Effects of Soil Temperature on Growth of Beans in Relation to Soil Compaction and Fusarium Root Rot

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ABSTRACT

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Low soil temperatures were more detrimental to both root and top growth of bean plants when the soil was infested by *Fusarium solani* f. sp. *phaseoli* than when it was not infested. Bean roots penetrated compact (1.5 g/cm^3) Fusarium-infested or fumigated soil more readily when soil temperatures during the night and day were 21 and 27 C, respectively, than when they were 16 and 21 C. Root penetration of compact soil also was greater at a constant soil temperature of 21 C than at 16 C, with plant tops exposed to either 21 or 27 C. Soil temperature affected root growth much less in loose (1.2 g/cm^3) soil than in compact soil. Air temperatures affected both root and top growth much less than soil temperatures. The amount of root growth in loose soil above compact soil generally was inversely related to the amount of root growth into the compact soil. Six cultivars differing in field resistance to Fusarium root rot did not differ significantly in their ability to penetrate compact Fusarium-infested soil at high or low temperatures.

Additional key words: Phaseolus vulgaris L., bulk density, root impedance.

Soil compaction increases the severity of Fusarium root rot of beans (*Phaseolus vulgaris* L.), caused by *Fusarium solani* (Mart.) Appel & Wr. f. sp. *phaseoli* (Burk.) Snyd. & Hans. (5,8). Soil temperatures lower than optimum for plant growth also aggravate root rot (2,3). Conversely, loose soil and temperatures favorable for rapid plant growth tend to counteract root rot (3,5). In the field, beans planted late in the season in warm soil frequently escape the yield-depressing effects of root rot that afflict beans planted earlier in the same fields in cold soil (2).

We studied the combined effects of controlled soil and air temperatures, soil compaction, and exposure to *F. solani* on root and top growth of bean cultivars differing in level of resistance to Fusarium root rot.

MATERIALS AND METHODS

Warden find sandy loam surface soil from a field heavily infested with *F. solani* f. sp. *phaseoli* was used in all experiments. Half of the soil was fumigated with methyl bromide to eliminate pathogens. A combination of several methods (1,6,10,11) was used to provide uniformly and differentially packed soil for growth of bean plants (Figs. 1 and 2). Screened air-dry soil was moistened to 17% by weight with tap water, and weighed in portions to provide bulk densities from 1.2 to 1.5 g/cm^3 when packed in measured volumes representative of loose soil and a tillage pan. Preliminary experiments indicated little impedance to root growth in moist soil until bulk densities approached 1.5 g/cm^3. Soil at the two levels of compaction was placed in the bottom 15-cm of rigid plastic tubes (water pipe) 10 cm in diameter and 25 cm long (hereafter referred to as the "substrate"), by use of a vibrating table (11) and a machine shop drill press with an adapted piston. Measurement of bulk densities with a gamma ray densitometer indicated that uniform compaction was obtained with one gradual compression of the soil in the tube, except for a more compact thin layer at the top and another at the bottom of the soil mass.

To permit contact of the bean roots with soil at the desired levels of compaction, we removed a 5 × 5-cm cylinder of soil from the top center of the packed soil substrate in each large tube and replaced it with a smaller 5-cm (diameter) × 15-cm (long) rigid plastic tube containing four bean seedlings growing in loosely-packed, fumigated soil. The soil surfaces were mulched with sterile sand (2.5 cm deep) (Fig. 1). Each tube assembly was weighed, and when bean plants showed moisture stress, as indicated by darkening of the foliage, water was added to the small tubes to bring the units to the original weight plus estimated plant weights.

Four experiments were conducted, each with four to six replications. In the first, Red Mexican beans (cultivar Bigbend) were grown in a growth chamber at 21 C during 12 hr of light (15,000 lx) and at 16 C during 12 hr of darkness. Roots and tops

