Unharvested Peanut Pods as a Potential Source of Inoculum of Soilborne Plant Pathogens

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ABSTRACT

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Peanut pods or foliage (leaves and stems) plus root debris collected 22 wk after harvest were placed in layers at depths of 0–5, 5–10, and 10–15 cm in pots of heat-treated soil and planted to corn and soybean. The root-mesocotyl disease index (RMDI) on corn and the root-hypocotyl disease index (RHDI) on soybean were higher when plants were grown in soil amended with pods (SAP) than in soil amended with foliage plus root debris (SAFR) and the indices increased with depth of placement of pods. Root growth and plant height of corn and soybean and green foliage weight of soybean were less when plants were grown in SAP than in SAFR. *Rhizoctonia solani* anastomosis group (AG) 4 and *Pythium* spp. were isolated primarily from corn roots and soybean hypocotyls grown in SAP. *Fusarium* spp. were isolated from corn roots and soybean hypocotyls grown in both SAP and SAFR. Emergence of peanut, soybean, snap bean, blue lupine, and sorghum but not corn was reduced by *R. solani* AG-4 isolates recovered from sound peanut seed in pods attached to plants at harvest. The AG-4 isolates caused high RHDI or RMDI on all crops except corn, and AG-2 type 2 isolates recovered from sound peanut seed in pods attached to plants at harvest caused moderate to severe RHDI or RMDI on all crops except peanut. The RHDI or RMDI caused by AG-2 type 1 isolates did not differ from those in the control.

In previous studies, isolates of *Rhizoctonia solani* Kühn anastomosis group (AG) 2 (types 1 and 2) and AG-4 were obtained from visibly sound peanut (*Arachis hypogaea* L.) seed at harvest (9). Isolates of AG-2-1 were avirulent on corn (*Zea mays* L.) and peanut; however, AG-2-2 isolates caused moderate to severe crown and brace root necrosis of corn and hypocotyls of soybean (*Glycine max* (L.) Merr.) and were weakly virulent on peanut. Isolates of AG-4 caused extensive necrosis on peanut and soybean hypocotyls but were weakly virulent on corn (9). The root disease index and incidence of postemergence damping-off of fall snap bean (*Phaseolus vulgaris* L.) were higher immediately following peanut than following corn, and the severity of root disease was significantly correlated with the isolation frequency of *R. solani* from seedlings (13). Root and hypocotyl necrosis of cucumber (*Cucumis sativus* L.) was greater after peanut than after turnip (*Brassica campestris* subsp. *rapifera* (Metzg.) Sinsk.), and *R. solani* AG-4 was isolated from 14% of diseased cucumber seedlings following peanut vs. 3% following turnip (12). *Pythium aphanidermatum* (Edson) Fitzp. and *P. irregulare* Buis. were isolated from 32% of diseased cucumber seedlings following peanut, whereas these and other *Pythium* spp. were isolated from 14% of diseased cucumber seedlings following turnip (12).

Peanut pods detached from the plant before or during harvest and foliage (leaves and stems) plus root debris from the combine discharge may remain on or in the soil for several weeks or months until the land is prepared for planting the next crop. Undecomposed or partially decomposed crop residue may remain near the surface if the soil is disked or subsoiled under the row, or the land may be deep-turned (about 30–40 cm deep) with a moldboard plow to bury the residue.

The objectives of this research were to determine whether peanut pods or foliage plus root debris left on and in the soil after harvest contained inoculum of soilborne pathogens and to evaluate the pathogenicity and virulence of isolates of *R. solani* AG-2-1, AG-2-2, and AG-4 from visibly sound peanut seed in pods attached to plants at digging. Primary emphasis was on unharvested peanut residues as a source of inoculum for *R. solani*. Preliminary reports have been published (1,3).

