Root Diseases Induced in Corn by *Rhizoctonia solani* and *Rhizoctonia zeae*

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ABSTRACT

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Numerous fungi isolated from diseased corn roots were pathogenic on corn seedlings and juvenile plants, but field-type symptoms were only produced by cultures of *Rhizoctonia solani* belonging to anastomosis group two (AG-2). Some isolates of *R. solani* belonging to anastomosis group four (AG-4) caused severe hypocotyl necrosis, but lesions were rare on lateral, crown, and brace roots, and most isolates were avirulent on corn. *Rhizoctonia zeae* was less virulent than *R. solani* AG-2 and AG-4 and caused indistinct buff to light brown lesions on primary and lateral roots. Binucleate *Rhizoctonia* spp. isolates were not pathogenic. *R. solani* AG-2 isolates were equally virulent at temperature ranges 8–21, 16–28, and 20–34 C, but *R. zeae* was most virulent at the highest temperature range. *R. zeae* survived in fallow soil in pots buried in a field for 6 mo. Isolates of *R. solani* AG-2 from corn were highly virulent on juvenile soybean, snap bean, pole bean, lima bean, southern pea, and cucumber, but only slightly virulent on peanut. Crown, brace, and lateral root rot caused by *R. solani* AG-2 was found only in corn monoculture or corn grown in rotation with peanut or soybean in irrigated fields in southeast Georgia. Symptoms rarely were observed in nonirrigated corn, and *R. solani* was not isolated from roots of corn grown in nonirrigated fields.

The acreage of irrigated corn in Georgia increased greatly in the past decade (21). Changing from a nonirrigated to an overhead sprinkler irrigation system of production was accompanied by changes in fertilization, tillage, and other cultural practices. Plant populations and fertilizer rates (particularly N) were increased and there was a more intensive use of herbicides, nematicides, and insecticides. Moldboard plowing has been used less and in-row subsoiling and chiseling have become common tillage practices. Since 1975, root diseases have been observed more frequently in irrigated than in nonirrigated field corn in the Georgia Coastal Plain. Reddish-brown degeneration of crown and brace roots of field corn was first observed in irrigated corn in southwestern Georgia in 1977. Numerous plants in a 2-ha area were leaning or lodged 2–4 wk after tasseling because roots on at least one side were completely decayed. Frequently roots disintegrated 2–5 cm below the soil surface, leaving the plants with little anchorage or root surface for nutrient and water absorption. The field had to be harvested early because most plants were lodging 6 wk after tasseling.

Plants with 10–100% of the lateral and crown roots rotted (usually 5–10 cm below the soil surface) were observed in numerous irrigated fields in 11 counties in southern Georgia from 1977 to 1980. Occasionally diseased plants were stunted and chlorotic, but frequently plants with severe crown and lateral root rot could not be differentiated from plants with well-developed root systems unless the plants were leaning. Leaning and lodging were especially noticeable after high winds or heavy rains. The crop was usually harvested as high moisture (20–25%) corn 6–8 wk after silking when plants were still green. Stalk rot was rare on plants with severe root rot.

Rhizoctonia solani Kuhn, *R. zeae* Voorhees, and binucleate *Rhizoctonia* spp. were isolated occasionally from lesions on corn roots, and *R. solani* was isolated frequently from severely rotted roots. One isolate of *R. solani* induced severe root rot on corn and foliage symptoms similar to nutrient deficiencies (12). *R. zeae* is known to be an ear and stalk rot pathogen (5,27,28) and *R. solani* was isolated infrequently from leaf sheaths and stalks (3,6,29), roots (18) and seedlings (2) of corn, but neither has been considered an important pathogen in the root disease complex in corn.

Numerous fungi were isolated from lesions on corn plants ranging in age from seedlings to maturity. A sterile basidiomycete induced gray to black lesions on secondary and brace roots and crowns of corn (24), and *Pythium aphanidermatum*, *P. arrhenomanes*, *Fusarium moniliforme*, *F. oxysporum*, *F. roseum* 'Graminearum,' *Phoma* spp., and *Pyrenochaeta terrestris* were pathogenic on lateral and crown roots (12,25). This research was designed to determine if the *Rhizoctonia* spp. associated with corn roots and isolated from the soil and from root lesions on other crops were involved in the root disease complex of corn in the Georgia Coastal Plain. A preliminary report was published (23).

MATERIALS AND METHODS

Tissues adjacent to lesions on roots and hypocotyls of field and sweet corn and other crops were surface disinfected 0.5–1.0 min in 0.5% NaOCl, rinsed under running tap water, blotted dry on sterile filter paper, and incubated on water agar at room temperatures (20–30 C). Hyphal tips of cultures from plant tissues were transferred to PDA and identified.