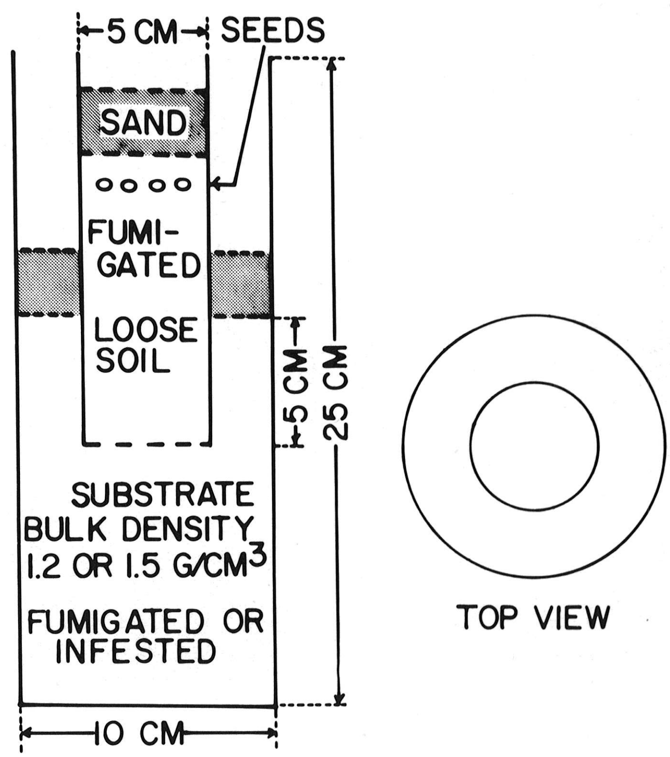

Fig. 1. Diagram of tube assembly used in study of bean root growth in relation to soil compaction and temperature.

were subjected to the same temperatures. Compact and loose substrate conditions were used; soil in one-half of the number of containers with each substrate condition was fumigated and one-half was Fusarium-infested.

In the second experiment, the root growth of two Red Mexican bean cultivars that differ in field tolerance to root rot (Bigbend, moderately tolerant; UI 36, highly susceptible) (4), were compared under the same conditions applied in the first experiment.

The third experiment involved only cultivar Bigbend, grown in the same manner but in temperature tanks providing for all combinations of 21 and 27 C air temperatures and 16 and 21 C soil temperatures.

In the fourth experiment, six bean cultivars differing in resistance to Fusarium root rot were compared under the same conditions applied in experiment 3, except that only Fusarium-infested soil was used in the substrate and it was packed uniformly to 1.5 g/cm^3.

One month after planting in all experiments, the plant tops were cut off at the soil surface and weighed. The undisturbed soil cores were pushed from the large tubes and each one was divided transversely at the bottom of the small tube. Roots within the substrate and those within the small tubes were washed from the soil, blotted on paper towels, and weighed separately. Because of the positively geotropic nature of bean roots (7), nearly all of them were found within or below the small tubes.

RESULTS

In the first two experiments in which roots and tops were exposed to the same diurnal temperatures, soil compaction suppressed root and top growth of both Red Mexican bean cultivars more in Fusarium-infested than in fumigated soil as illustrated in Fig. 3, and more with a 21 C day and a 16 C night than with a 27 C day and a 21 C night. Responses of the two cultivars were nearly alike.

In experiments 3 and 4, with different temperatures for plant tops and roots, results were similar to those obtained in the first two trials, except that the effect of Fusarium root rot was more pronounced (Figs. 3 and 4). The six cultivars differing in field resistance to Fusarium root rot did not differ significantly in rooting within the compact soil, and differences in rooting above the substrate and in top growth could not be correlated with previously observed field performance. Therefore, only average data for all cultivars are presented. Soil temperatures affected root and top growth much more than did air temperatures (Fig. 4). Root growth into the substrate was restricted severely in soil at 16 C. Root growth in loose soil (in the small tubes) above the packed substrate generally was inversely related to the root growth into the substrate.