MATERIALS AND METHODS

Intact peanut pods (shells plus seeds) and foliage plus root debris were collected separately on 8 February from the upper 5 cm of soil and the soil surface, respectively, in a field where peanuts were harvested the previous 21 September. In a greenhouse study, a split-plot experiment with a randomized complete block design was used. Types of residue were whole plots with four replicates. Residue was mixed with heat-treated (60 C, 30 min) Tifton loamy sand (about 85, 10, and 5% sand, silt, and clay, respectively) soil (1:4, v/v) and layered 0–5, 5–10, or 10–15 cm deep in pots of heat-treated soil. Subplots were crops, three seeds of corn (cultivar Funks G-4507) and seven seeds of soybean (cultivar Bragg) planted 3 cm deep in each pot. Pots were watered as needed to prevent visible stress. Maximum and minimum soil temperatures in the upper 10 cm of soil averaged 30.1 and 20.5 C, respectively. Maximum and minimum air temperatures at pot height averaged 33.0 and 20.4 C, respectively. Initial fertilization was 0.9 g/L of soil (equivalent to 1,120 kg/ha) of 5-10-15 (N, P_2O_5, K_2O). Soil was watered with a solution of NH_4NO_3 equivalent to 56 kg/ha of N at 14 and 21 days after planting. The test was prepared on 17 and 18 February, planted on 19 February, and harvested 4 wk later. A root-mesocotyl disease index (RMDI) and root-hypocotyl disease index (RHDI) were determined for corn and soybean, respectively, where 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and necrosis and 5 = dead plants. Crown and brace roots on corn and hypocotyls of soybean with reddish brown lesions were counted. Root growth was estimated visually on an empirical scale of 1–5, where 1 = very poor and 5 = excellent. Isolations were made from representative samples of lesions on crown and brace roots of corn and hypocotyls of soybean. Necrotic tissue was surface-disinfested for 30 sec in 0.5% NaOCl and plated on water agar for isolation. Putative isolates of *R. solani* were identified as multinucleate on potato-dextrose agar (PDA) (6) and AG typing was done on water agar (7). Other potential pathogens were transferred from water agar to PDA for identification. Data of parameters measured on plants were analyzed using multiple regression techniques describing the effect by linear contrast, but data on isolations of various fungi were not analyzed. Logarithmic and square root transformations were used in analyses where appropriate, but actual means are tabulated.

Three isolates of *R. solani* AG-2-1, six of AG-2-2, and 14 of AG-4 from visibly sound peanut seed in pods attached to plants at digging and one isolate of AG-2-2 from a corn root were used to infest soil planted to six crops. Heat-treated Tifton loamy sand was infested with 3% cornmeal-sand inoculum of each *R. solani* isolate (1:303, inoculum/soil) and blended with fertilizer in a concrete

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mixer. Styrofoam flats with 72 compartments each (about 5 × 5 × 8 cm) were filled with soil infested with one isolate or uninfested control soil (whole plots) and replicated twice in a randomized complete block design. The six crops (subplots) were randomized and one row of 12 seeds per crop was planted in each flat. Spanish type peanut (cultivar Starr) was planted about 4 cm deep with radicles downward, and soybean (cultivar Bragg), snap bean (cultivar Eagle), blue lupine (cultivar Tifblue 78), corn (cultivar Funks G-4507), and sorghum (cultivar Funks G-522 DR) were planted about 2–3 cm deep. The flats were arranged on a greenhouse bench and watered as needed. Maximum and minimum air temperatures at flat height averaged 33.8 and 17.2 C, respectively.

Twelve days after planting, percentage emergence and RHDI were determined for peanut, soybean, snap bean, and blue lupine and RMDI was determined for corn and sorghum. Data were analyzed to evaluate the pathogenicity and virulence among the groups of *R. solani* AG-2-1, AG-2-2, and AG-4 isolates compared with the control on the six hosts.

Table 1. Peanut residue as a source of inoculum of pathogens infecting mesocotyls and crown and brace roots of corn

Type of residue	Residue depth (cm)	Emergence (no. plants)[a]	Green foliage weight (g)	Plant height (cm)	Root growth[b]	Crown and brace roots (no. lesions)[c]	RMDI[d]
Pods (P)	0–5	2.0	22.8	71.5	4.0	2.5	2.0
	5–10	2.3	47.2	78.3	4.3	6.5	2.3
	10–15	3.0	81.4	90.8	4.8	8.8	2.3
Foliage + roots (FR)	0–5	2.0	63.4	93.5	5.0	1.0	1.3
	5–10	2.3	54.5	87.3	5.0	0.3	1.1
	10–15	2.8	65.1	95.0	5.0	1.5	1.4
Control	···	2.8	78.2	96.5	5.0	1.8	1.3
Comparisons of interest							
Control vs. other		–	0.01[e]	–	–	–	–
P vs. FR		–	–	0.01	0.01	0.01	0.01
Depth (D)		0.01	0.01	–	–	0.01	–
D × D		–	–	–	–	–	–
P vs. FR × D		–	0.01	–	–	0.05	–
P vs. FR × D × D		–	–	–	–	–	–

[a] Analyses were made on transformed data except where indicated, but actual means were tabulated.
[b] Visual rating, where 1 = very poor to 5 = excellent. Analysis of root growth was with nontransformed data.
[c] Means = numbers of lesions for entire root system, not limited to respective depth zones.
[d] Visual rating of root-mesocotyl disease index: 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and necrosis and 5 = dead plant. Analysis of RMDI was with nontransformed data.
[e] Significance levels; – = no significant differences.

