertilizers for control of *Sclerotium rolfsii* on processing carrots grown at Cairo, GA, with two tillage practices.

	Percentage of plants dead at two dates on deep-plowed or disked plots			
	13 July		9 August	
Treatment[a]	Deep plow	Disk	Deep plow	Disk
None	8.4	11.7	33.8	34.3
Calcium nitrate	3.1	8.4	19.7	24.4
Calcium sulfate	2.7	9.1	30.1	33.9
Ammonium bicarbonate	1.4	3.6	11.3	20.2
Ammonium nitrate	2.4	7.2	22.6	27.9
Urea	1.5	5.3	14.1	22.4
LSD ($P = 0.05$)	1.1	2.9	6.7	7.8

[a] Fertilizers were applied to provide 112 kg of calcium or nitrogen per hectare, except for ammonium bicarbonate, which was used at 84 kg of nitrogen per hectare. Applications were made three times at 3-wk intervals starting on 7 June 1983 (46 days after seeding).

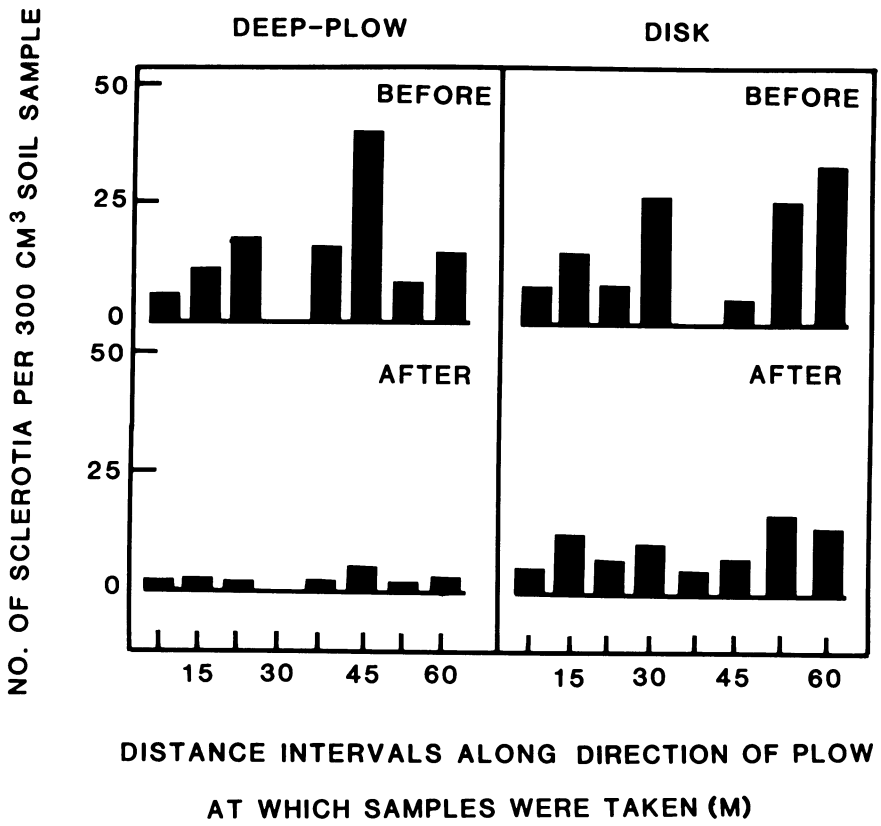

Fig. 2. Inoculum density of *Sclerotium rolfsii*, expressed as numbers of sclerotia per 300 cm^3 of soil, before and after deep plowing or disking plots at Maxton, NC, in 1983. Samples were taken at 7.5-m intervals along the direction in which the tillage was conducted and assayed for sclerotia by a wet-sieving procedure.

Table 3. Influence of calcium fertilizer applications to carrots grown at Maxton, NC, on calcium levels in root tissues

Treatment[a]	Level of calcium (% of dry weight) in root tissues[b]		
	Periderm and pericyclic parenchyma	Phloem parenchyma	Entire root
None	0.25	0.15	0.29
Calcium nitrate	0.41	0.39	0.54
Calcium sulfate	0.36	0.30	0.50
LSD ($P = 0.05$)	0.04	0.06	0.03

[a] Fertilizers were applied at a rate of 112 kg of calcium per hectare three times at 3-wk intervals starting on 7 June 1983 (53 days after seeding).
[b] Calcium levels were determined by atomic absorption spectrophotometry after dry-ashing and acid digestion of the samples. Values represent the mean of three replicates; data were analyzed using Fisher's LSD test.

