Distribution of Fusarium solani f. sp. phaseoli and Bean Roots in Relation to Tillage and Soil Compaction

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ABSTRACT

Propagules of *Fusarium solani* f. sp. *phaseoli* were found distributed throughout the plowed layer (20-30 cm depth) of sandy loam and silt loam bean fields in Central Washington. Numbers in each field varied with season and location from about 100 to 5,500/g dry soil. In contrast, the pathogen was seldom detected in platings of subsoil (33-41 cm depth), but it was isolated from sparse root lesions on plants grown 2-4 weeks in pots of subsoil. Root excavations revealed that many bean roots also were confined to the plowed soil layer. Root obstruction was caused by compact soil within and below the plowed layer, but especially at the plow sole and at a disk sole formed during herbicide incorporation. Roots penetrating or evading areas of compact soil reached depths of 100 cm or more. Fewer roots entered the subsoil in *Fusarium*-infested fields than in noninfested fields. However, in a *Fusarium*-infested field containing undecomposed barley crop residues, the soil was less dense, and bean root penetration was more extensive than in adjacent fields containing only bean crop residues.

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Bean roots (*Phaseolus vulgaris* L.) suppressed or restricted in growth in the presence of *Fusarium solani* (Mart.) Appel & Wr. f. sp. *phaseoli* (Burk.) Snyd. & Hans. are predisposed to damage or destruction by the fungus (1, 2). However, this fungus seems to have little effect on vigorously growing roots. In recent studies (2, 5), the yield-depressing effects of root rot were virtually eliminated in *Fusarium*-infested sandy loam fields by a subsoiling immediately before planting. Subsoiling permitted extension of bean roots through the plowed soil layer into the subsoil. The subsoil may be somewhat of a haven in which roots can escape high populations of pathogens in the plowed layer (4).

In further investigations, we examined (i) the concentration of *Fusarium* inoculum at different depths in fields where bean root rot occurs; (ii) the relative soil hardness or compaction in the plowed layers and subsoils of *Fusarium*-infested and noninfested fields; and (iii) the relative ability of bean roots to penetrate the undisturbed subsoil in infested and noninfested fields (3).

MATERIALS AND METHODS.—Soil samples were collected from three Ritzville sandy loam (RSL) fields and one field of Shano silt loam (SSL) wherein beans had been grown each year or in alternate years for 7-9 years. Most bean roots in these fields had cortical rot caused by *Fusarium solani* f. sp. *phaseoli*. One of the RSL fields had produced alternate crops of barley and beans. Soil samples were collected in March before plowing; in June when plants were young; in July; in August shortly before harvest; and in October. Samples were collected from within and between plant rows and from plot border areas where beans had not been grown for 1 year or more. Soil collections were also made in October from another field of Shano silt loam in which beans had been grown for the first time that year, and from 15 locations in noncropped sagebrush land.

Four to ten excavations, up to 1.5 m in each dimension, were made at random across rows of Red Mexican or Pinto bean plants in each field at each time of soil sampling. Three 8-cm soil layers were sampled, with a clean trowel, between the soil surface and a depth of 31 cm (0-8, 10-18, and 23-31 cm), which comprised the plowed layer of soil. However, the third layer, 23-31 cm, usually contained soil from both the plowed layer and "subsoil". Subsoil (below 31 cm) samples were collected from the 33- to 41-cm depth. Samples were collected also from a depth 90 to 100 cm in 12 *Fusarium*-infested field locations in August. All soil samples were collected in 4-lb. paper bags and dried at room temperature.

Root distribution was observed after washing a wall of each excavation with water (Fig. 5). Root distribution was studied also by driving 41-cm long X 5-cm-diam sampling tubes vertically into the soil 2.5 cm to the side of random bean plants, and measuring vertical distribution of roots in 2.5-cm increments within the tube.

At each sampling site, soil compaction was measured in walls of the excavations, at intervals of 2.5 cm, from the soil surface to a depth of 41 cm, with a force-gage penetrometer (11) by determining the pressure required to push a rod (8 mm diam) 2.5 cm into the soil. Air-dry bulk density of the soil (as determined by the paraffin wax method) and soil moisture determinations for 2.5-cm increments (5 cm diam) from the 10-cm to the 41-cm depth were made in each field during the June sampling.

