Proceedings of the
AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE
1943 42:39-45

Solid, Liquid, Gaseous Phase Relationships of Soils on Which Avocado Trees Have Declined

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In the main, the commercial avocado industry of California has developed during the last 25 years in the mild temperature of the coastal region of Southern California. In seeking favorable climatic conditions the developers of avocado orchards have often overlooked undesirable soil conditions, for unfortunately many of the soils in which avocado trees were planted are shallow, heavy textured, and poorly drained. As most of the area planted to avocados had not previously been under irrigation, these undesirable features had not been particularly noted.

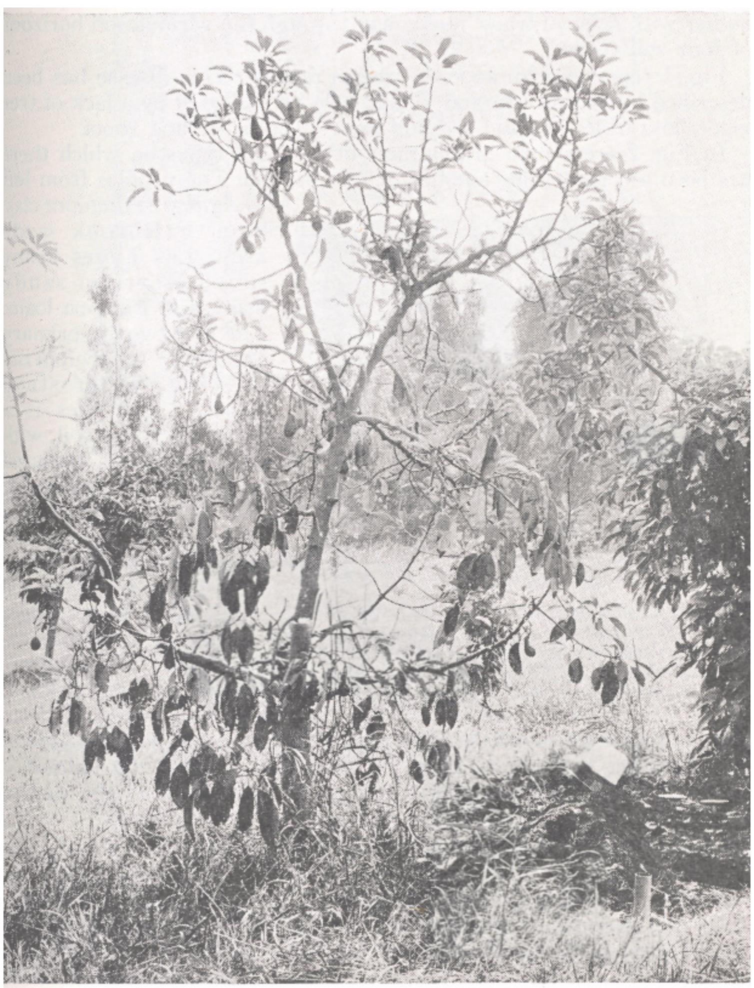

FIG. 1. A declining avocado tree at the spot near top of hill, Ramona loam soil. Sampling location shown at right. Note cover crop.

It is a common belief, and field observations made by us during 1936-37 indicate that the avocado tree decline disease is normally associated with poor drainage conditions (3, 4). The data herein presented express the solid, liquid, gaseous phase relationships, together with rates of water movement through the various soil horizons of four soil types.

Fig. 1 represents an avocado tree in decline. This disease has been described by Home (3) and Wager (9) as indicated by a lack of tree vigor, loss of leaves, and a dying back of branches and roots.

In Fig. 2 are shown profile monoliths of soil types on which there has been a considerable amount of tree decline. The profiles from left to right are Altamont clay loam, Fallbrook sandy loam, Las Flores loamy sand, Merriam sandy loam, and Ramona loam. The first two are primary (residual) soils, often occupying rather steep slopes. Las Flores is a marine terrace soil with a loamy sand textured surface and a dense clay pan subsoil overlying a consolidated substratum. At one time avocado trees were planted on this soil type, but it is no longer considered a suitable orchard soil. The Merriam soil is a light reddish-brown soil derived from igneous rock high in quartz. The subsoil is very dense, and calcareous. The Ramona soil differs from the Merriam in that the subsoil is slightly less compact, and the reaction is neutral both in the surface and subsoil.