Soil samples from numerous fields in 1979 and 1980 were assayed for *Rhizoctonia* spp. on a tannic acid medium (8) modified with benomyl (7) (hereafter abbreviated TAB) that was prepared as follows: 20 g agar, 0.5 g $MgSO_4$, 1 g KH_2PO_4, 20 mg $CuSO_4$, and 800 ml of deionized water in one flask and 0.8 g casein hydrolysate (vitamin- and salt-free), 2 ml glycerol, 120 mg tannic acid, and 200 ml of deionized water in another flask were autoclaved separately; cooled to 50 C, and blended; the pH was adjusted to 6.5 and 700 mg neomycin sulfate, 95 mg pyroxychlor, and 2 mg of benomyl were added. Pyroxychlor was replaced with metalaxyl in some experiments without significantly changing the growth of *Rhizoctonia* spp. The medium was stored in the dark in a refrigerator at 3–5 C.

A multiple soil-pellet sampler (9) adjusted to ~120 mg of oven-dry soil per pellet, was used to assay 10–20 g of soil in each sample. Petri dishes of soil were incubated in the dark at 26 C for 48 ± 2 hr, the number of Rhizoctonialike cultures was counted, and hyphal tips of three to five colonies of each distinct morphological type were transferred to PDA and identified. Cultures of binucleate *Rhizoctonia* spp., *R. solani*, and *R. zeae* were grown 1–3 wk on 3%

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(w/w) cornmeal-sand (CMS), and used as inoculum for tests in greenhouses and growth chambers.

Heat-treated (6 hr at 65–70 C dry heat) Dothan loamy sand (approximately 85, 11, and 4% sand, silt, and clay, respectively) or Lakeland sand (approximately 100% sand) was infested with CMS cultures, 1:100 to 1:1,000 (v/v), and fertilized by blending 19, 38, and 57 μg/g N, P, and K, respectively, for 5 min in a concrete mixer. If the soil pH was below 5.8, 1,000 μg/g of powdered $CaCO_3$ was included to raise the soil pH to 6.5–7.0. For pathogenicity tests, soil of each type was placed in two Styrofoam trays with six rows of 12 5 × 5 × 4-cm compartments. One seed of each cultivar tested was placed in each compartment of a row. Plants were removed 10–18 days after planting and the roots and hypocotyls were rated for disease severity with an index scale of 1–5: 1 = <2%; 2 = 2–10%; 3 = 11–50%; 4 = >50% discoloration and decay; and 5 = dead plants.

From 1974 to 1980, approximately 180 Rhizoctonialike fungal isolates from soil or plant tissues were tested for pathogenicity on corn seedlings and other crops. Approximately 120 selected isolates were grown on PDA and PDYCA (39 g Difco dehydrated PDA, 0.5 g yeast extract, 0.5 g casein hydrolysate, 2 g agar, and 958 ml of deionized water) 2–3 wk at 20–25 C under Sylvania Lifeline® (Sylvania Lighting Center, Danvers, MA, 01923) fluorescent lights, and classified according to cultural morphology and color. Fifty isolates were stained to determine the number of nuclei and hyphal morphology (10). Isolates identified as *R. solani* were paired with known AG-1, AG-2, AG-3, and AG-4 tester isolates (provided by L. Burpee and R. T. Sherwood) to identify their anastomosis groups. Isolates of *R. zeae* and binucleate *Rhizoctonia* spp. were classified into similar types based on morphology and color. No attempt was made to subdivide the binucleate *Rhizoctonia* spp. isolates into anastomosis groups (4) because tester isolates were unavailable, but selected isolates of each *R. zeae* type were paired with isolates of the other type.

Data were analyzed by least squares analysis of variance and general linear models procedures (22).

RESULTS

Isolations. All isolates of *R. solani* from corn were either AG-2 or AG-4. The AG-2 was only isolated from roots of irrigated corn, peanut seeds and hypocotyls, snap bean hypocotyls, and (rarely) from soil, whereas AG-4 was isolated from roots and hypocotyls of corn (both nonirrigated and irrigated), snap bean, lima bean, southern pea, soybean, cucumber, cotton, and peanut; from peanut seed and from soil. Binucleate *Rhizoctonia* spp. were isolated from roots and hypocotyls of corn, snap bean, southern pea, cucumber, onion, and lima bean; from peanut seed and from soil. *R. zeae* was isolated from roots and hypocotyls of corn and sorghum and also from soil.

Cultural morphology and characteristics. Cultures of virulent *R. solani* AG-2 isolates were at first sparsely covered with tan mycelium, but within 2–3 wk were usually covered with a brown to dark brown, velutinous to lanose, plectenchymatous, crustaceous layer of mycelium and sclerotia. Sclerotia were abundant, up to 5 mm in diameter, frequently forming over the entire surface. Occasional cultures were tan to light brown with few sclerotia. Pigmentation of the medium was extensive and dark brown. Avirulent cultures of *R. solani* AG-2 had floccose mycelia, and no crustaceous layer of sclerotia. Pigmentation of the medium was moderate and tan to light brown. In contrast, AG-4 cultures were light tan to chocolate brown, coriaceous and appressed to rugose or cerebriform (Fig. 1). Sclerotia were usually formed only on the periphery or the center of the cultures, or sparsely scattered over the surface, and were rarely >2 mm in diameter. Typical characteristics were recognizable in 5–10 days at 25 C. There was no association of virulence and cultural morphology (Fig. 1).