Fusarium counts were made on a modified Nash PCNB agar medium (10). Soil samples were plated once or twice in four-six replicate dishes at dilutions of 1:200 in 0.1% water agar. Subsoil samples and samples from new bean land and sagebrush land were also plated at dilutions of 1:100 and 1:20. Dishes were incubated in diffuse daylight at 20-22 C. Representative isolates from each field were tested for pathogenicity on bean roots. Total numbers of other *Fusarium*-like colonies and those of other fungi were recorded.

The subsoil and soil from sagebrush land was

TABLE 1. Seasonal and vertical distribution of *Fusarium solani* f. sp. *phaseoli* in two bean fields (1967)[a]

Depth	Ritzville sandy loam				Shano silt loam			
	March	June	Aug.	October	March[b]	June	Aug.	October[b]
cm	*propagules/g*				*propagules/g*			
0-8	1,140	620	442	797	490	795	368	1,546
10-18		380	345			650	278	
23-31[c]	540	80	185	587	26	340	135	20
33-41[d]	80	0	0	0	66	0	0	0
No. plates/level	15	16	160	60	15	10	100	30

[a]Propagules per gram of air-dry soil.
[b]Land in winter wheat cover crop, between crops of beans.
[c]Contained soil from the plowed layer and subsoil in differing proportions.
[d]Subsoil.

bioassayed for *F. solani* f. sp. *phaseoli* by growing Red Mexican bean plants in six 10-cm pots of each soil collection and isolating the pathogen from roots plated on PCNB agar.

RESULTS.–*Fusarium solani* f. sp. *phaseoli* was abundant in nearly all samples from the plowed layers. In contrast, it was isolated from subsoil platings only in March (Table 1). The pathogen was not found in soil platings from 90-100 cm deep in any field; nor even from the top layers of the first-year bean field or sagebrush land. Populations of the pathogen were similar in RSL and SSL fields. Alternate cropping with barley and beans appeared not to have affected population levels when compared to continuous cropping with beans. Lowest populations occurred in August. In most locations, populations of *F. solani* f. sp. *phaseoli* and other fungi appearing on the plates were larger in the top 8 cm of soil than in deeper layers. This tendency was most noticeable in the fall after harvest and in the spring before plowing. Figure 1 shows a frequency distribution of the pathogen in platings from five levels in 10 locations in the *Fusarium*-infested SSL field in March 1969.

Collections in August, as plants approached maturity, were made beneath resistant and susceptible bean selections, within and between bean rows, and beneath irrigation ditches and regular routes of tractor wheels. No significant differences in populations or vertical distribution of propagules were observed among such locations.

The largest lateral variations in surface populations occurred when samples within rows were compared with those from between rows in the October platings. Propagule numbers were sometimes much higher in the bean row, where the old hypocotyls and shallow roots were concentrated, than between rows (Fig. 2).

Although the pathogen was seldom isolated in subsoil platings, it was isolated consistently from bean roots collected from the subsoil in September and from the sparse lesions that developed on roots of bean plants grown for 2-4 weeks in subsoil collections in the greenhouse. Colonies of the pathogen occurring in platings of subsoil were nearly all of one clone which produced deep blue colonies

