Counteracting Bean Root Rot by Loosening the Soil

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ABSTRACT

Subsoiling to reduce soil compaction after seedbed preparation in two sandy loam fields significantly increased yields of three bean cultivars whose roots were infected by *Fusarium solani* f. sp. *phaseoli*. Subsoiling under the drill row before planting was more effective than subsoiling between the rows before planting or after plant emergence. Subsoiling before plowing was ineffective. Yield increases appeared to result not from reduced infection but from counteraction of effects of the disease through increased rooting depth and volume, and through greater regeneration of roots as the season progressed. Response to subsoiling was greater in a bush bean highly sensitive to root rot than in two less sensitive Red Mexican cultivars. In fields containing the previous season's barley crop residues, the soil was less uniformly compacted; subsoiling was therefore less beneficial than in adjacent fields where beans had grown the previous year. Subsoiling in *Fusarium*-infested or noninfested silt loam fields, where soil moisture was maintained near optimum for plant development, increased rooting depth and volume, but failed to affect seed yields.

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Mechanical impedance of bean roots (*Phaseolus vulgaris* L.) by compact soil predisposes them to damage by *Fusarium solani* (Mart.) Appel & Wr. f. sp. *phaseoli* (Burk.) Snyd. & Hans. (1, 2). Furthermore, in some *Fusarium*-infested fields, both bean roots and the pathogen are largely confined to the plowed soil layer by compacted subsoils. In a previous study (1), subsoiling after seedbed preparation (i.e., breaking the soil with chisels to depths below the plowed layer) in a sandy loam field permitted greater rooting depth and volume, and thus largely negated effects of the disease on seed yields of Red Mexican beans. Barley crop residues and other high-carbon materials also have reduced damage to beans by *F. solani* f. sp. *phaseoli* (5, 6), and we have used alternate cropping of barley and beans to reduce Fusarium root rot in experimental bean plantings in Washington. Another means for partial control of the disease is the use of bean cultivars with tolerance to the disease (4).

In a 3-year study, we investigated the effects of subsoiling before plowing and after seedbed preparation on Fusarium root rot severity in fields of different soil type and soil moisture characteristics, and in fields with and without barley crop residues. We also studied yield responses of different bean cultivars to subsoiling, and the effect of subsoiling on soil water distribution and on soil temperature.

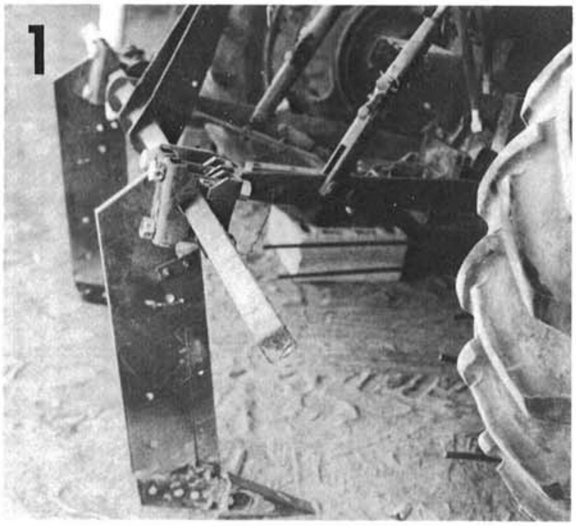
MATERIALS AND METHODS.—Subsoiling in 1968 consisted of chiseling to a depth of 51 cm at 45-cm spacings before spring plowing. Three subsoiled strips, 110 m long and 4.5 m wide, were alternated with control strips in four bean fields. The soil in two *Fusarium*-infested fields and one noninfested field, near Prosser, was Ritzville sandy loam (RSL). *Fusarium*-infested soil in the fourth field, near Othello, was Shano silt loam (SSL). In one *Fusarium*-infested RSL field, where barley and bean crops were alternated, the entire barley crop residue (about 10 ton/hectare) was plowed under with a moldboard plow, to a depth of 25-30 cm, in the fall before the experiment. Three bean cultivars differing in tolerance to bean root rot (4) were planted: two vine-type Red Mexican selections, Bigbend (most tolerant) and UI-36; and Royal Red Kidney, a bush type (least tolerant). Seed was planted at a rate of 120 kg/hectare in two random eight-row plots, 18 m long, in each strip. Rows were 56 cm apart. Subsoiling before plowing failed to affect disease severity or plant yields.