Table 4. Efficacy of calcium sulfate and ammonium bicarbonate fertilizers used singly and in combination for control of *Sclerotium rolfsii* on processing carrots grown at two locations with two tillage practices

Treatment[a]	Percentage of plants dead at two locations on deep-plowed or disked plots[b]			
	Maxton, NC		Cairo, GA	
	Deep plow	Disk	Deep plow	Disk
None	15.2	17.3	27.1	30.8
Calcium sulfate	8.4	14.9	21.3	26.9
Calcium sulfate + ammonium bicarbonate	3.2	6.9	8.9	18.4
Ammonium bicarbonate	4.1	6.8	9.7	21.3
LSD ($P = 0.05$)	3.9	5.3	5.9	7.1

[a] Calcium sulfate (1,120 kg/ha) was applied on 7 June and ammonium bicarbonate (84 kg N/ha) on 28 June and 25 July 1984.
[b] Disease was rated on 9 August. Values represent the mean of four replicates; data were analyzed using Fisher's LSD test.

In plots at Cairo, disease incidence on both assessment dates was generally lower in deep-plowed than in disked plots (Table 2). On 13 July, all treatments applied to deep-plowed plots resulted in significantly ($P \leq 0.05$) reduced disease incidence compared with untreated plots. On disked plots, only ammonium bicarbonate reduced the percentage of plants dead to less than 5%. On 9 August, none of the treatments on either deep-plowed or disked plots reduced disease to less than 5%, although statistically significant differences were observed among treatments (Table 2).

Influence of calcium fertilization on calcium levels in carrot root tissues. The total calcium content in carrot roots from plots receiving calcium nitrate or calcium sulfate was significantly ($P \leq 0.05$) higher than in roots from unfertilized plots (Table 3). Plants fertilized with calcium nitrate had higher calcium levels in roots than those receiving calcium sulfate. Calcium levels were generally higher in the outer periderm and pericyclic parenchyma than in the inner phloem parenchyma for all treatments (Table 3).

1984 Study. The average stands in fields A and B were 5.3 and 10 plants per 30.5 cm of row, respectively. The percentage of plants dead was higher in all plots in Cairo than in Maxton (Table 4). Disease incidence was generally higher on disked than on deep-plowed plots. At both locations, applications to deep-plowed plots of ammonium bicarbonate alone or combined with calcium sulfate resulted in significantly reduced disease incidence compared with untreated plots (Table 4).

Influence of ammonium bicarbonate applications on viability of sclerotia of *S. rolfsii*. Viability of sclerotia in control plots after 1 or 2 mo of burial was reduced from 100% to 85 and 78%, respectively. In plots receiving ammonium bicarbonate applications, viability was 67 and 59%, respectively.

Influence of calcium and nitrogen compounds and fungicides on sclerotial germination and infection of carrot tissue in vitro. Sclerotial germination of both isolates was significantly lower on nonsterile soil moistened with 20 mM solutions of ammonium bicarbonate and urea or 10 μg/ml of chlorothalonil or PCNB than on the water control (Table 5). The two nitrogen compounds completely inhibited infection of carrot petioles by sclerotia placed 2 cm away (Table 5). Infection also was reduced by chlorothalonil and PCNB but not by calcium nitrate. On autoclaved soil, germination of sclerotia and infection of petioles by mycelium were increased over that in nonsterile soil (Table 5).

DISCUSSION

Application of calcium nitrate has been reported to reduce the rate of development of *S. rolfsii* on sugar beet (14) and tomato

(27), but the mechanism by which disease was reduced was undetermined. Higher levels of calcium in root tissues after fertilization with calcium nitrate and calcium sulfate in this study may have rendered tissue more resistant to ingress of *S. rolfsii* by forming insoluble calcium pectate and by sequestering fungal oxalic acid and inhibiting the activity of cell-wall degrading enzymes, all of which may have reduced disease (5,22,24). Calcium nitrate did not affect sclerotial germination in this study or reduce the extent of mycelial growth of *S. rolfsii* on the soil surface, confirming previous observations (14,19). Levels of calcium were generally higher in the outer periderm and pericyclic parenchyma than in the inner phloem parenchyma. Levels also were higher after calcium nitrate versus calcium sulfate fertilization. The high cost of calcium nitrate compared with gypsum, however, may make it less economical for use on carrots. Calcium fertilization did not effectively reduce disease incidence under high inoculum (disease) pressure on carrot in our study or on other crops (14,29). Applications of calcium hydroxide also did not significantly reduce disease incidence in this study, confirming results from other studies (8,14,21).

Deep plowing, which reduced overall inoculum levels in this study, reduced disease incidence early in the season; however, extensive secondary plant-to-plant spread during the growing season (26) nullified the initial delay in onset of disease development resulting from plowing. Because burial of sclerotia of *S. rolfsii* at depths greater than 8–10 cm inhibits germination (23) and infection of carrot roots (26), the reduction in disease early in the season after plowing probably was due to displacement of inoculum from the root zone or the zone of potential infection surrounding the carrot root (26) to depths where germination and infection were prevented. Although earlier investigators attributed the benefits of plowing to burial of surface organic residues, thus depriving the fungus of a food base believed necessary for infection (6,11), germinating sclerotia of *S. rolfsii* can initiate infection without a food base (18). Deep burial of sclerotia may enhance decay and reduce longevity in soil by increasing nutrient leakage and microbial antagonism (23), indicating that inoculum density of *S. rolfsii* may be reduced over time with repeated plowings.