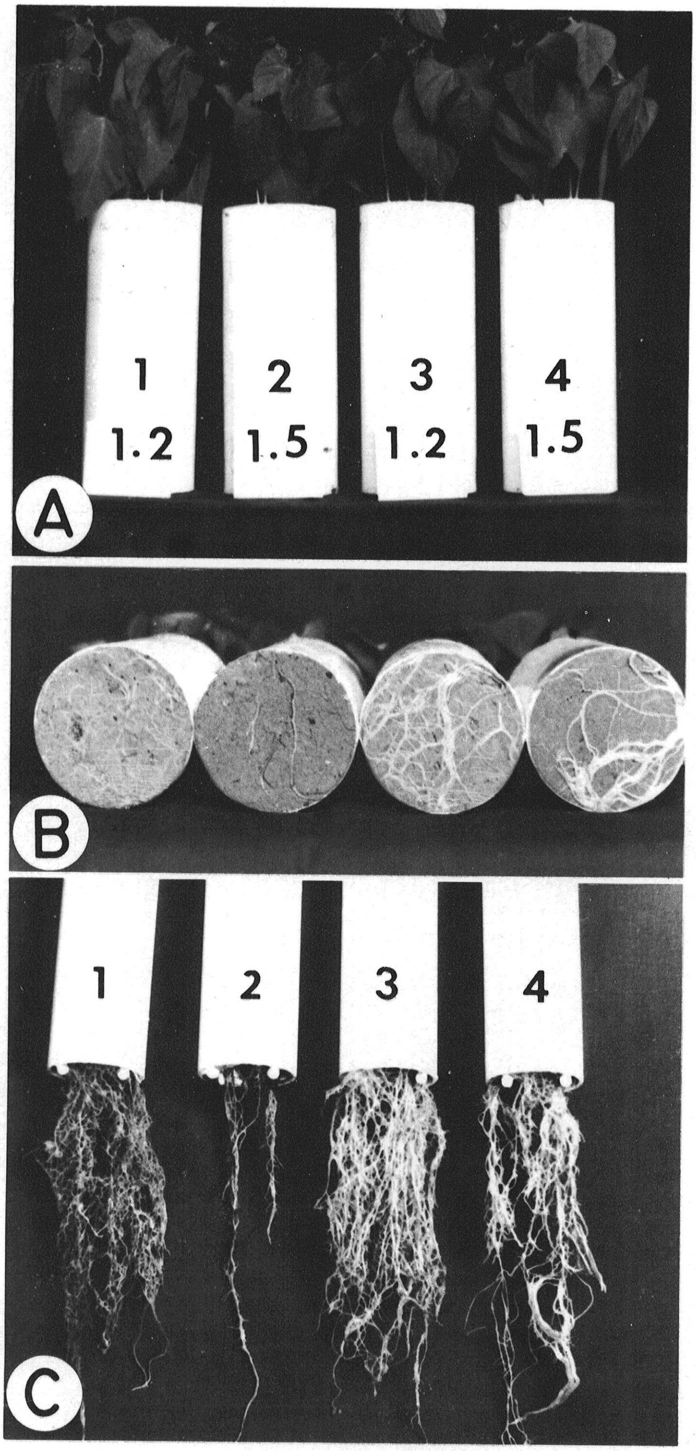

Fig. 2. Plastic tube assemblies with 1-mo-old bean plants: **A**, complete assemblies; **B**, bottoms of substrates, and **C**, small tubes with roots that penetrated into substrates. Substrates were Fusarium-infested soil in units 1 and 2, and fumigated soil in units 3 and 4, which were packed to the indicated bulk densities (g/cm^3).

