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# Root Training by Plastic Tubes[1]

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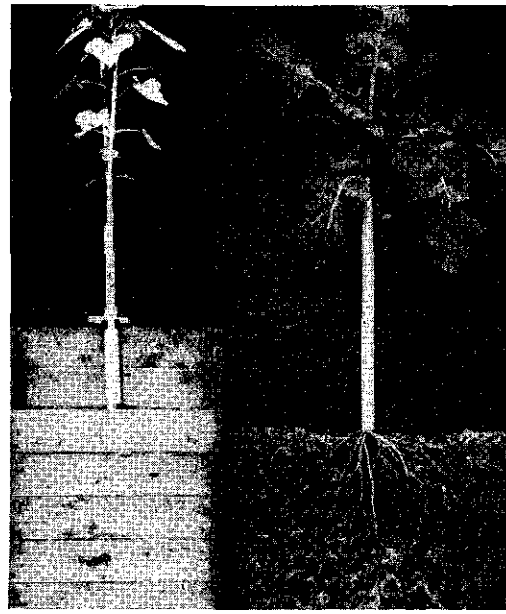
A SOIL, either in natural condition, normally or deeply tilled, has layers or horizons that differ in nutrients, water, oxygen, and availability to roots.[2] Just how much can each horizon contribute to plant growth? To answer this one must learn the potential ability of each soil horizon to supply nutrients, water, and oxygen under vigorous and continuous extraction by the plant. This appraisal of the deeper horizons, for example, will reveal the potential benefit of the costly deep-tillage and associated soil management practices, or the significance of natural or infiltrated supplies of plant nutrients in the subsoil. Clearly the exposure of a horizon to roots does not reveal its "potential" unless the root system is excluded from other horizons. Furthermore, the potential productivity of each horizon must be determined for each of the important groups of plants.

The simple technique described herein trains the roots through narrow plastic tubes to certain soil depths at which they fan out from the lower end of the tube. In this way the roots are required to obtain nutrients, water and oxygen from lower soil horizons by being excluded from other horizons above. Thus the maximum possible utilization of the different horizons *in situ* can be measured in terms of the growth of the plant shoot and its nutrient content. This *in situ* potential of the different soil horizons is not only determined by the extent of soil utilization by the plant,[3] but also by the possibility of permeation of such horizons by the roots. Finally, the maximum potential of the horizon can be defined in terms of the plant grown upon the same soil in pots and under the conditions of optimum soil looseness, supply of water and oxygen; this maximum potential should be more indicative of the nutrient potential of these soil horizons. A brief exploration of the technique follows.

The plastic tubes were rigid, translucent and had inside diameters of 2.5 and 4 cm. They were filled with rooting media while being tamped gently. The media were soil-peat-sand mixtures: the soil was greenhouse compost soil, which contributed fertility to the mix; the peat was sphagnum peat moss, which provided an open-structured, water-holding medium; the sand was loose, coarse sand.

Seeds or young seedlings of tomato, rape, bean, sunflower, corn and oat were planted in the easily-penetrable media that filled the tubes.

Trials with different media showed that a mix of 1 volume soil, 1 volume peat, and 1, 2, 3 or 4 volumes sand served the purpose well. The goal was to cause the roots to grow through the tubes as fast as possible and at a low level of fertility. Clearly a low nutrient supply in these tubes would mean that the response of the plant was a better indication of the nutritional condition of the soil in the horizons to which the roots were being trained; and this, after all, was one of the things to be measured. A convenient way of supplying water to the roots was to moisten the mix sufficiently before filling the tubes with it. The small amount of evaporation at both ends of the tube was eliminated by setting the tubes in wet sand and by covering the top openings.



(Left) Figure 1—Sunflower plant grown on a block of soil of 70 × 60 × 18 cm. for 8 weeks. The plant was started in the greenhouse in a 60 × 2.5 cm. plastic tube.

(Right) Figure 2—Mature rape plant on a pin-board. The roots grew through a 60 × 2.5 cm. plastic tube into a 40 × 60 × 18 cm. soil monolith.

All plants were started in the greenhouse, the tubes standing upright in glass jars or, more often, in pots filled with moist sand. The bottom ends were covered with a single layer of cheesecloth held in place with an elastic band.

Within 19 days after they were seeded in the tubes, roots of rape, *Brassica Napus* (L.), *var. Pabularia,* and a maize plant, Zea Mays, passed through tubes that were 60 cm. long, 2.5 cm. in diameter, and filled with a 1:1:1 mix. Fourteen days after germination or 8 days after transplanting, sunflower, *Helianthus annuus,* protruded its first root from the bottom end of the tube.

