Aeration conditions, as measured by the platinum microelectrode technique, were less favorable in compacted soil layers than conditions known to limit root growth in noncompacted soil. However, reduced root penetration and top growth of tomatoes grown above these compacted layers could not be blamed upon either the high physical resistance to root penetration or poor aeration, individually, because both factors were simultaneously present in the compacted soil layers.

SOIL ON OXYGEN AND

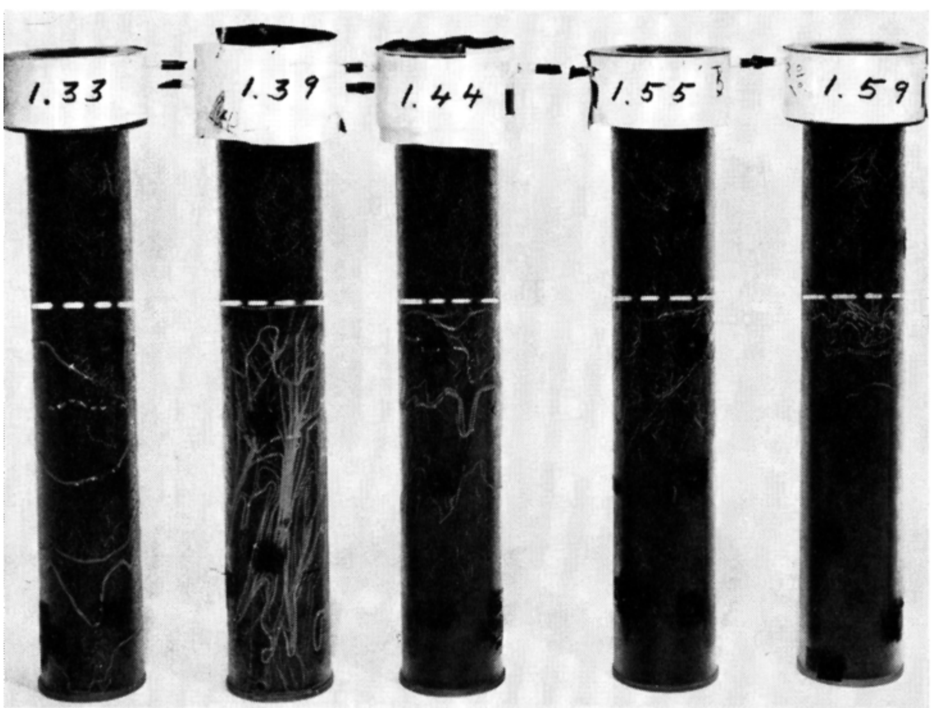
LAYERS OF COMPACT, high bulk density soil are often found in the field. These layers may be inherent in the soil profile or created by mechanical operations. Plants growing on such soils are often restricted in production, because of poor root development. Poor root growth may be the result of high mechanical impedance which the root faces in trying to penetrate the compact layers. Another factor which could restrict root growth is inadequate aeration in the compacted layer. This condition may be present particularly when considerable water is added, either through irrigation or precipitation. Water movement through the layer is slow and much water can be retained by the small pores.

Platinum electrode

It has been difficult to establish whether poor root growth results from high mechanical impedance, or poor aeration. This difficulty resulted mostly from the lack of a meaningful method of measuring soil aeration in terms of root growth, but now has been alleviated by the platinum microelectrode technique for measuring oxygen diffusion rates in soils.

The platinum electrode measures the rate at which oxygen diffuses to the wire electrode. This rate is related to the amount of oxygen diffusion to a plant root in the same position in the soil. No consideration is needed regarding either the unknown local variation of oxygen content of gas in the soil, or the further complicating local variation of compaction. The measurement made by the electrode shows the rate at which oxygen has traveled through the soil system, however varied it may be, to the electrode surface.

Controlled aeration experiments on several plant species have shown that whenever the passage of oxygen through the



Tomato root distribution in cylinders with soil layers compacted to bulk densities marked on each cylinder. White dashed line locates the compacted layer surfaces.