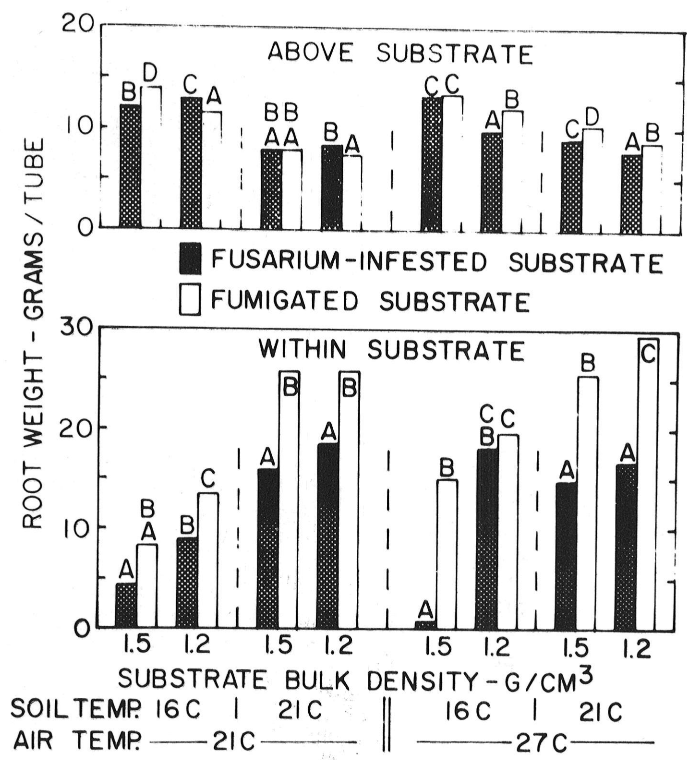

Fig. 3. Effect of air and soil temperatures on root growth of 1-mo-old bean (cultivar Bigbend) plants within and above Fusarium-infested and fumigated soil substrates with two levels of compaction. Bars in each set of four having the same letter at the top are not significantly different, $P = 0.05$.

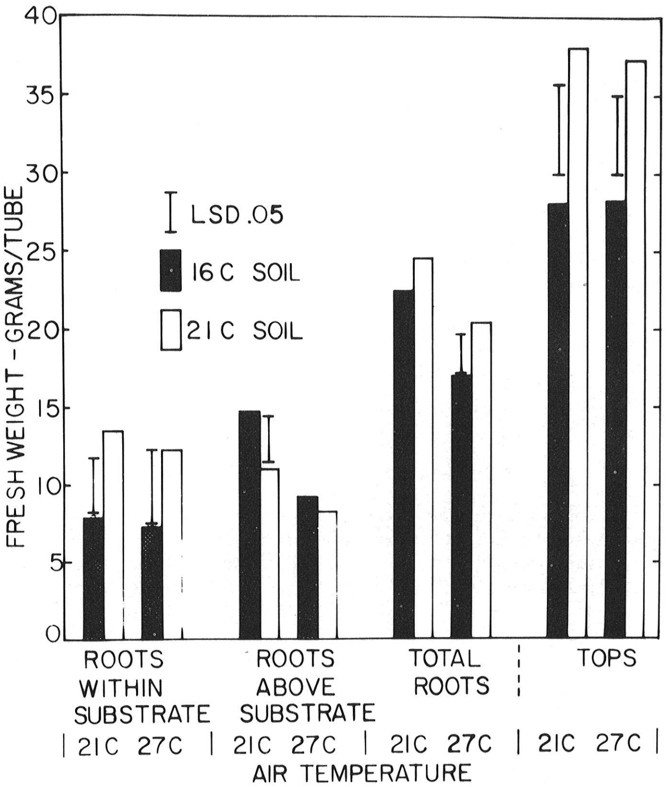

Fig. 4. Effect of air and soil temperatures on the average weight of roots and tops of plants of six bean cultivars grown in tube assemblies containing a compact (1.5 g/cm^3) substrate infested with *Fusarium solani* f. sp. *phaseoli*. Plants were 1 mo old.

DISCUSSION

Like soil water stress (8) and poor aeration (9), less-than-optimal soil temperatures for growth of bean plants reduce the ability of roots to penetrate compact soil and increase the effects of Fusarium root rot. Root growth into loose soil or Fusarium-free soil is less affected by soil temperatures that it is in compact and Fusarium-infested soil.

In the fumigated loosely packed soil in the small tubes above the substrate, root growth tended to be inversely related to root growth in the substrate. This relationship was much less obvious, however, in other (authors' unpublished) experiments in which the small tubes above the substrate contained Fusarium-infested soil. The latter "profile" would more nearly simulate field conditions and possibly would better differentiate rooting abilities of Fusarium-resistant and -susceptible cultivars. This arrangement was not used, however, because of the difficulty of obtaining uniform emergence of plants in the small tubes containing infested soil.

Known differences in root rot resistance among the six cultivars did not seem to be related to their responses to soil compaction or soil temperature, at least during the first month of growth, which is all that was measured in this study.

The activity of other pathogens, such as *Pythium ultimum* Trow, was not ruled out as a factor in the results of these experiments. However, in previous laboratory experiments (9) related to those reported here and employing soil from the same field, fumigated soil reinoculated with *Fusarium solani* f. sp. *phaseoli* gave the same results as naturally infested soil.

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