As soon as roots appeared at the bottom openings of the tubes, some plants and tubes were transferred to wooden boxes for studies of roots. These boxes, 100 × 60 × 18 cm., were standing in the open and partially filled with a medium textured sandy loam, composed of a mixture of sandy and loamy soils. The tubes with the plants were set upright on the block of soil in the box, with the tube inserted 1 to 2 cm. into the soil (Figure 1). A rape plant was transferred to such a box filled with 40 × 60 × 18 cm. of soil. Fifty days after transfer the rape plant was full grown. To study the character, amount, and distribution of roots within the soil monolith, the boards on the front of the box were removed and replaced by a pinboard with needles 15 cm. long.[4] Before inserting the pinboard, however, any mat of roots on the interface between soil and boards was scraped away. After inserting the pins, plant and box were tipped and rested on the pinboard. Then the box was removed and the other faces of the soil monolith were scraped if necessary. When the soil was carefully washed from the roots, a strongly-branched, fine, fibrous root system, which is normal for rape, was freed (Figure 2). The root

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[1] Contribution from The Connecticut Agr. Exp. Sta., New Haven, and Institute for Soil Fertility, Groningen, Netherlands. Received Nov. 12, 1962. Work done during sabbatic leave of senior author at the Institute for Soil Fertility.

[2] De Roo, H. C. Deep tillage and root growth. Connecticut Agr. Exp. Sta. Bul. 644. 1961.

[3] Wiersum, L. K. Utilization of soil by the plant root system. Plant and Soil 15:189–191. 1961.

[4] Schuurman, J. J., and Goedewaagen, M. A. J. A new method for the simultaneous preservation of profiles and root systems. Plant and Soil 6(4):373–381. 1955.

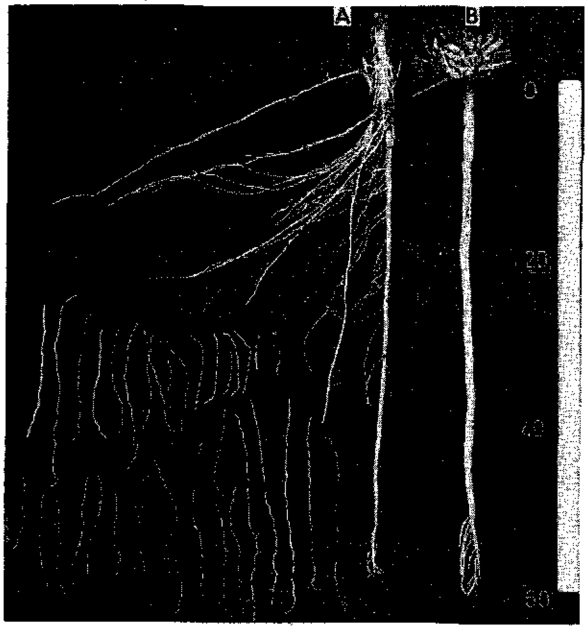


Figure 3—Enlarged tap roots grown in the plastic tubes. A: roots of the sunflower plant of Figure 1. B: the thickened, prominent taproot of the rape plant of Figure 2. Removal of these roots from the tubes was difficult; the finer branches of the rape root were lost, while the detached ends and branches of the main laterals of the sunflower were laid out for the photograph.

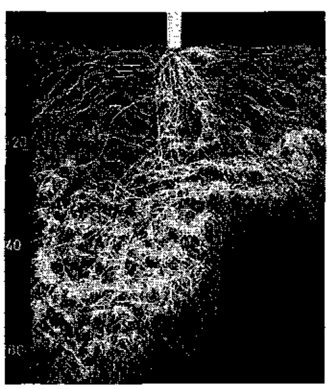

Figure 4—Root system of a 3-months-old sunflower. The roots grew through a 60 × 2.5 cm. tube into a 70 × 60 × 18 cm. soil monolith.

system permeated the whole soil mass in the box. The large laterals protruding from the tube grew mainly vertically or obliquely downward, showing little lateral spread. The absence of widely spreading main laterals is natural for this species, which has a pronounced taproot; some of their branches or secondary laterals, however, spread horizontally along the soil surface.

The roots developed in the plastic tubes were also investigated. Generally the media in the tubes were sufficiently porous and loose to permit unhindered root growth and thickening, although sometimes it was difficult to remove a root crown or greatly enlarged taproot from the narrow tubes without damaging it or detaching some of the finer laterals (Figure 3). The taproots of the sunflower and rape plants shown in Figures 1 and 2 were remarkably enlarged and tapered slowly within the tubes, as shown in Figure 3. Over the last 10 cm. of tubing, however, these taproots tapered rapidly, giving off large branches. Figure 4 shows that these large branches and other laterals of the sunflower taproot fanned out from the tube, running not only straight downwards into the 70 × 60 × 18 cm. monolith of soil, but also obliquely and horizontally, parallel with the soil surface. These roots branched and rebranched profusely, forming a dense network in the root box. Although the sunflower has a definite taproot system, it is known for its large and numerous laterals, often 30 to 45, and its wide lateral spread.[5] Again, as with the rape plant, the root habits of the sunflower were not markedly modified by the tubing; beyond the tube the plant developed the same profuse root network for which this species is known (Figure 4).


Figure 5—A: The shoot of a 3-month-old corn plant. It was cut from its root system flush with upper end of tube. Some short aerial or brace roots had grown over the edge and outside of the tube. B: Washed root system with tube removed.