AVERAGE OXYGEN DIFFUSION RATE VALUES THROUGHOUT VARIOUS CYLINDERS IN SOIL COMPACTION—PLANT GROWTH STUDIES

Bulk Densities (gm/cc)				
1.33	1.39	1.44	1.55	1.59
Oxygen Diffusion Rates (μgm cm^{-2} min^{-1})				
.50	.44	.47	.47	.52
.34	.51	.42	.55	.61
.43	.45	.48	.52	.66
.40	.52	.47	.65	.81
------ level of compacted layer surface ------				
.35	.43	.24	.28	.26 **
.27	.22	.15	.13	.09
.33	.34	.21	.14 **	.05
.28	.25	.18 **	.10	.09
.22	.33	.10	.13	.19
.28 **	.39 **	.05	.06	.10
level of container bottom				

** Location of roots after 6 weeks.

COMPACTION EFFECTS DIFFUSION RATES PLANT GROWTH

R. W. RICKMAN
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soil water films (oxygen diffusion rate, O.D.R.) as measured by the platinum electrode falls below a value of .20μgm cm^{-2} min^{-1}, root growth is greatly retarded or stopped for many species. These experiments were conducted in loosely compacted soils so that root restriction was due to insufficient oxygen and not due to mechanical impedance.

Since the O.D.R. that is limiting to root growth in low compaction soils has been established, measurements in compacted soils will indicate whether the O.D.R. is low enough to restrict root growth in compacted soils. Where values greater than .20 μgm cm^{-2} min^{-1} are measured, but roots have not yet penetrated the soil, mechanical impedance is evidently restricting root growth. With this in mind, an experiment was conducted to determine the effect of layers compacted to various bulk densities on plant growth and to distinguish between mechanical impedance and low oxygen supply as the causative factor in poor root growth.

Test cylinders

Tomato seedlings of the Rutgers variety were grown in plexiglass cylinders 6.7 cm in diameter and 42 cm long. Krilium-treated Yolo silt loam, passed through a 1 mm screen, was packed to the desired density into each container by repeatedly dropping filled containers onto a padded block. The upper 12 cm (5 inches) of each container was filled with soil compacted to a bulk density of approximately 1.3 g/cc to provide a common loose top layer of soil for root establishment.

Containers were wetted to the bottom and allowed to stand three days before the seedlings were planted. Periodically, each cylinder was brought back to its original weight with nutrient solution. Small holes in the sides of the cylinders were sealed with black plastic electrical tape and each container was wrapped with black plastic sheeting to exclude light from the tomato roots.

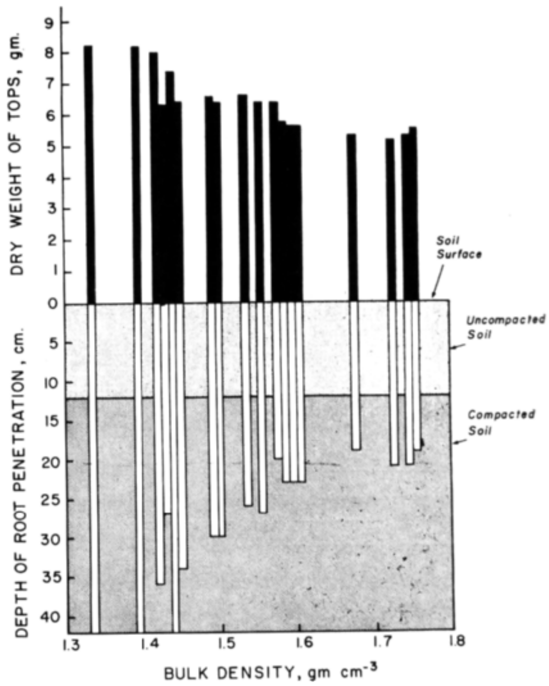
Timing

Four times during the experiment, electrodes were inserted through the electrical tape in 10 positions along each cylinder, and O.D.R. readings were taken. Timing of readings following irrigations is quite important. In wet soils, water films are thick, and O.D.R. values are naturally low. As the soil dries and water films become thin, O.D.R. values may or may not increase. In soil with large pores where water films fill only a small percentage of the pore space, O.D.R. will increase as the soil dries. In compacted soils, however, even the thin water films fill a large amount of the pore space and the O.D.R. can remain low. If O.D.R. values do remain low for an appreciable time following irrigations, the oxygen supply must be considered one of the factors retarding plant growth.

The growth of plant tops and roots in containers having layers of various bulk densities is shown in the graph. As can be noted, increasing the bulk density caused a decrease in both top and root growth.