Unidentified *Rhizoctonia* spp. were usually white to gray, appressed to floccose, with filiform to filamentous hyphae, and did not produce sclerotia. There was little pigmentation in the medium. Rarely, cultures resembled *R. solani* AG-4 in appearance and color and formed sclerotia.

Cultures of *R. zeae* were at first white to tan, and sclerotial initials were evident within 4–7 days as white to orange, punctiform spots on the mycelium (Fig. 1); viewed through the bottom of the petri dish, these were seen embedded in the agar. There was dolipore septation in the hyphae and six to eight nuclei per cell. Sclerotia were formed from monilioid cells, and no clamp connections were observed.

Cultures of *R. zeae* 2–3 wk old and with sclerotia ~1 mm in diameter could be classified into two groups designated here WM and RBF. WM isolates had white to tan, peach, salmon, or pale orange, and sparse to abundant, floccose mycelium, sclerotia orange to red, frequently at the periphery of the agar and more commonly, embedded in the agar. RBF isolates were tan to burnt orange or reddish brown, sclerotia tan to red to orange (frequently not evident on the surface, but abundantly visible in the agar when cultures were inverted), and with a superficial velutinous and plectenchymatous (somewhat like *R. solani* AG-2) to floccose and lanose mycelium.

In addition to *R. zeae*, a sterile basidiomycete with clamp

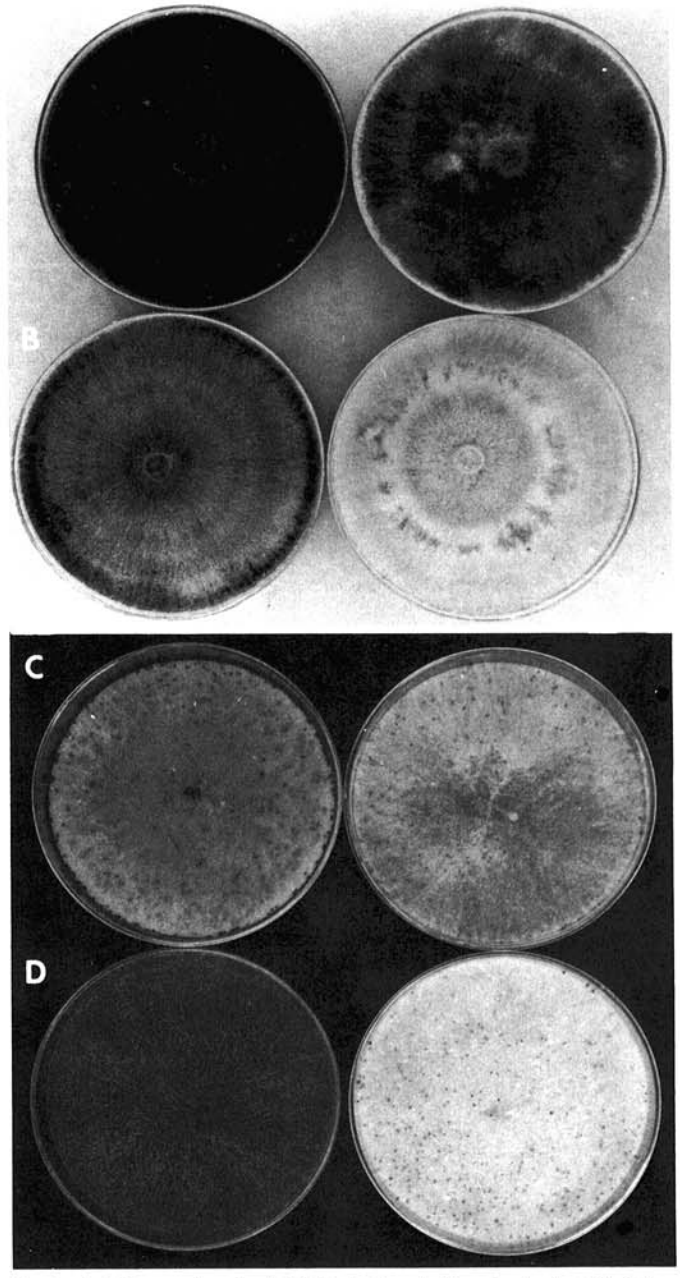

Fig. 1. A, *Rhizoctonia solani* AG-2, virulent (left) and avirulent (right) on corn; **B,** *R. solani* AG-4, virulent (left) and avirulent (right) on corn; **C,** *Rhizoctonia zeae*, RBF (left) and WM (right); and **D,** sterile basidiomycete, BR (left), and *R. zeae* WM (right).

connections resembling *R. zeae* was frequently found in soil. It produced brick-red to dark-red sclerotia singly and in clusters or rhizomorphlike chains, both superficial and embedded in the agar (Fig. 1). Mycelium was sparse to absent with eight or more nuclei per cell.

Five *R. zeae*-RBF isolates anastomosed with each of five *R. zeae*-WM isolates and with each other, but RBF and WM isolates did not anastomose with isolates of the sterile, red basidiomycete.