In 1969 and 1970, other parts of the same fields were subsoiled only after seedbed preparation. As in a previous study (1), two chisels (Fig. 1) were used to break the soil to a depth of 51 cm. Four treatments were applied in six replicates of four-row plots, 18 m long, for each of the same three bean cultivars used in 1968. These treatments were 1) chisels spaced 56 cm apart, directly under the two center drill rows in each plot, immediately before planting; 2) chisels spaced 112 cm apart, midway between the middle and outside rows in each plot, before planting; 3) the same as 2, but applied 3-5 days after plant emergence; and 4) the control.

Tensiometers were used to measure soil moisture suction at depths of 30 and 61 cm in four plots of treatments 1 and 4 in each field. Soil temperature records were maintained for the same depths throughout July 1970.

Excavations were made at four locations in each field, 45 days and 90 days after planting, in 1970, to reveal plant rooting and extent of *Fusarium* infection in subsoiled and control plots. A force-gauge penetrometer (2, 3) was used to compare fields and plots for relative soil hardness at 5-cm intervals vertically in the soil profile 24 hr after an irrigation. The two center rows in each plot were harvested for seed yield.

RESULTS.—All subsoiling treatments applied after seedbed preparation increased rooting depth and plant vigor (Fig. 2, 3). All bean cultivars grown in RSL fields yielded significantly more in plots subsoiled after seedbed preparation than in nonsubsoiled plots in both seasons (Table 1). Royal



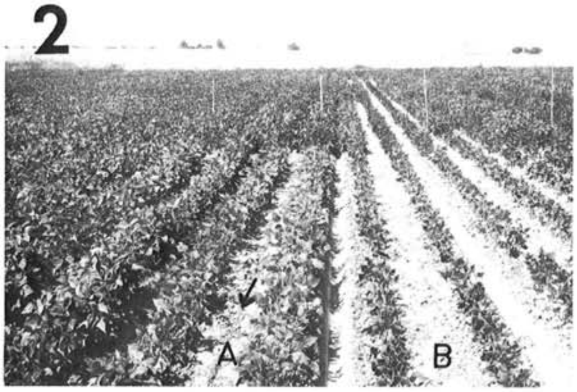


Fig. 1-2. 1) Equipment used for subsoiling immediately before planting and after plant emergence. **2)** Red Kidney bean plants (foreground) and Red Mexican bean plants (background), 7-8 weeks old, in four-row plots; A = subsoiled between the rows (arrow marks a subsoiler chisel path); B = not subsoiled.

Red Kidney was most reduced in yield by the disease, and exhibited the greatest benefit from subsoiling. Red Mexican UI-36 and Red Mexican Bigbend performed almost equally, even though UI-36 is usually considered more sensitive to root rot than is Bigbend (4). In fields containing barley residues, effects of the disease on plant vigor and yield were less severe than in adjacent fields where beans followed beans. Therefore, benefits from subsoiling in barley land were less pronounced (Table 1).

Rooting depth and plant vigor were increased by subsoiling after seedbed preparation in both infested and noninfested SSL fields, but bean yields were not increased. Yields were near optimum and nearly the same in infested and noninfested fields, with or without subsoiling, apparently because soil moisture was maintained at near optimum levels by seepage from an adjacent canal.

In contrast, in RSL soil, plants in control plots usually showed moisture stress between irrigations, whereas plants in subsoiled plots generally did not. However, soil moisture suctions at the 30-cm and 61-cm depths were similar in subsoiled and nonsubsoiled rows. Moisture stress symptoms in the control plots probably resulted from poor root penetration, with ramification largely restricted to the 30-cm depth. In contrast, roots in subsoiled plots generally penetrated the soil 60 to 100 cm by the end of the season.

By 45 days after planting in *Fusarium*-infested fields, the entire root system on most plants, except for root tips, showed cortical necrosis by the *Fusarium* (Fig. 3-A, B). This was true for both subsoiled and nonsubsoiled plots, whether or not the soil contained barley residues. By 85-90 days after planting, many roots and hypocotyls in subsoiled plots, and in fields containing barley residues, were strong and vigorous after regeneration of cortical tissues. In contrast, roots in control plots remained small and necrotic (Fig. 3-C).

Soil temperatures during July 1970 were generally the same in subsoiled and control plots. Subsoiling reduced soil compaction as measured with a penetrometer. Barley residues also reduced soil compaction (Fig. 4).

DISCUSSION.—Soil compaction, occurring as a result of current-season tillage in preparation of the seedbed, appears an important factor in the Fusarium root rot problem. This is indicated by the fact that subsoiling after seedbed preparation, but not before, greatly increased bean rooting and yields.