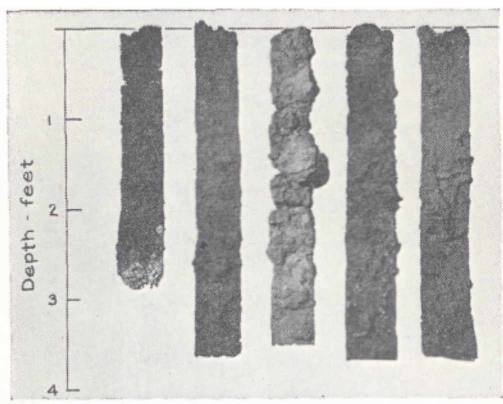

Fig. 2. Profile monoliths of several soils on which avocados have been planted. L to R: Altamont clay loam, Fallbrook fine sandy loam, Las Flores loamy sand, Merriam sandy loam, and Ramona loam.

Characteristics of the last four soils are indicated in Table I. The apparent density of the subsoils (B. horizon) is high in all soil types. This is an important factor in the passage of water through the soils. Field and laboratory permeability measurement on four soil types are reported in Table II. Differences in permeability of the surface and subsoils of the Fallbrook series, while not especially wide, were more pronounced in the in situ field tests than on undisturbed laboratory-samples 2 inches in diameter and about 1% inches in thickness.

TABLE I—Soil Characteristics

Soil and Location	Texture of Sample	Hori-zon	Depth Sample (Inches)	Real Density $\left(\frac{Gms}{Cm3}\right)$	Apparent $\left(\frac{Gms}{Cm3}\right)$ Density of		Mois-ture Equiva-lent	Soil-Water pH (1:2 Suspen-sion)	Mechanical Analysis					
									Wet Sieve Method (Per Cent)		Hydrometer Method (Per Cent)			
					Moist Soil	Air-Dry Clods			<2.362 (Mm)	<1.651 (Mm)	<1.168 (Mm)	<0.05 (Mm)	<0.005 (Mm)	<0.002 (Mm)
Fallbrook...... (Ridge)	Fine sandy loam	A	1	—	1.16	—	—	—	—	—	—	—	—	—
	Fine sandy loam	A	2	2.55	1.26	—	16.7	7.4	99.2	97.8	95.4	38.0	14.1	11.1
	Fine sandy loam	A	4	—	1.36	—	—	—	—	—	—	—	—	—
	Very fine sandy loam	B	14	2.69	1.52	—	19.4	7.8	99.8	99.2	98.5	49.5	25.0	19.7
Fallbrook...... (Swale)	Fine sandy loam	A	1	—	1.36	—	14.8	7.2	99.1	97.6	95.2	42.9	15.6	13.1
	Fine sandy loam	A	10	—	1.53	—	13.4	7.2	—	—	—	—	—	—
	Very fine sandy loam	B	16	—	1.67	—	16.6	—	98.1	95.4	90.0	43.8	20.4	17.9
Las Flores..... (Side hill)	Loamy fine sand	A	0	2.58	1.45	1.63	6.5	6.2	100.0	99.9	99.9	23.6	8.7	5.2
	Very fine sandy loam	B	6	2.63	1.50	1.81	20.8	8.0	100.0	100.0	100.0	34.0	20.0	17.8
Merriam...... Bottom of hill)	Fine sandy loam	A	0	—	1.44	—	11.6	6.0	99.9	99.3	97.0	33.0	9.2	7.5
	Fine sandy loam	A	8	2.61	1.48	—	10.9	6.4	99.9	99.1	96.7	35.6	9.0	8.5
	Clay loam	B	20	2.67	1.64	1.92	25.3	7.4	100.0	100.0	99.9	58.0	42.7	40.6
Ramona....... (Top of hill)	Loam	A	0	—	1.28	—	18.4	—	—	—	—	—	—	—
	Loam	A	4	—	1.40	—	19.4	—	—	—	—	—	—	—
	Clay loam	B	12	—	1.48	1.87	24.9	—	—	—	—	—	—	—
Ramona....... (Side hill)	Loam	A	0	2.50	1.25	—	17.6	7.7	97.6	95.9	92.5	52.3	16.9	14.4
	Clay loam	B	18	2.61	1.47	—	24.0	7.7	99.2	98.1	96.3	67.9	43.7	38.9

TABLE II—PERMEABILITY MEASUREMENTS OF THE VARIOUS SOILS

Soil and Location	Horizon	Depth of Sample (Inches)	Field Infiltration Capacity Rate (Inches Per Hour)		Laboratory Permeability Rates‡ (Inches Per Hour)	
			Range	Average	Range	Average
Fallbrook*	A	1	—	5.9	—	11.2
	A	2	—	—	30.6–36.0	33.3
(Ridge)	A	4	—	—	—	33.0
	B	14	0.2–3.0	1.9	4.0–16.4	10.2
Fallbrook*	A	1	8.4–24.4	16.4	—	—
	A	10	—	—	0.8–1.3	1.1
(Swale)	B	16	1.3–7.7	4.5	0.5–3.5	2.0
Las Flores†	A	0	8.1–10.1	9.1	39.5–54.1	46.8
(Side hill)	B	6	0.1–0.3	0.2	0.2–0.3	0.3
Merriam†	A	0	—	119.0	4.9–39.1	22.0
(Bottom of hill)	A	8	—	—	1.8–1.8	1.8
	B	20	0.1–0.3	0.2	0–0.01	0.004
Ramona*	A	0	0.9–43.6	11.4	6.2–20.2	13.2
(Top of hill)	A	4	—	—	45.0–82.0	63.0
	B	12	0–0.2	0.1	0.2–4.5	1.7
Ramona*	A	0	—	22.8	45.0–68.0	58.0
(Side hill)	B	18	—	0.1	0.1–0.3	0.2
Altamont		—	—	—	—	—