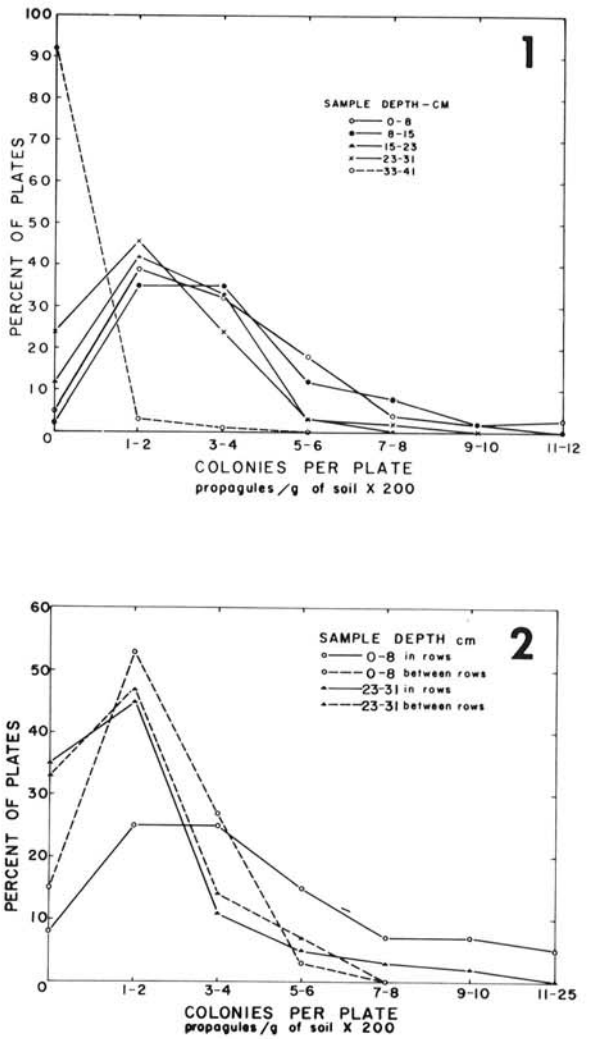
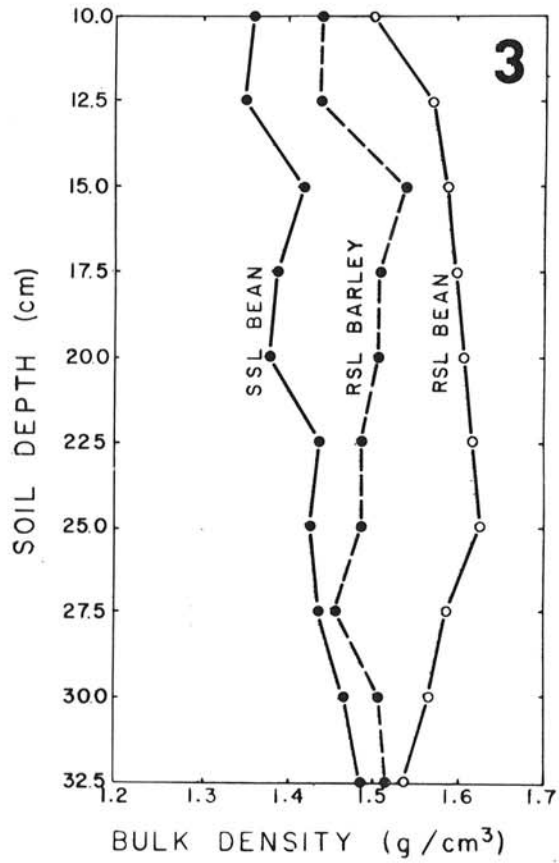
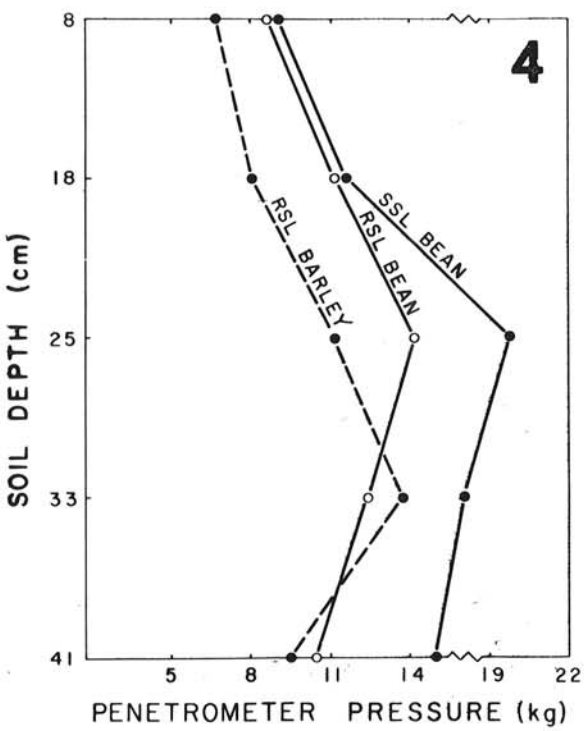


Fig. 1-2. 1) Distribution of *Fusarium solani* f. sp. *phaseoli* in platings of soil from different depths in a Shano silt loam bean field, March 1969. **2)** Distribution of *F. solani* f. sp. *phaseoli* in platings of soil from an unplowed Ritzville sandy loam bean field in October 1967, within the plant rows vs. between the plant rows, at two levels.





on potato-dextrose agar, but subsoil isolates from old roots collected from the subsoil represented at least four or five clones. The pathogen was also isolated 3 times from root lesions produced in sagebrush soil, but aerial contamination could not be ruled out as the source of inoculum.