Loosening the soil, by subsoiling or by incorporation of barley residues, did not prevent root infection by *F. solani* f. sp. *phaseoli*, but it permitted the development of deeper, more vigorous root systems. In the dry RSL soil, the larger root systems were essential to optimum seed production. However, in the SSL fields where soil moisture and nutrients were evidently sufficient near the soil surface, even severely rotted and restricted roots supported optimum yields. Similarly, in California (7), cotton yields were increased by subsoiling in coarse-textured soils, but not in clay soils where soil moisture conditions were better.

The beneficial effects of barley and other carbonaceous crop residues are sometimes attributed to the stimulation of microbial populations which either compete with the *Fusarium* for available nitrogen (6) or otherwise antagonize the pathogen (5). In the present study, the soil had been fertilized with 100 kg/hectare of nitrogen (as NH_4NO_3) before the barley residues were plowed under. Barley residues did not prevent extensive root necrosis by *F. solani* f. sp. *phaseoli*, but they did reduce soil compaction, and thus permitted more extensive rooting. Also, irrigation water infiltration was more rapid and uniform in the barley field than in adjacent plots containing no barley residues. Nevertheless, subsoiling improved bean seed yields in the barley land, probably because barley residues were not uniformly distributed and because subsoiling broke the plow sole, a barrier to deep rooting. Whether the low level of inoculum in the subsoil (2, 3) makes

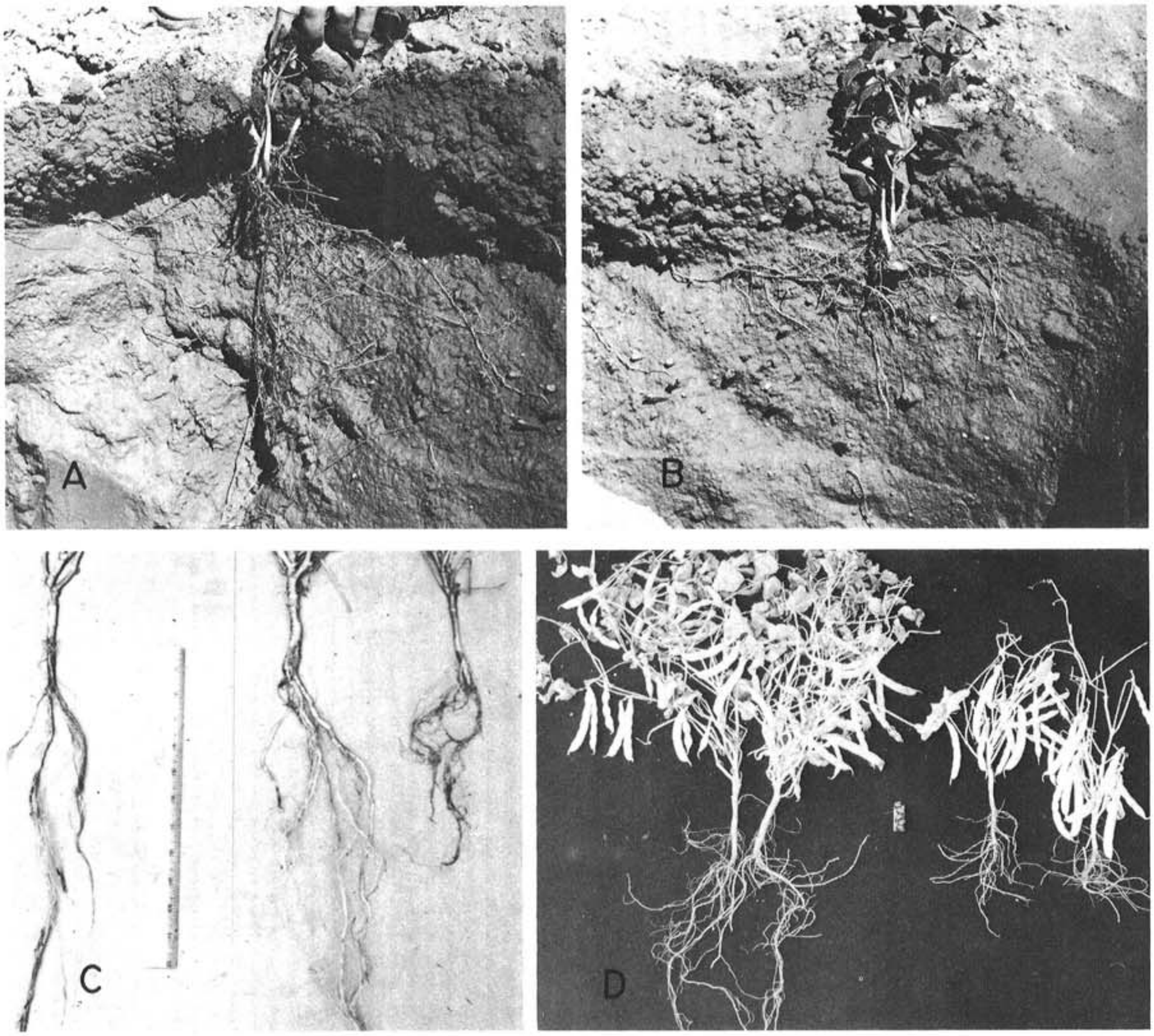
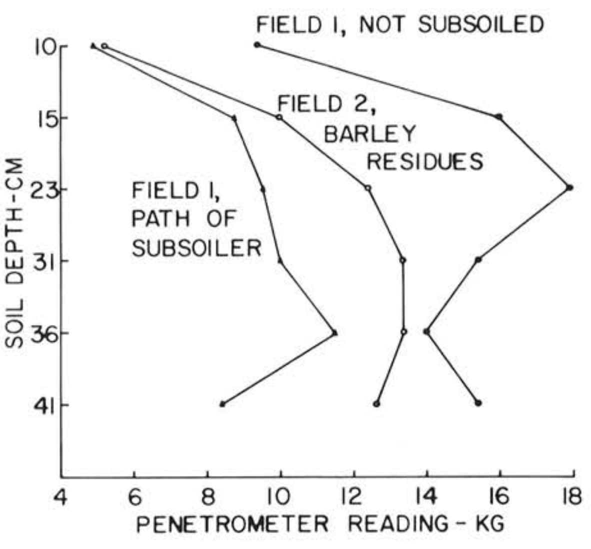