Table 2. Peanut residue as a source of inoculum of pathogens to hypocotyls and roots of soybean

Type of residue	Residue depth (cm)	Emergence (no. plants)[a]	Green foliage weight (g)	Plant height (cm)	Root growth[b]	Hypocotyls (no. lesions)	RHDI[c]
Pods (P)	0–5	3.8	15.3	35.5	4.0	2.3	1.9
	5–10	4.8	13.9	34.0	4.0	4.3	3.4
	10–15	6.3	23.4	38.0	4.5	4.5	2.6
Foliage + roots (FR)	0–5	4.5	28.8	42.0	5.0	2.0	2.0
	5–10	6.5	34.2	42.0	5.0	0.3	1.3
	10–15	5.0	24.4	40.3	4.5	1.8	1.4
Control	···	5.8	32.0	42.3	4.8	0.8	1.5
Comparisons of interest							
Control vs. other		–	–	–	–	0.05[d]	–
P vs. FR		–	0.01	0.01	0.01	0.01	0.01
Depth (D)		0.05	–	–	–	–	–
D × D		–	–	–	–	–	–
P vs. FR × D		–	–	–	–	–	0.05
P vs. FR × D × D		–	–	–	–	0.05	0.01

[a] Analyses were made on transformed data except where indicated, but actual means were tabulated.
[b] Visual rating, where 1 = very poor to 5 = excellent. Analysis of root growth was with nontransformed data.
[c] Visual rating of root-hypocotyl disease index: 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and necrosis and 5 = dead plant. Analysis of RHDI was with nontransformed data.
[d] Significance levels; – = no significant differences.

RESULTS

Plant stands of corn and soybean increased as the depth of layers of soil amended with pods (SAP) or foliage plus root debris (SAFR) increased (Tables 1 and 2). Differences in stand were not significant between residues in either host. The lowest stands, however, for both hosts and with both types of residue were in soil amended at the depth of 0–5 cm. The dense layer of residue in the upper 5 cm of soil partially hindered germination and emergence of corn and soybean.

The green foliage weight of corn increased with each increase in depth of SAP (Table 1). There was no difference in green foliage weight between residues in corn. In soybean, green foliage weight was greater in SAFR treatments than in SAP treatments (Tables 1 and 2). There was better root growth of corn and soybeans in the SAFR than in the SAP treatments. Heights of both corn and soybeans were greater in SAFR than in SAP, but only the height of corn increased with depths of placement of residues (Tables 1 and 2).

There were more reddish brown lesions on the crown and brace roots of corn and hypocotyls of soybean grown in SAP than in SAFR. The number of lesions increased with depth of pod residue but not with depth of foliage plus root residue (Tables 1 and 2).

The RMDI of corn growing in SAP was greater than in corn growing in SAFR, but there were no differences among depths (Table 1). The RHDI of soybean growing in SAP was greater than that of soybean growing in SAFR (Table 2). In contrast to corn, the RHDI of soybean growing in SAP was greater with the deeper layers of debris, but in SAFR, the RHDI was less with deeper layers than with the top layer (0–5 cm) (Table 2).

Fungi isolated from corn roots growing in SAP included 67 isolates of *R. solani* AG-4, with the majority from pod layers placed 5–10 and 10–15 cm deep. *R. solani* AG-4 was not isolated from corn roots growing in SAFR, and *R. solani* AG-2-2 was not recovered from corn roots growing in SAP or SAFR. Thirty-two isolates of *Pythium* spp. and 21 isolates of *Fusarium* spp. were recovered from corn roots growing in SAP, with the majority from treatments with layers of pods placed 5–10 and 10–15 cm deep. Six *Fusarium* spp. isolates were recovered from corn roots growing in SAFR at 10–15 cm, but *Pythium* spp. were not isolated from corn roots in SAFR treatments. *F. oxysporum* Schlecht. and *F. moniliforme* Sheld. predominated, but *F. solani* (Mart.) Appel & Wor. was isolated occasionally from corn roots. Some isolates of *Pythium* spp. from corn

were identified as *P. aphanidermatum*; others resembled *P. myriotylum* Drechs., *P. graminicola* Subram., and *P. catenulatum* Matt. but were not positively identified.