The next subject was the effects of the tubing on the root habits of cereals. In spite of the cold and wet summer, corn developed well, standing on the top of a 60 × 2.5 cm. tube, filled with a 1:1:1 mix in which the corn was seeded (Figure 5). Under natural conditions corn has a coarse, fibrous root system which spreads widely and penetrates deeply.[5] The main lateral root system and its branches protruding from the tube were washed from a 80 × 60 × 18 cm. soil monolith and showed a pattern that was normal for corn. Within the 2.5-cm.-diameter tube 28 roots were counted, tangled closely, but not difficult to remove from the tube (Figure 6). Again this number is normal for the number of roots of maturing corn plants has been found to be 20 to 35.[5] Most of these roots are covered with short branches. Only the succulent ends of the younger, rapidly growing roots were free from branches. A few of these younger roots were brace roots, which penetrated and grew through the tube.

The behavior of oat roots in the field was studied. Earlier, oats grown in tubes and pots of soil had revealed

[5] Weaver, J. E. Root development of field crops. McGraw–Hill Book Co., Inc., New York. 1926.

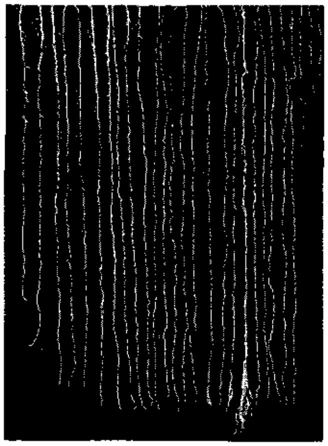

Figure 6—Corn roots which grew within the 60 × 2.5 cm. tube (Figure 5B). The roots were disentangled and spread.

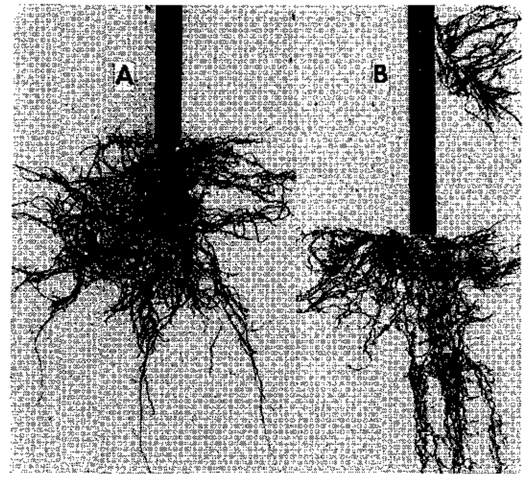


Figure 7—The root systems of oat plants grown through 2.5 cm. diameter tubes inserted into a soil in the field. The plowlayer was 25 cm. deep and underlain by a pan. The system in A had grown through a tube 15 cm. long, that in B through one 25 cm. long. Note the one root that slipped over the top of tube B and grew into the surface soil.

no remarkable effect of different tube lengths and widths on the number and characteristics of the roots in the tubes. The oats destined for the field were seeded in tubes filled with a 1:1:4 mix; within 9 days the first roots were protruding from the 15 × 2.5 cm. and within 13 days from the 25 × 2.5 cm. tubes. Fourteen days after seeding a few of these plants were moved to the field. The soil was an old arable-land soil, consisting of a black, humic, fine sandy profile, 80 to 90 cm. deep and containing 5.2% organic matter.[6] The field has been plowed to a depth of 25 cm., for about 20 years. This plow layer was underlain by a distinct plowsole pan. The pan was tinted grey by bleached sand while the plow layer was dark grey-brown. The 15- and 25-cm. tubes that held the young oat plants were inserted into this soil through auger holes in which the tubes fitted closely; the upper edges of the tubes were level with the adjacent soil surface. Almost 10 weeks after seeding, and after the 2 to 4 tillers of the shoots were cut off, the distribution of the roots throughout the soil profile was determined by the pin-board method. The root profiles demonstrated that in general the lateral spread of the roots was moderate, which, however, is normal for oat. The roots, upon leaving the tubes, generally did not grow upward into the soil profile (Figures 7A and B).

The absence of an upward bending of the roots was particularly remarkable from the plants grown through the 25-cm. tubes (Figure 7B). As is clear from our short profile description, these tubes nearly stood on the plowsole pan, a soil layer more compact and presumably less fertile than the plowlayer. Nevertheless the roots grew into the pan rather than upward into the plowlayer. Although the pan was easy to see and feel, its pore space was apparently not reduced to the extent of severely blocking the penetration of the oat roots. This is not surprising, for van Lieshout[6] has analyzed this pan and found 43.3% pore space.

In conclusion then, this work[7] indicates that this new and simple technique might be a useful procedure for introducing plant roots into selected soil layers.—H. C. De Roo *and* L. K. Wiersum, *Soil Scientist and Plant Physiologist, respectively. The Connecticut Agricultural Experiment Station, New Haven, Connecticut, U.S.A., and Institute for Soil Fertility, Groningen, Netherlands.*

[6] van Lieshout, J. W. Effect of soil conditions on development and activity of the root system. Versl. Landbouwk. Onderz. 66.18, 1960.