Pathogenicity and symptoms. Cultures of *R. solani* AG-2 isolated from corn and peanut induced more severe root rot in corn than *R. solani* AG-4 isolated from corn. Isolates of *R. solani* AG-2 were avirulent or moderately to highly virulent, whereas *R. solani* AG-4 isolates ranged from mostly avirulent to slightly virulent, causing injury mostly on hypocotyls (Table 1). The severe lateral and crown root rot symptoms observed in commercial fields of irrigated corn and in research plots at the Georgia Coastal Plain Station could only be reproduced with cultures of *R. solani* AG-2 (Fig. 2).

R. zeae (RBF and WM cultures) caused buff, tan to light brown water-soaked lesions 1–3 cm long, sometimes with dark brown to reddish-brown borders, on primary and lateral seminal roots, but root apices were rarely killed, and development of lateral and crown roots was similar to root development on plants grown in uninfested soil. Incipient root lesions caused by *R. zeae* were sometimes elliptical, 1–2 × 5–10 mm, with white centers and tan to reddish brown borders. Similar eyespot lesions were observed occasionally on the basal leaf sheath and the rind of the stalk adjacent to the soil. *R. zeae* was not pathogenic on southern pea (*Vigna unguiculata*), but caused preemergence damping-off and seedling rootrot in sorghum. Binucleate *Rhizoctonia* spp. and the sterile, red basidiomycete caused little or no discoloration on corn roots, and were considered avirulent. Isolates of *R. solani* AG-4 frequently caused severe, brown hypocotyl decay in seedlings, but they rarely caused dark brown lesions on lateral and crown roots that form the bulk of the root system in juvenile and mature corn plants.

Two isolates of *R. solani* AG-2 from peanut caused severe root rot on corn and soybean and little or no root or hypocotyl necrosis in peanut. A third isolate was avirulent on all three crops. In contrast, three *R. solani* AG-4 isolates from peanut caused only slight discoloration on corn roots but caused severe root and hypocotyl rot on peanut and soybean (Table 2). Isolates of *R. solani* AG-2 and AG-4 were highly virulent on snap bean, pole bean, lima bean, southern pea, and cucumber seedlings.

R. solani AG-2 rotted roots severely and reduced root and foliage weight of 5-wk-old corn by 80 and 57%, respectively, compared with corn grown in heat-treated uninfested soil (Table 3). An isolate of *R. zeae* caused significant root decay, but had no influence on plant top growth. Corn grown in soil infested with a binuclueate *Rhizoctonia* sp. had no root decay, and growth was not different from that of the control.

Survival in soil. *R. solani* AG-4, *Rhizoctonia* spp. (binucleate), and *R. zeae* were recovered frequently, and AG-2 infrequently from soil samples from fields assayed on TAB by using the multiple-pellet soil sampler. In four fields of irrigated corn on one farm, following soybean, peanut, or corn, populations of AG-2 ranged from six to 11 propagules per 100 g in soil taken from around rotted roots of 8- to 12-wk-old corn plants. Cultures of *R. solani* and binucleate *Rhizoctonia* spp. produced plumose, coarse colonies and usually caused a tan, yellowish green, or olive green discoloration in the agar, when backlighted with a fluorescent laboratory lamp. In contrast, colonies of *R. zeae* frequently were colorless or a light yellow-green in the agar, and were not plumose. *R. solani* AG-4 and AG-2 isolates and binucleate *Rhizoctonia* spp. could not be separated on TAB, but were identifiable when hyphal tips were transferred to PDA. Colonies of *Pythium* spp. occasionally grew 1–3 cm from the soil pellets, but they produced sparse, filamentous, colorless hyphae easily distinguished from those of all *Rhizoctonia* spp.

In a greenhouse test, where soil was separately infested with seven isolates (WM or RFB type) of *R. zeae* from soil, sorghum, or corn, and planted with corn, the plants were rated for root disease severity when 2 wk old, and the soil placed in 20-cm-diameter clay pots. The pots were buried to the rim in a fallow field in February 1979, and populations of *R. zeae* were determined 3 and 6 mo later. The populations ranged from 91 to 490 propagules per 100 g of oven-dry soil (P/100 g) when the pots were buried, from 52 to 568 P/100 g 3 mo later, and from 22 to 135 P/100 g 6 mo later. In two uninfested controls, propagules of *R. zeae* were not detected, but the sterile basidiomycete was occasionally identified. Corn seeds were planted in the soil 6 mo after burial and 2 wk later the roots were rated for disease. Tan lesions were observed on hypocotyls of 46% of 69 seedlings in infested soil, but there were no lesions on seedlings in uninfested soil. *R. zeae* was reisolated from one lesion, but only *Trichoderma* spp. or *F. oxysporum* were isolated from the other lesions. No lesions were observed on the seminal roots of any plants.