*Soil moist when field infiltration rates measured.
†Soil dry when field infiltration rates measured.
‡Undisturbed samples saturated from bottom for 24 hours, and permeability determined with distilled water under head of 25 centimeters, during third hour of run. Samples were 1½ inches deep and 2 inches in diameter.

The granitic bedrock, which was immediately below the B horizon, was undoubtedly a factor in the field test but not in the laboratory tests. The surface Las Flores soil, as shown by field test, is about 45 times more permeable than the subsoil, while for the laboratory test the ratio is about 160 to 1. Comparable ratios for the Merriam soil are: 600: 1 and 5500: 1, and for the Ramona clay loam 230: 1 and 290:1. Such differences in permeability clearly indicate the probability of producing a water table immediately above the B horizon following the addition of water, either as rain or as an irrigation, in amounts in excess of that required to wet the soil to field capacity. With primary soils on steep slopes there is always the possibility of having water move down hill above the bed rock. Where no interrupting drains are present the seepage of water through the soil occupied by plant roots might continue for considerable periods. Not only is the soil in which the water table is present deficient in opportunity for aeration, but also the soil within the range of capillary rises is affected. This is clearly indicated by the data presented in Table III and Fig. 3.

Field observation indicates that unusually high amounts of organic matter on the ground surface are the rule in our avocado plantings. In the younger orchards permanent cover crops are common, and in the large, well shaded, orchards the ground is generally covered with a thick mat of leaves and twigs from the trees. Disregarding any other effects of such organic matter, it at least should accentuate the difficulty by increasing the permeability of the A horizon without a comparable increase in the permeability of the B horizon.

TABLE III—AVERAGE MACROPOROSITY AND MOISTURE CONTENT BY VOLUME AT VARIOUS TENSIONS

Soil and Location	Horizon and Depth (Inches)	Number of Observations	Average Macroporosity and Standard Error	Average Moisture Content of Soil (Per Cent by Volume)								
				pF 0	pF 0.50	pF 1.00	pF 1.20	pF 1.40	pF 1.60	pF 1.80	pF 1.90	pF 1.95
Fallbrook (Ridge)	A– 1	1	20.0	58.8	52.4	50.2	48.1	44.9	38.8	31.7	29.9	28.8
	A– 2	2	22.7 ±6.4	55.8	48.2	43.3	39.8	35.8	33.2	29.6	28.8	28.0
	A– 4	1	16.5	44.2	42.4	36.9	34.6	32.6	27.7	27.0	25.8	24.8
	B–14	4	8.1 ±0.8	38.8	36.5	35.9	34.5	32.9	30.7	28.4	27.4	26.8
Fallbrook (Swale)	A– 1	2	17.2 ±1.0	55.4	49.8	47.4	45.8	43.1	38.2	31.4	29.6	28.2
	A–10	2	15.3 ±0.5	44.8	40.6	38.4	37.1	34.0	29.5	25.0	23.2	22.1
	B–16	4	7.3 ±0.4	34.8	32.4	32.2	31.2	29.7	27.5	25.6	24.5	23.8
Las Flores (Side hill)	A– 0	4	13.4 ±1.3	48.8	44.3	42.8	41.9	40.4	35.4	25.8	22.8	21.2
	B– 6	4	4.1 ±0.7	38.9	38.2	38.0	37.2	36.4	34.8	31.8	31.1	30.4
Merriam (Bottom hill)	A– 0	2	16.5 ±1.0	47.8	45.4	42.2	40.8	36.2	31.3	26.6	24.4	23.5
	A– 8	2	13.0 ±5.6	43.8	39.0	37.8	36.2	33.3	30.8	26.9	24.9	23.6
	B–18	2	7.5 ±0.2	42.5	40.8	40.4	39.1	37.1	35.0	32.0	31.5	31.0
	B–20	2	2.0 ±0.5	35.0	35.0	35.0	34.9	33.8	33.0	32.0	31.7	31.3
Ramona (Top hill)	A– 0	2	15.4 ±6.4	48.5	41.0	37.8	36.2	34.6	33.2	31.0	—	—
	A– 4	2	9.2 ±0.8	41.2	39.1	36.7	34.8	33.5	32.0	30.2	—	—
	B–12	4	3.7 ±0.3	39.8	38.9	37.9	37.0	36.6	36.2	35.2	—	—
Ramona (Side hill)	A– 0	4	12.0 ±1.4	44.4	39.4	36.8	34.7	33.6	32.4	30.9	—	—
	B–18	4	5.0 ±0.6	41.8	39.2	38.4	37.6	37.4	36.8	36.2	—	—