Thirty-nine isolates of *R. solani* AG-4 were recovered from soybean hypocotyls from SAP, with the majority of isolates from treatments where pods were placed 5–10 and 10–15 cm deep, and one culture of AG-4 was isolated from a soybean root growing in SAFR at 10–15 cm. *R. solani* AG-2-2 was not recovered from soybean hypocotyls growing in SAP or SAFR. Seven cultures of unidentified *Pythium* spp. were isolated from soybean hypocotyls growing in pod layers at 5–10 cm, but *Pythium* spp. were not isolated from soybean in the SAFR. Fifty-eight cultures of *Fusarium* spp. (53% *F. oxysporum*, 33% *F. solani*, and 14% *F. moniliforme*) were isolated from soybean hypocotyls, with the majority from treatments where pods were placed 5–10 and 10–15 cm deep. *Fusarium* spp. were not isolated from soybean in the SAFR.

Emergence of peanut, soybean, snap bean, blue lupine, and sorghum was significantly greater in the control and soil infested with *R. solani* AG-2-1 or AG-2-2 than with AG-4 (Table 3). Emergence of snap bean and blue lupine was less in soil infested with AG-2-2 than with AG-2-1. There was no difference among treatments in emergence of corn (Table 3).

R. solani AG-4 isolates caused severe root-hypocotyl necrosis of peanut, soybean, snap bean, and blue lupine and severe root-mesocotyl necrosis of sorghum but were weakly virulent on corn (Table 4). The AG-2-2 isolates were moderately virulent on corn and sorghum and highly virulent on soybean, snap bean, and blue lupine. The AG-2-1 isolates were not pathogenic (Table 4).

DISCUSSION

The predominant pathogen recovered from lesions on corn and soybean plants grown in SAP was *R. solani* AG-4. In contrast, *R. solani* AG-4 was isolated infrequently from lesions on plants grown in SAFR. The survival of *R. solani* in unharvested pods during prolonged natural weathering was expected. In previous work, eight of 15 isolates of *R. solani* AG-4 survived (av. 13 propagules per 100 g [P/100 g] of oven-dry [OD] soil) 283 days of natural weathering in fallow Tifton loamy sand and still caused root and hypocotyl necrosis of snap bean but not of corn (2). In this study, however, the occurrence of sufficient inoculum of AG-4 in unharvested pods to cause substantial necrosis of brace and crown roots of corn was not anticipated. In a previous study (9), isolates of *R. solani* AG-4 from corn roots and other hosts were mostly avirulent to slightly virulent on crown and brace roots of corn and primarily caused lesions on the mesocotyl and on seminal roots. *R. solani* AG-2-2 is more difficult to isolate than AG-4 and could have been in corn roots in this test, even though it was not isolated.

The incorporation of unharvested pods containing a moderate to high amount of inoculum of *R. solani* AG-4 into the soil may partially explain reports of the occurrence of more root and hypocotyl necrosis on snap bean and cucumber immediately following peanut than after corn or turnip (12,13).

The depth of pod placement in soil was an important factor affecting disease severity caused by pathogens contained in pods. The higher RMDI and RHDI with increasing depth of pods was indicative that corn and soybean roots grew rapidly through inoculum of *R. solani* in pods at 0–5 cm and proliferated in deeper layers of SAP, but the roots were not severely damaged by pathogens contained in the pods. Injurious effects of the deeper inoculum, however, may have become more evident 6 wk or more after planting if small lesions enlarged and destroyed roots.

The stand of peanut was thick and grew rapidly in the SAP at 0–5 cm deep and possibly competed with the corn and soybean for space, nutrients, and water. This may explain partially why growth parameters frequently were lower when pods were 0–5 cm deep, and the opposite was often true at the same depth with SAFR.

A large number of pods may be left on and in the soil at harvest. In an irrigation study on Florunner peanut, 630–778 kg/ha of pods were removed from the soil after those on the vines were harvested (8). These loose pods normally would remain in the soil and could provide a large reservoir of inoculum for *R. solani*, *Pythium* spp., and *Fusarium* spp.

The tillage practice used could determine whether pathogens contained in unharvested pods would be a problem on the crop immediately following peanut. Shallow disking (about 8–15 cm deep) would distribute unharvested pods throughout the seed-germination and root zones of shallow-rooted crops. Population densities of *R. solani* in soil were reduced more by deep moldboard plowing than colonies of *Pythium* spp. (11). Many peanut seeds contained in unharvested pods remain viable for 8–10 mo and provide a substrate for rapid growth of *R. solani* and other pathogens in the spring in the Georgia Coastal Plain soils. The inocula in pods buried 30–40 cm would be removed from contact with most crops during the highly susceptible germination, emergence, and seedling stages (4).