Temperature effects. Corn was grown in heat-treated (pasteurized) Dothan loamy sand soil infested with 13 isolates of *R. zeae* from soil cropped to continuous corn, five isolates of the sterile basidiomycete (BR), and two isolates of *R. solani* AG-2 from corn roots, in environmental chambers. The *R. zeae* isolates were of both cultural types, were yellow-green or colorless on TAB, and represented three ranges of colony sizes (extra-large, large, and small, which were >4, <4>2, and <2 cm in diameter, respectively) from soil pellets incubated 48 hr at 26 C on TAB.

TABLE 1. Pathogenicity and virulence of *Rhizoctonia solani, Rhizoctonia zeae,* and binucleate *Rhizoctonia* spp. to corn roots in greenhouse and growth chamber tests

Fungus	Source	Number of isolates with root disease severity[a]			
		None (<1.5)	Slight (1.5 to 2.5)	Moderate (2.5 to 3.5)	Severe (>3.5)
Rhizoctonia solani, AG-2	Corn	3	0	4	5
Rhizoctonia solani, AG-2	Peanut	0	1	1	2
Rhizoctonia solani, AG-4	Corn	4	5	5	1
Rhizoctonia solani, AG-4	Other crops	3	11	2	0
Rhizoctonia spp., binucleate	Corn	7	0	0	0
Rhizoctonia spp., binucleate	Other crops	8	1	0	0
Rhizoctonia spp., binucleate	Soil	4	1	0	0
Rhizoctonia solani[b]	Corn	2	0	1	0
Rhizoctonia solani[b]	Other crops	9	3	2	0
Rhizoctonia solani[b]	Soil	11	13	5	0
Rhizoctonia zeae, RBF	Corn and soil	2	8	0	0
Rhizoctonia zeae, WM	Corn and soil	6	15	0	0
Unidentified basidiomycete, BR	Corn and soil	4	1	0	0

[a] Scale of 1–5: 1 = <2%; 2 = 2–10%; 3 = 11–50%, 4 = >50% root discoloration and decay; and 5 = dead plants.
[b] Anastomosis group was not determined for most isolates tested from 1976 to 1978.

Soil was infested 1:120 (v/v) with 6- to 8-wk-old cultures on cornmeal sand. Controls were uninfested. Population densities of *R. zeae* were 49 and 54 P/100 g in two soils selected at random and assayed immediately after infestation. *R. solani* was not detected (<6 P/100 g).

One environmental plant growth chamber was used for each of three night-day temperature ranges: 8–21, 16–28, and 20–34 C. Corn was grown 12–17 days with 12 hr of light per day (13,000 lux), and rated for root disease severity.

R. solani AG-2 induced seedling root rot at all temperatures, but was more severe at the two lowest temperature ranges. In contrast, the *R. zeae* isolates caused only slight root discoloration at lower temperatures, but became increasingly virulent as the temperature increased (Table 4). The BR isolates caused slight discoloration at the lowest temperature range, but were not significantly different from the control at the two highest temperature ranges and were