Fig. 3. Roots of Red Mexican beans grown in fields infested by *Fusarium solani* f. sp. *phaseoli*. Plants 45 days old in plots **A)** subsoiled beneath the drill row; and **B)** in plots not subsoiled, respectively. **C)** Typical mature roots, left to right, from a plot containing barley crop residues, and from subsoiled and nonsubsoiled plots in a field containing only bean crop residues (ruler graduated in inches). **D)** Mature plants from (left) subsoiled and (right) nonsubsoiled plots.



subsoil rooting beneficial to the plants, or whether the benefits come only from the greater root volume, has not been determined.

Loosening the soil by subsoiling or other means appears to be a promising method for reducing crop damage by bean root rot, especially in coarse-textured soils, where deep rooting is needed to avoid excessive moisture stress. In finer-textured soils, such as the SSL, subsoiling may make it feasible to reduce the frequency of irrigation.

Results of this study indicate that the greater the sensitivity of a bean cultivar to Fusarium root rot, the greater will be its growth and yield responses to subsoiling.

Fig. 4. Effects of subsoiling and barley crop residues on soil compaction as measured with a force-gauge penetrometer (24 hr after an irrigation and 60 days after bean planting).

TABLE 1. Effect of subsoiling after seedbed preparation on seed yields of three bean cultivars in *Fusarium*-infested Ritzville sandy loam[a]

Chisel treatment	Season	Bean cultivars		
		Bigbend	UI-36	Royal Red
		kg seed/hectare		
Bean land	1969			
1 Under plant row, preplant		3,838 a	3,783 a	2,475 a
2 Between rows, preplant		3,450 b	3,424 a	1,915 a
3 Between rows, after emergence		3,639 ab	3,463 a	1,998 a
4 Control		2,251 c	2,176 b	927 b
Barley land				
1 Under plant row, preplant		4,079 a	3,852 a	3,122 a
2 Between rows, preplant		3,780 ab	3,794 a	2,758 a
3 Between rows, after emergence		3,705 ab	3,569 a	2,753 a
4 Control		3,544 b	2,867 b	1,976 b
Bean land	1970			
1 Under plant row, preplant		4,226 a	4,252 a	3,492 a
2 Between rows, preplant		3,138 b	3,492 b	2,599 b
3 Between rows, after emergence		2,893 b	3,057 c	2,125 c
4 Control		2,100 c	1,996 d	1,495 d
Barley land				
1 Under plant row, preplant		3,818 a	4,241 a	3,480 a
2 Between rows, preplant		3,051 b	3,141 b	2,671 b
3 Between rows, after emergence		2,997 b	3,246 b	2,290 b
4 Control		2,683 b	2,736 c	1,915 c

[a] Yield figures in each group of four, when followed by the same letter, are not significantly different at the 5% level.

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