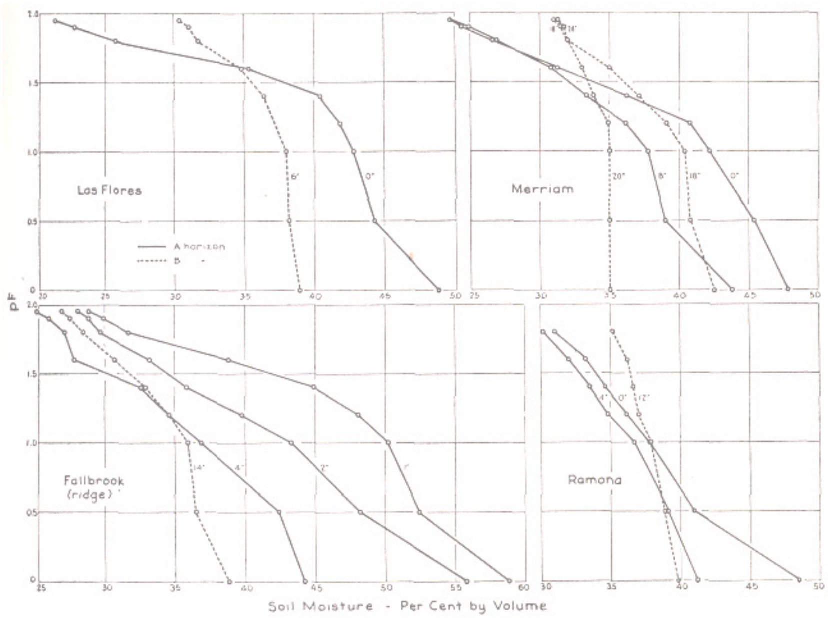

FIG. 3. Moisture — pF relationships.

Soil permeability has been related to the so-called "non-capillary" porosity by Baver (1) and Nelson and Baver (7). Since such "non-capillary" porosity is largely within the range of moisture contents accompanying capillary rise, the terms "macro pores" and "macroporosity" as suggested by Jamison (5) appear preferable and are used herein. The macro pores are essentially the larger pores between soil aggregates or particles which drain most readily, and are evaluated herein by investigating the equilibrium moisture retained in a soil under various increases in soil-moisture tension. The term pF proposed by Schofield (8) is used to express such tension. Macroporosity is herein defined as the per cent moisture by volume drained from a soil between pF 0 and pF 1.6, the volume of the soil as pF 1.6 being the basis. Selection of pF 1.6 is based on the work of Nelson and Baver (7), and substantiated by Baver and Farnsworth (2) and Jamison (5). Actually, permeability is an exponential function of the pore size, as shown by Nelson and Baver (7) so macroporosity, as here defined, cannot be perfectly correlated with the permeability of all soils. Shown in Table III are the macroporosity determinations for each soil, as well as the moisture by volume for the various pF values investigated. Comparison of Tables II and III will show the correlation between permeability and macroporosity.

For both the investigations of laboratory infiltration rates and moisture -pF relationships, undisturbed cores of soil were obtained in the field and brought to the laboratory without permitting them to dry out. They were 2 inches in diameter and 11/2 inches deep. The samples were immediately wet from the bottom and left for 24 hours to saturate all readily available pore space. For the moisture -pF relationships an apparatus as described by Learner and Shaw (6) was used.

CONCLUSIONS

Studies of some soils in which avocado trees have declined indicate well defined horizons which vary greatly in permeability. Differences in permeability between the surface soil and the subsoil were as great as 5500 to 1 for one soil. Under these conditions, water contents in excess of field capacity could easily prevail for considerable periods of time following heavy rains or large applications of irrigation water. Under such conditions, the data indicate that there would be very little opportunity for gas exchange in that portion of the soil normally most favorable for root activity. Further, the environment would be especially favorable for soil organisms associated with tree decline.

Macroporosity as herein used is the per cent volume of a soil drained between pF 0 and 1.6 (0 to 40 centimeters of water tension). Because this definition does not give increasing weight to increasing pore size, and no weight to the pores drained at a somewhat higher tension than pF 1.6, its use is only tentative. The macroporosity of a soil and its measurement appears to offer a more certain and definite method of determining the permeability and other related physical characteristics of undisturbed samples than do the commonly practiced methods.

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