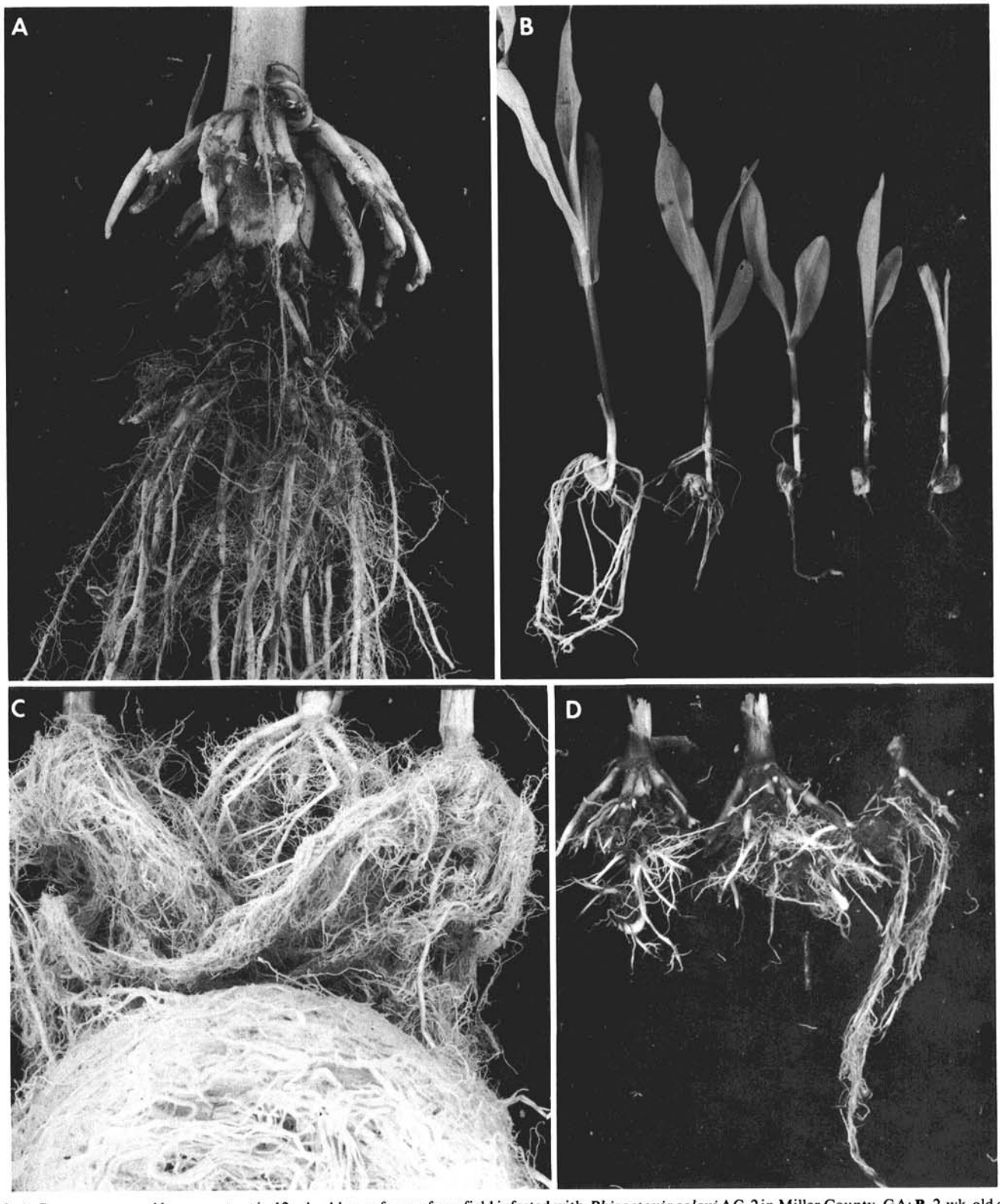

Fig. 2. A, Severe crown and brace root rot in 12-wk-old corn from a farm field infested with *Rhizoctonia solani* AG-2 in Miller County, GA; **B,** 2-wk-old corn seedlings grown in uninfested soil (left plant) and in soil infested with *R. solani* AG-2 (right four plants); **C,** 5-wk-old corn grown in uninfested soil; and **D,** soil infested with *R. solani* AG-2.

TABLE 2. Pathogencity of *Rhizoctonia solani* AG-2 and AG-4 isolates from peanut on corn, peanut, and soybean

Isolate	Anastomosis group	Root and hypocotyl disease index[y]					
		Corn	Peanut			Soybean	
		Dekalb XL80	Florunner	Early Bunch	Starr	Hutton	Bragg
SRB 1	4	2.2 b	4.2 a[z]	4.2 a	4.2 a	4.2 ab	3.3 b
SRB 2	4	2.2 b	4.3 a	3.9 a	3.9 a	5.0 a	4.5 a
SRB 3	4	2.2 b	4.6 a	4.2 a	4.2 a	5.0 a	3.7 b
WRB 1	2	3.9 a	1.7 bc	2.0 b	2.0 b	3.5 bc	3.6 b
WRB 5	2	1.7 c	1.5 bc	1.2 bc	1.2 bc	1.8 d	2.7 c
WRB 6	2	3.9 a	1.9 b	1.7 bc	1.7 bc	3.4 c	3.8 ab
Control		1.6 c	1.0 c	1.0 c	1.0 c	1.5 d	1.9 c

[y] 1 = <2%; 1 = 2–10%; 3 = 11–50%; 4 = >50% discoloration and decay; 5 = dead plants.
[z] Numbers followed by the same letter in a column are not different according to Duncan's multiple range test, $P = 0.05$.

TABLE 3. Foliage and root weight, root disease severity, and height of Pioneer 3369A corn grown 5 wk in heat-treated (pasteurized) Dothan loamy sand infested with *Rhizoctonia solani, R. zeae,* and binucleate *Rhizoctonia* sp.[x]

Fungi	Oven-dry wt (g)			Height (cm)		Foliar chlorosis 2 wk (% plants)
	Foliage	Roots	RDI[y]	2 wk	5 wk	
None	144 a[z]	10.7 a	1.0 c	32 a	84 a	0
Rhizoctonia solani, AG-2	62 b	2.1 b	4.0 a	17 c	60 b	72
Rhizoctonia zeae	149 a	8.6 a	2.3 b	30 a	79 a	9
Rhizoctonia sp. (binucleate)	159 a	10.1 a	1.2 c	31 a	78 a	0

[x] Data are for two to three plants grown in 3.4 L of soil in a clay pot 20 cm in diameter, one pot per treatment in 16 replications.
[y] Root disease index on a 1–5 scale: 1 = <2%; 2 = 2–10%; 3 = 11–50%; 4 = >50% root discoloration and decay; and 5 = dead plants.
[z] Numbers followed by the same letter are not different according to Duncan's multiple range test, $P = 0.05$.