Five containers are shown in the photograph to illustrate the appearance of the root growth. Roots in the columns more dense than 1.6 g/cc were similar to the 1.59 g/cc container photographed. The centers of the soil columns were found to have root penetration inside that was very similar to the roots visible through the container walls. The root growth above the compacted layer was similar for all treatments. On the roots in soil compacted to a bulk density of 1.39 g/cc, it was observed that the resistance to root growth was apparently less between the soil and the container wall than

Top and root growth of tomatoes grown in soils with layers compacted to various bulk densities.



within the soil, because once a root arrived at the container wall, it grew along the wall and was flattened.

Growth effects

As the plants grew larger and used more water, the presence of the highly compacted layers became more detrimental. After each irrigation, a water table tended to form above the compacted layers and persisted for a short time, depending on the size of the irrigation, and the dryness of the compacted layer. Root tips submerged for long periods in this water table were observed to die back, and many branch roots would form from the sides of the original root after the water had moved into the compacted layer. Whenever some root tips did die, water consumption by the plant decreased and overall plant vigor appeared poor until the new branch roots developed.

Was the restricted root penetration due to mechanical impedance or low oxygen supply? The average O.D.R. values for the cylinders photographed are presented in the table along with the depths of root penetration at termination of the experiment. The O.D.R. values in the upper low-compaction part of the containers were about the same in each container. However, O.D.R. values in the compacted layers were generally lower as soil compaction increased. The O.D.R. values in the compacted layers were lower than those which would allow root growth in uncompacted soil. In general, there was fairly good agreement between depth of penetration and O.D.R. indicating that, in this experiment, low aeration was sufficient to restrict root growth in the compacted layers. Mechanical impedance may well have been an additional factor slowing root growth, but the low soil aeration would have been sufficient to restrict roots even if mechanical impedance had not been a factor.

Interaction

Since no high O.D.R. values were measured in areas where roots were not growing, the effect of mechanical impedance alone could not be detected. Other experiments where O.D.R. values were artificially increased in compacted layers have been conducted to get a clearer picture of the interaction of mechanical impedance and soil aeration on root growth.

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Sprays for Aphid Control Increase Sugar Beet Yields in Davis Tests

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For the third consecutive year, sprays for aphid control applied to sugar beets planted at Davis, decreased yellows virus infection and substantially increased root production. Three sprays applied to beets planted in March, April or May, 1964, resulted in yield increases of 6, 9 and 5 tons per acre respectively.

SUGAR BEETS were planted March 1, April 1 and May 1, 1964, for these studies. At each planting date, some beets were sprayed a limited number of times; some were sprayed more frequently to provide protection from the time of emergence until aphid flights had ceased, and others were left unsprayed.

The spray schedules were as follows:

Planting dates	Dates of spray application							
	April			May				
	3	17	24	1	8	15	22	29
3/1	x	x		x				
3/1	x	x	x	x	x	x	x	x
4/1		x		x		x		
4/1		x	x	x	x	x	x	x
5/1						x		
5/1						x	x	x

The spray material used was Metasystox-R (0, 0, dimethyl S-2-(ethylsulfinyl) ethyl phosphorothioate) at 12 ounces in 40 gallons of water per acre, applied with a back-sprayer. This material has federal approval for use on sugar beets in the nation, but the current registration allows for only two applications, each at ½ pound per acre. An application may not be made later than 30 days prior to harvest, and tops may not be fed to dairy or meat animals. The recommendation of Metasystox-R as an aphicide by the University is pending a review of residue and performance data.

The effectiveness of the spray treatments was evaluated by disease counts and by yield data. In contrast to results for 1963 (as reported in *California Agriculture*, May 1964), yield increases resulted from three spray applications applied to beets planted in March and April. These three spray applications increased root yields about as much as the more extensive spray schedules (table 1). In 1963, three sprays applied to March- and April-planted beets increased yields only slightly. The improvement in effectiveness of limited sprays in 1964 could have resulted from the fewer numbers of winged aphids and the sharp peak of their flights, as indicated in the graph.

Yellows infection

Yellows infection was high for non-sprayed beets planted March 1 and April 1, but root yields were appreciably higher —about 5 tons per acre more than for beets planted on comparable dates of the previous two years. Improved production from the early planted beets could have resulted in part from a lower incidence