Bulk density measurements of the soil in each field except the barley field showed a gradual increase in soil density from the surface to the subsoil (Fig. 3). Noticeable increases in bulk density occurred at the 12- to 15-cm level in each field, corresponding to the depth of preplanting disking for incorporation of herbicides. Other noticeable increases in bulk density occurred at depths of 23-27 cm in some fields, probably corresponding to plowing depth in those fields.

The SSL field had lower bulk densities than any of the sandy loam fields. The RSL field containing barley crop residues from the previous season had lower bulk densities throughout most of the profile than other fields of the same soil type. Penetrometer measurements in each field (Fig. 4) corresponded roughly with the bulk density measurements (Fig. 3). However, penetrometer readings were generally higher in SSL than in RSL soils. Soil moisture content affected penetrometer measurements, and, therefore, complicated this means of measuring soil density.

Root distribution.—Numerous excavations showed that bean roots were obstructed by the compact areas within and below the plowed soil layer and were, therefore, more concentrated in the plowed layer than in the subsoil (Fig. 5). In noninfested fields and in the *Fusarium*-infested field containing barley residues, many roots penetrated to a depth of 1 m or more. In other *Fusarium*-infested fields, roots of most plants penetrated the subsoil no more than a few centimeters. Root restriction was especially noticeable at the bottom of the plowed layer, and at the depth of disking for herbicide application (Fig. 6).

DISCUSSION.—Distribution of *F. solani* f. sp. *phaseoli* in the plowed layer found in this study is in accord with that reported for California fields by Nash & Snyder (9). Vertical distribution is similar also to that reported for *F. solani* (Mart.) Appel & Wr. f. sp. *pisi* (F. R. Jones) Snyd. & Hans. and *Aphanomyces euteiches* Drechs. in Wisconsin soils (4).

Bean roots, like those of other species (7), are restricted by the relatively more compact soil such as that occurring at the bottom of disked and plowed layers. Although they are largely geotropic (6), bean

Fig. 3-4. 3) Bulk density of the soil at different depths in three bean fields: two adjacent Ritzville sandy loam (RSL) fields, one in which the preceding crop was beans and the other in which the preceding crop was barley; and a Shano silt loam (SSL) field in which the preceding crop was beans. **4)** Soil compaction, as measured with a force-gage penetrometer at different depths in the same three bean fields.