TABLE 4. Influence of temperature on root disease severity in Funk's 4507 corn grown in soil infested with *Rhizoctonia zeae, R. solani,* and a sterile, red basidiomycete

Fungus	Number of isolates	Root disease index[x] (night-day temperature range, C)		
		8–21	16–28	20–34
Rhizoctonia solani, AG-2	2	2.6 a[z]	2.7 a	2.3 a
Rhizoctonia zeae, WM[y]	9	1.8 b	2.1 b	2.5 a
Rhizoctonia zeae, RBF[y]	4	1.6 b	1.7 b	2.0 a
Sterile basidiomycete, BR[y]	5	1.6 b	1.3 c	1.3 b
Control		1.1 c	1.6 bc	1.0 b

[x] 1 = <2%; 2 = 2–10%; 3 = 11–50%; 4 = >50% root discoloration and decay; and 5 = dead plants.
[y] WM = mycelium floccose, sparse to abundant, white to tan, peach, salmon; sclerotia orange to red.
RBF = mycelium velutinous and plectenchymatous to floccose and lanose, clusters or rhizomorphlike chains. Clamp connections present.
BR = mycelium sparse or absent, sclerotia brick red to red, single and in clusters or rhizomorphlike chains. Clamp connections present.
[z] Numbers followed by the same letter are not different according to Duncan's multiple range test, $P = 0.05$.

considered avirulent.

Cultural morphology and size of colonies on TAB were not related to virulence in isolates of *R. zeae*. Small colorless colonies were significantly more virulent than small yellow-green colonies (RDI 2.4 vs 1.9), but color was not associated with virulence in large or extra-large colonies.

DISCUSSION

The severe crown and lateral root rot found in irrigated corn in the Georgia Coastal Plain in recent years could only be reproduced with cultures of *R. solani* AG-2 that produced crustaceous layer of mycelium and sclerotia. Numerous other fungi caused decay and discoloration of primary and lateral seminal roots (12), and a sterile, white basidiomycete also caused gray to black lesions on crown roots (24), but none of these fungi caused a reddish-brown decay of the crown roots near the soil surface. A few isolates of *R. solani* AG-4 induced severe root rot on seminal roots in seedlings, but not on crown roots of juvenile plants.

Lesions caused by *R. zeae* were a distinct tan to light brown, and the necrosis rarely killed the roots. *Rhizoctonia zeae* was a much less virulent pathogen on corn than either *R. solani* AG-2 or AG-4, but the fungus is distributed widely in Georgia Coastal Plain soils, and was isolated infrequently from lesions on corn roots in numerous fields. Some isolates killed seedlings by girdling the hypocotyl, or mesocotyl, and the fungus may cause stand losses in farm fields. Also, it is more virulent at high temperatures, and could be pathogenic on corn late in the season.

Voorhees (28) originally found *R. zeae* associated with ear rot of mature plants in Florida. We made no attempt to study its role in ear rot, or in root and stalk rot of corn at maturity. Tu et al (26) indicated that *R. zeae* was binucleate, but our cultures are multinucleate. We were unable to obtain cultures of *R. zeae* from the ATCC or other sources in the United States to compare to our cultures, but the characteristics of the *R. zeae* isolates that are common in Georgia Coastal Plain soils are similar to those in Voorhees' original description, and we believe it is the same fungus. Others (5,13,19,27) have occasionally reported *R. zeae* on corn and other crops, but they did not report pathogenicity tests. The fungus has been reported mostly in subtropical and tropical environments, but it was isolated by Ullstrup (27) in northern Indiana.

Isolates of *R. solani* AG-2 are pathogenic on cabbage, radish, and spinach seedlings (1,15,20); carrot (14) and sugar beet plants (11,15); and induce limited root rot on flax (1). The fungus was reported on bean roots in Wisconsin (17) and bean leaves with web blight in Costa Rica (17). Ogoshi (16) subdivided AG-2 into type 1 and type 2 isolates based on anastomosis within the group and cultural characteristics. Our isolates that were highly virulent on corn also were highly virulent on snap bean, lima bean, southern pea, soybean, and cucumber; moderately virulent on peanut; and corresponded to the type 2 isolates. Our avirulent isolates were similar to type 1 isolates, but we did not test them on crucifers. An epidemic of web blight occurred in a field of snap bean following sweet corn in southwestern Georgia in 1978, but only *R. solani* AG-1 with typical large (2–5 mm), brown sclerotia were isolated from diseased plants.

Corn is grown in rotation with peanut, soybean, and vegetables in the Georgia Coastal Plain, and rye is grown commonly during the winter for forage and to reduce soil erosion. We have isolated *R. solani* AG-2 occasionally from peanut and snap bean, but not from other crops. The prevalence of *R. solani* AG-2 and severe brace root rot of corn in southwestern Georgia appears to be unique to the rotation of corn with peanut in irrigated fields. Isolates of *R. solani* AG-2 were not found in corn from other areas of Georgia where peanut production is limited or nonexistent and fewer fields

are irrigated, but occasionally *R. solani* AG-4 was isolated from diseased roots of corn collected in nonirrigated fields in central Georgia.