Ammonium bicarbonate consistently reduced the percentage of plants dead in this study when used in combination with deep plowing. The effectiveness of ammonium bicarbonate may be due in part to release of ammonia (14,19), which is lethal to *S. rolfsii* (8,14,19), and to the toxicity of the bicarbonate ion to the fungus (19). The distance over which mycelium of *S. rolfsii* grew through soil to infect plant tissue (18,26) was reduced by ammonium bicarbonate treatment, and survival of sclerotia was lower in plots that received ammonium bicarbonate. Higher levels of ammonium bicarbonate were required in this study to control disease than rates previously used on turf in California (20), perhaps because of leaching of the compound from the sandier soils encountered in this study. For maximum efficacy, ammonium bicarbonate would need to be retained within the upper 8 cm.

Urea has been reported to reduce populations of soilborne fungi through release of toxic ammonia (7). Germination of sclerotia of *S. rolfsii* and infection of carrot petioles in soil were reduced by an application of urea, although the effect on sclerotial viability in the field was not determined. Urea at rates of 160–200 kg of nitrogen per hectare was reported to reduce disease caused by *S. rolfsii* on potato (4) and sugar beet (28). Ammonium nitrate and ammonium sulfate did not significantly reduce disease incidence on carrots in this study although they were effective on other crops (14,20,28). Substitution of ammonium nitrate, which is presently used as the source of nitrogen in the commercial production of carrots, with ammonium bicarbonate as a fertilizer, may reduce losses caused by *S. rolfsii*. The high cost of urea could make it uneconomical for use on processing carrots.

The best fungicidal control was obtained with PCNB (used as FF-II with fertilizer), followed by chlorothalonil and TPTH. In previous studies, PCNB significantly reduced disease caused by *S. rolfsii* on a number of crops (2,4,12,13, 20,21,27). Although TPTH was reported to reduce mycelial growth of *S. rolfsii* on soil and increase yield on peanut (9), results from our study indicated that TPTH was not as effective in reducing disease incidence on carrot as chlorothalonil, which in a previous study inhibited sclerotial germination to a greater extent than TPTH (20). For maximum efficacy, the fungicides would need to be applied to the soil surface and be retained within the upper 8 cm, where most of the infective propagules are located.

Disease incidence in both years of this study was higher in Georgia than in North Carolina, and most treatments provided less effective control in the plots in Georgia. This may have been due, first, to the higher plant stands in Georgia, and thus the closer spacing of carrot roots, that would have permitted greater plant-to-plant spread of the pathogen. Second, the higher initial inoculum density in the field in Georgia could have resulted in greater percentage of plants dead. Third, the soil in Georgia contained a higher proportion of sand and possibly had a lower cation exchange capacity, and retention of fertilizers may have been lower. Fourth, the warmer, more humid environment in Georgia may have enhanced rate of disease development and disease progression.

To reduce incidence of *S. rolfsii* on carrot, control measures must reduce both the initial numbers of disease foci that result from infection by germinating sclerotia and the extent of mycelial growth of the pathogen from these foci during the growing season. Treatments need to be made within 95–100 days of planting, because the extensively developed canopy makes movement of cultivators and other equipment difficult after this time. We recommend the following strategies for control of root rot on processing carrots grown in North Carolina and Georgia: 1) A field with a low initial inoculum density should be selected, where possible, by sampling either in late fall or early spring to determine inoculum levels by the procedures described previously (25). 2) The field should be deep-plowed before planting to bury inoculum and surface residues from the preceding crop. 3) A calcium fertilizer (such as gypsum)

Table 5. Germination of sclerotia of *Sclerotium rolfsii* and infection of detached carrot leaf petioles on soil amended with various fertilizers and fungicides

Treatment[a]	Percent sclerotial germination[b]	Percent infection of carrot leaf petioles by germinating sclerotia[c]
Water control	80	72
Autoclaved soil	92	85
Calcium nitrate	75	71
Ammonium bicarbonate	22	0
Urea	13	0
Chlorothalonil	40	24
PCNB	57	12
LSD ($P = 0.05$)	9	11

[a] Soil (30 cm^3) contained in petri dishes was moistened to field capacity with aqueous solutions of the fertilizers (20 mM concentration) or fungicides (10 μg/ml) and incubated for 24 hr before the experiment began.

[b] Dried sclerotia of two isolates from 3-mo-old oat cultures were incubated on moistened soil for 6 days at 28 C. Percent germination values are the means of five replicates; the experiment was repeated twice.

[c] Eight sclerotia were placed 2 cm from the carrot petiole in each petri dish; infection was rated after 6 days of incubation at 28 C.

should be applied within 50 days of planting. 4) Two follow-up applications of ammonium bicarbonate should be made between 50 and 95 days after planting.

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