Influence of Endogone Mycorrhiza on Phytophthora Rot of Soybean

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ABSTRACT

Internal stem discoloration developed on 88% of Phytophthora rot-susceptible soybean plants growing in a sandy loam soil infested with *Phytophthora megasperma* var. *sojae* and a chlamydosporic species of *Endogone*, and 33% of the plants died. In plots infested with *Phytophthora* alone, 17% of the plants developed internal stem discoloration, but none died. *Endogone* had no effect on Phytophthora rot symptoms on a more disease-tolerant cultivar.

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Wilt, root rot, and stem rot diseases caused by root-invading pathogens are especially responsive to soil conditions. Besides physical factors such as soil type, temperature, moisture, pH, and fertility, the density and form of inoculum of the pathogen in the soil and the action of other organisms may influence development of these diseases. Although the role of ectotrophic mycorrhizal fungi in the resistance of pine roots to infections by fungi was studied (3), the influence of ubiquitous vesicular-arbuscular (VA) mycorrhizae on root invading pathogens has not been reported (2).

Several species of *Endogone* (6, 7) infect soybean (*Glycine max* [L.] Merr.), and mycorrhizal soybean plants yield significantly more on low-phosphate soils than do nonmycorrhizal plants (5). The current study was undertaken to determine the effect of a chlamydosporic species of *Endogone* (5, 6) on infection of soybean by *Phytophthora megasperma* Drechs. var. *sojae* Hildeb.

MATERIALS AND METHODS.—The experiment was conducted during the summer of 1971 in plots (0.3 m^2) (4) containing a sandy loam soil with 300 kg/hectare of weak-acid extractable phosphorus. On 20 April 1971, soil was fumigated with 90 ml/m^2 of methyl bromide plus 27 ml/m^2 of chloropicrin, and covered with polyethylene plastic for 2 days.

Cultures used for *Endogone* inoculum were initiated with surface-sterilized chlamydospores isolated from roots of mature soybean (6). The inoculum was produced on roots of soybean plants grown in steam-sterilized soil in 6-inch pots in the greenhouse. After 4 months, 800 g of soil and roots (ca. 10,000 chlamydospores) from the pots were used as inoculum for each experimental plot. Control plots each received 800 g of autoclaved soil and roots from the *Endogone* cultures.

Inoculum of *P. megasperma* var. *sojae* (Race 1) was grown on a medium prepared by adding 300 ml of aqueous soybean seed extract to each 100 g of shredded dry pods and stems from mature soybean plants. The extract was prepared by soaking 250 g seed overnight, blending them in 1.8 liters of water, and removing the pulp by straining through cheesecloth. The medium was placed in Erlenmeyer flasks, autoclaved twice, inoculated with *Phytophthora*, and incubated at 20 C; cultures developed numerous oospores. Each *Phytophthora*-infested plot received 430 g of the 6-week-old culture, and each control plot received 600 g of sterile soybean stem medium.

Inocula of *Endogone* and/or *Phytophthora* were mixed into a 30-cm layer of soil ca. 30 cm below the soil surface of each plot on 20 May. Plots were planted either to cultivar Lee or D 60-12,058, which are *Phytophthora*-tolerant and susceptible soybean lines, respectively. Before planting, seed were surface-disinfested with 1% NaClO, dried, and treated with commercial *Rhizobium* inoculum. Each treatment and control were replicated in three plots. Four weeks after planting, plants were thinned to eight/plot.

During the last week in September, plants were lifted, weighed, split longitudinally, and observed for internal tap root and stem discoloration. The extent of mycorrhizal development was based on root fragments washed from soil samples taken from the plots after plant removal. The fragments were weighed and blended in water, and the chlamydospores separated from the debris by decanting and sieving. The spores were counted under the dissecting microscope.

RESULTS.—Six weeks after planting, three D 60-12,058 plants growing in *Phytophthora* + *Endogone*-infested plots had brown necrotic lesions encircling their stems. Lesions progressed upward from the stem base to about one-half the plant height. After the plants died, stems were cut off at the soil level and examined microscopically. Oospores of *P. megasperma* var. *sojae* were found in the pith tissue. By the end of September, eight plants in *Phytophthora* + *Endogone*-infested plots had

TABLE 1. Effect of mycorrhizal development by *Endogone* on Phytophthora root and stem rot of soybean

Cultivar	Plots infested with	Avg plant wt (g)	No. dead plants[a]	No. plants with internal discoloration[a]		Avg spores/g of root
				Root	Stem	
Lee	*Phytophthora*	153	0	5	0	29
	Phytophthora + *Endogone*	204	0	5	0	1,652
	Endogone					1,070
	Control	181	0	0	0	7
D 60-12,058	*Phytophthora*	126	0	9	4	7
	Phytophthora + *Endogone*	110	8	13[b]	13[b]	1,023
	Control	284	0	0	0	4

[a] Each treatment contained a total of 24 plants.
[b] Does not include dead plants.

developed these stem rot symptoms (Table 1), whereas plants in plots not infested with *Endogone* did not develop these symptoms.

Foliage of D 60-12,058 plants growing in soil infested with *Phytophthora*, with or without *Endogone*, developed chlorosis typical of the root rot phase of the disease. No Lee plants developed external Phytophthora rot symptoms.

Root and stem discoloration of D 60-12,058 in *Phytophthora*-infested plots was more frequent and extensive in *Endogone*-infested than in noninfested soil (Table 1). There were no differences in the amount of root and stem discoloration between mycorrhizal and nonmycorrhizal Lee plants from *Phytophthora*-infested plots. Neither D 60-12,058 nor Lee plants from control plots manifested internal or external symptoms.

Mycorrhizal development in Lee roots, as indicated by chlamydospore counts, was not affected by the presence of *Phytophthora*; however, spore counts varied considerably among replications (Table 1). The few *Endogone* spores found in roots from plots not infested with *Endogone* indicate that the fumigation did not completely eradicate the fungus. Plant growth was not influenced by *Endogone*. *Phytophthora* reduced plant growth of D 60-12,058 but did not affect the growth of Lee plants.

DISCUSSION.—The increased development of Phytophthora rot which resulted in the death of D 60-12,058 plants suggests that *Endogone* may either predispose the host to infection or enhance the disease in doubly infected plants. Since D 60-12,058 plants developed chlorotic foliar symptoms in all *Phytophthora*-infested plots, the presence of mycorrhizae may enhance pathogen development within the host. Development of arbuscules, vesicles, and chlamydospores in the root cortex may affect penetration and/or development of the pathogen.

The development of stem rot symptoms on D 60-12,058 in mycorrhizal plots with high soil phosphorus indicates that the effect exerted by *Endogone* on susceptibility is related to mycorrhizal infection per se rather than to alterations in host nutrition. Since stem rot developed only in mycorrhizal plots, the appearance of this symptom under field conditions may be associated with abundance of VA mycorrhizae.

The failure of Lee plants to develop symptoms of Phytophthora rot other than a slight discoloration in the tap roots is probably a reflection of the disease tolerance of this cultivar. Since the disease is most severe in poorly drained areas such as on heavy clay (1), and the soil in this experiment was a well drained sandy loam, the increased *Phytophthora* susceptibility caused by *Endogone* on a cultivar with disease tolerance of Lee might be more apparent under more adverse environmental conditions.

The marked susceptibility of D 60-12,058 to Phytophthora rot was reflected in the reduction of plant weights in *Phytophthora*-infested soil. The high phosphorus levels in these plots probably accounts for the lack of yield response of Lee to *Endogone*, as shown previously (5).

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