The peanut shell also may be infested with *R. solani*, and because of high cellulose (48.5%) and lignin (28.7%) content (5), peanut shells decay slowly in soil. Therefore, *R. solani* may survive longer in colonized shells than in colonized seed, foliage, or roots. *R. solani* AG-2-2 grown on unamended peanut shells in flasks and stored dry at 20–30 C in the laboratory survived for at least 1 yr, as evidenced by growth when dry shells were plated on PDA (D. R. Sumner and D. K. Bell, *unpublished*). We have not determined the longevity of *R. solani* AG-2-2 or AG-4 in infested peanut shells buried in soil and exposed to natural weathering.

The root-mesocotyl necrosis caused by AG-2-2 on corn and sorghum probably would have been greater had the test

Table 3. Emergence of six crops in soil infested with *Rhizoctonia solani* anastomosis group (AG) 2 types 1 and 2 and AG-4

	Emergence[y]					
AG	Peanut	Soybean	Snap bean	Blue Lupine	Corn	Sorghum
Control	9.0 a[z]	12.0 a	11.0 ab	11.0 a	11.5 a	10.5 a
AG-2 type 1	10.3 a	11.7 a	11.2 a	11.8 a	11.8 a	11.3 a
AG-2 type 2	10.3 a	11.1 a	8.3 b	5.3 b	11.3 a	8.6 a
AG-4	1.4 b	4.8 b	6.5 c	0.4 c	12.0 a	3.4 b

[y] Maximum mean emergence = 12.
[z] Means within columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 4. Root-hypocotyl and root-mesocotyl disease indices of six crops in soil infested with *Rhizoctonia solani* anastomosis group (AG) 2 types 1 and 2 and AG-4

	Root-hypocotyl disease index[y]				Root-mesocotyl disease index[y]	
AG	Peanut	Soybean	Snap bean	Blue lupine	Corn	Sorghum
AG-4	4.5 a[z]	3.3 a	3.8 a	4.9 a	1.2 b	3.4 a
AG-2 type 2	1.6 b	3.0 a	3.7 a	4.1 a	2.9 a	2.8 b
AG-2 type 1	1.4 b	1.1 b	1.3 b	1.4 b	1.2 b	1.3 c
Control	1.4 b	1.1 b	1.1 b	1.4 b	1.1 b	1.1 c

[y] Visual rating of root-hypocotyl and root-mesocotyl disease indices: 1 = <2, 2 = 2–10, 3 = 11–50, and 4 = >50% discoloration and necrosis and 5 = dead plant.
[z] Means within columns followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

continued for 6 wk. Disease ratings of the AG-2-1 isolates did not differ from the control in this test, but some isolates were moderately virulent in other experiments (9).

A selective medium was used to isolate AG-2-1, AG-2-2, and AG-4 from visibly sound peanut seed in pods attached to plants at digging and from visibly sound and discolored seed in pods loose in the soil at digging (9). Isolations of *R. solani* usually have been more frequent from seed in loose pods at digging than from seed in attached pods. In a field of Bonifay sand (about 95% sand) naturally infested with *R. solani*, the isolation percentages of AG-2-1 and AG-2-2 from seed in loose pods at digging averaged 0.03 and 0.1%, respectively, but the isolation percentage of AG-4 from seed in loose pods averaged 4% (D. K. Bell and D. R. Sumner, *unpublished*). The peanut residues (pods and foliage plus root debris) used in the first experiment came from this field. The low frequency of isolation of AG-2-2 from seed in loose pods may explain partially why this pathogen was not isolated from diseased corn roots or soybean hypocotyls growing in pod residue.

Four of 11 isolates of *R. solani* AG-2 (types 1 and 2 not separated) survived (av. 16 P/100 g of OD soil) 283 days of natural weathering in fallow Tifton loamy sand and caused moderate root-hypocotyl necrosis of snap bean but slight necrosis on roots of corn (2). In field microplots, *R. solani* AG-2-2 did not reduce significantly the yield of peanut, but corn following peanut the next year sustained a 36% reduction in grain yield (10). The host range, pathogenicity, and virulence of *R. solani* AG-2-1 and AG-2-2 in crops economically important in Georgia Coastal Plain soils means that these AG types, in addition to the long recognized AG-4, should be considered in genetic, chemical, and cultural programs to control soilborne diseases.

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