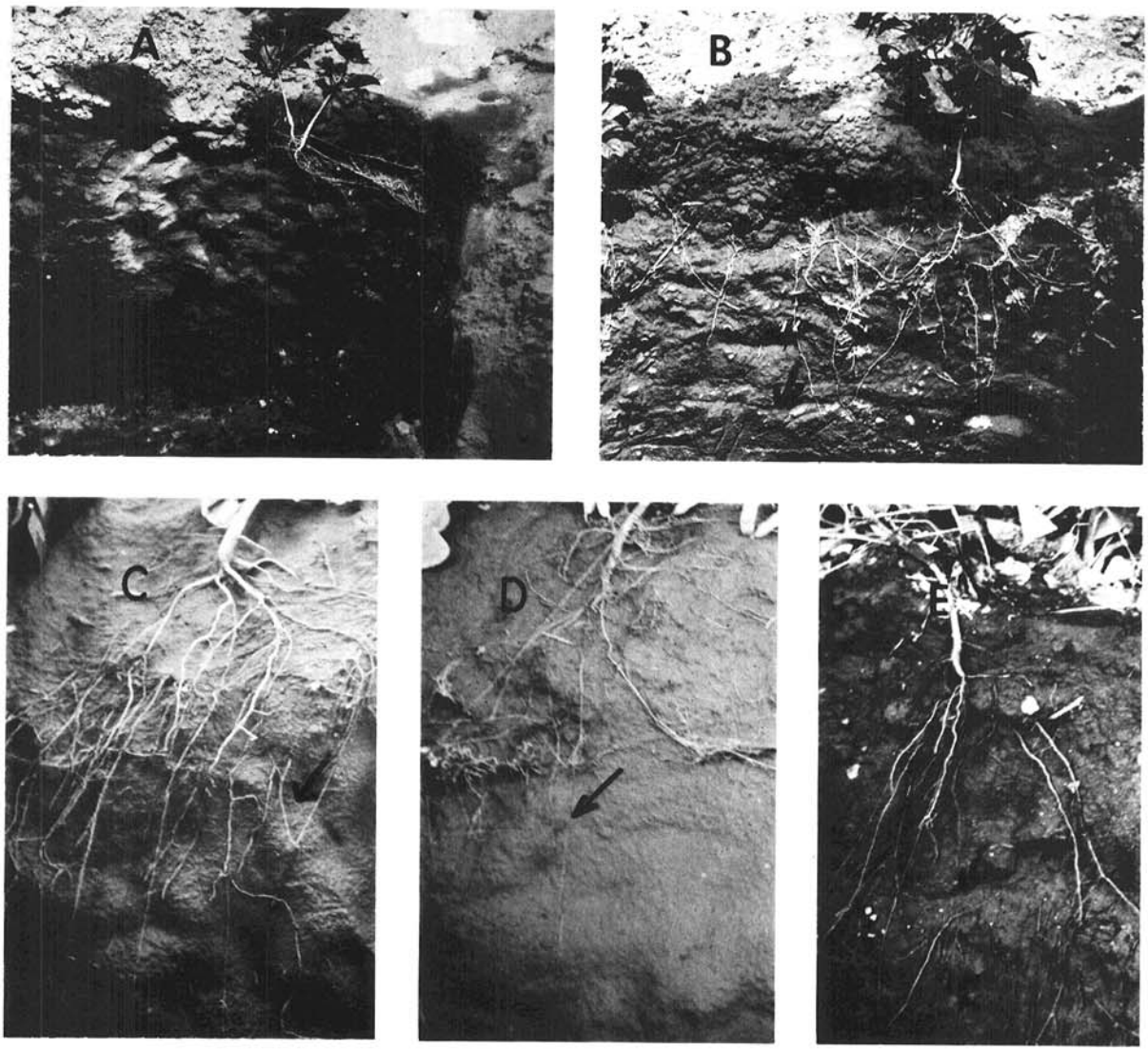


Fig. 5. Bean root distribution in soil: **A, B)** 6 weeks after planting, *Fusarium*-infested roots **A)** in a field in which the previous crop was beans; and **B)** in an adjacent field in which the previous crop was barley; **C, D, E)** 12 weeks after planting; **C)** in a field not infested by *Fusarium solani* f. sp. *phaseoli*; **D)** in the same field as A; and **E)** in the same field as B. (Arrows mark approximate bottom of the plowed layer. Roots in A and B were sprayed with yellow paint for photographic purposes.)

roots tend to grow laterally on compact horizontal soil layers such as disk soles and plow soles.

Vertical distribution of *F. solani* f. sp. *phaseoli*, to some extent, coincides with bean root distribution. A large part of the supply of chlamydospore inoculum is produced on and within bean stems and shallow roots as the plants senesce (8). However, the entire root system provides inoculum distribution to the extent of its growth. Tillage tends to distribute the fungus propagules throughout the plowed layer.

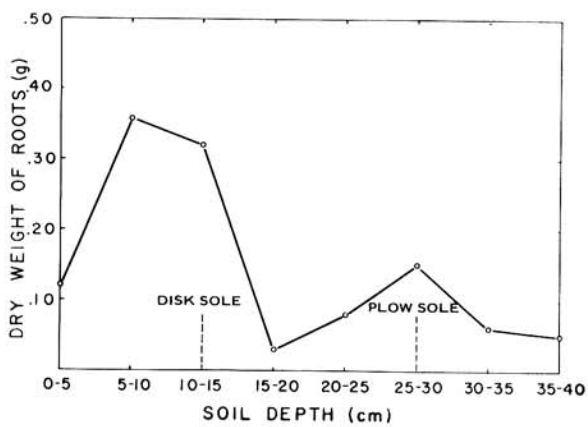


Fig. 6. Depth distribution of bean roots, as measured with sampling tubes, 8 weeks after planting, in a Ritzville sandy loam field infested by *Fusarium solani* f. sp. *phaseoli*.

Distribution of *F. solani* f. sp. *phaseoli* in the subsoil may be largely dependent upon root distribution.

The low incidence of the *Fusarium* in subsoils of infested fields, including the barley field, where many bean roots entered the subsoil, suggests that conditions there are unfavorable to this fungus. However, the occurrence of several clones of this fungus in roots collected from the subsoils, although principally only one clone appeared in platings of subsoil, indicates that specialization for subsoil survival may exist in this pathogen. Studies on these points are in progress.

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