LITERATURE CITED

1. Anderson, N. A. 1977. Evaluation of the Rhizoctonia complex in relation to seedling blight of flax. Plant Dis. Rep. 6:141-142.
2. Berger, R. D., and Wolf, E. A. 1974. Control of seedborne and soilborne mycoses of 'Florida Sweet' corn by seed treatment. Plant Dis. Rep. 58:922-923.
3. Bertus, L. S. 1927. A sclerotial disease of maize (*Zea mays* L.) due to *Rhizoctonia solani* Kuhn. Pages 44–46 in: Yearb. Agric., Ceylon.
4. Burpee, L. L., Sanders, P. L., Cole, H., Jr., and Sherwood, R. T. 1980. Anastomosis groups among isolates of *Ceratobasidium cornigerum* and related fungi. Mycologia 72:689-701.
5. Dalmacio, S. C., and Exconde, D. R. 1970. Diseases of corn unreported in the Philippines. Philippine Phytopathol. 6:89-97.
6. Deighton, F. C. 1932. Mycological work. Pages 20–25 in: Annu. Rep. Agric. Dep., Sierra Leone, 1931.
7. Ferris, R. S., and Mitchell, D. J. 1976. Evaluation of three selective media for the recovery of *Rhizoctonia solani*. (Abstr.) Proc. Am. Phytopathol. Soc. 3:335-336.
8. Flowers, R. A. 1976. A selective media for isolation of *Rhizoctonia* from soil and plant tissue. (Abstr.) Proc. Am. Phytopathol. Soc. 3:219.
9. Henis, Y., Ghaffar, A., Baker, R., and Gillespie, S. L. 1978. A new pellet soil-sampler and its use for the study of population dynamics of *Rhizoctonia solani* in soil. Phytopathology 68:371-376.
10. Herr, L. J. 1979. Practical nuclear staining procedures for Rhizoctonialike fungi. Phytopathology 69:958-961.
11. Herr, L. J., and Roberts, D. L. 1980. Characterization of Rhizoctonia populations obtained from sugarbeet fields with differing soil textures. Phytopathology 70:476-480.
12. Keisling, T. C., and Sumner, D. R. 1978. Changes in tissue analysis caused by soil-borne pathogenic fungi. Commun. Soil Sci. Plant Anal. 9:915-929.
13. Luttrell, E. S. 1954. Diseases of pearl millet in Georgia. Plant Dis. Rep. 38:507-514.
14. Mildenhall, J. P., and Williams, P. H. 1973. Effect of soil temperature and host maturity on infection of carrot by *Rhizoctonia solani*. Phytopathology 63:276-280.
15. Naiki, T., and Kanoh, M. 1978. Grouping of *Rhizoctonia solani* Kuhn causing root diseases of spinach in plastic crop housing. Ann. Phytopathol. Soc. Jpn. 44:554-560.
16. Ogoshi, A. 1976. Studies on the grouping of *Rhizoctonia solani* Kuhn isolated from plants and soils with hyphal anastomosis and on the perfect stages of groups. Bull. Nat. Inst. Agric. Sci., Jpn., Ser. C. 30:1-63.
17. Parmeter, J. R., Jr., Sherwood, R. T., and Platt, W. D. 1969. Anastomosis grouping among isolates of *Thanatephorus cucumeris*. Phytopathology 59:1270-1278.
18. Peltier, G. L. 1916. Parasitic Rhizoctonias in America. Ill. Agric. Exp. Stn. Bull. 189:279-390.
19. Ryker, T. C., and Gooch, F. S. 1938. Rhizoctonia sheath spot of rice. Phytopathology 28:233-246.
20. Sherwood, R. T. 1969. Morphology and physiology in four anastomosis groups of *Thanatephorus cucumeris*. Phytopathology 59:1924-1929.
21. Skinner, R. E. 1980. Irrigation survey, 1979. Univ. Ga. Coop. Ext. Serv. Loose-leaf, mimeographed letter.
22. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York. 481 pp.
23. Sumner, D. R., and Bell, D. K. 1980. Root diseases of corn caused by *Rhizoctonia solani* and *Rhizoctonia zeae*. (Abstr.) Phytopathology 70:572.
24. Sumner, D. R., Bell, D. K., and Huber, D. M. 1979. Pathology, host range, and ecology of a sterile basidiomycete causing root diseases on corn. Plant Dis. Rep. 63:981-985.
25. Sumner, D. R., Dowler, C. C., Johnson, A. W., and Chalfant, R. B. 1978. Root diseases of corn in an integrated pest management system. Page 176 in: Abstracts of Papers, Third Int. Cong. Plant Pathology, 16–23 August, Munich, West Germany.
26. Tu, C. C., Roberts, D. A., and Kimbrough, J. W. 1969. Hyphal fusion, nuclear condition, and perfect stages of three species of *Rhizoctonia*. Mycologia 61:775-783.
27. Ullstrup, A. J. 1963. A note on the geographic distribution of *Rhizoctonia zeae*. Mycologia 55:682-683.
28. Voorhees, R. K. 1934. Sclerotial rot of corn caused by *Rhizoctonia zeae* n. sp. Phytopathology 24:1290-1303.
29. Young, T. R., and Kucharek, T. A. 1977. Succession of fungal communities in roots and stalks of hybrid field corn grown in Florida. Plant Dis. Rep. 61:76-80.