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The pH of Soils in Avocado Orchards

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The determination of pH (1) in orchard soils for the most part has been carried on heretofore in a suspension of one part of soil in five parts of water (the so-called 1-5 soil-water ratio). Most of the better agricultural soils are those that contain appreciable amounts of calcium carbonate (limestone). The large amount of water used at the 1-5 soil-water ratio permits the calcium carbonate to dissolve and react with the water. In this hydrolysis of the calcium carbonate there are formed chiefly calcium hydroxide (lime-water) and carbonic acid. Since the former reacts as an alkali more strongly than the latter reacts as an acid, the net result is an increase in the pH value of the solution. Furthermore, avocado trees are not grown in soil containing water in an amount equal to five times its dry weight.

pH determinations made at the 1-5 soil-water ratio are of value in ascertaining the hydrolytic properties of the soils. They thus serve to indicate how high the pH values may rise when the soil moisture becomes excessive and interferes with soil aeration and nutrient availability. When the soil moisture is controlled, the pH values that affect the nutrition of the trees are those in the soil-moisture range, extending approximately from the wilting point to the moisture equivalent percentages or, roughly, to the field capacity.

The recent improvements in the pH meter equipment and in the technique employed have made it possible to obtain the pH values of orchard soils at moisture percentages approaching those commonly found in the field (2), (3), (4) and (5). In most cases the pH tests were made directly in the orchard, making use of freshly drawn auger or soil tube samples. In some cases the pH values were obtained directly in the soil *in situ* (in its nearly natural position). In this investigation the sample ' depth represents a soil tube or auger sample of soil for the interval or the soil column extending from the depth of the preceding sample as its upper limit to the designated depth in the table as its lower limit. In contrast with tests made on intervals or columns of soil, other tests *in situ* were made directly in the soil in its natural position in the orchard. These tests were made by inserting the electrodes into the soil at the depths given in the tables and the soil samples were taken at these points or locations rather than from a mixed column of soil.

Special attention was given to orchards in San Diego County on account of the large acreage planted to avocado trees in that area. Included in the present study, however, were quite a number of orchards located in Los Angeles, Orange and other counties. Table 1 contains data regarding the pH of soils in avocado orchards in the various counties of southern California while table 2 contains notes of interest in regard to the orchards tested.

The pH values of the samples from orchard no. 1 are very acid and are comparable to those reported as being very favorable for the growth of seedling avocado plants in soil cultures (6). Orchard no. 2 contains large trees but of an unproductive strain. The second location in orchard no. 3 is in a dry area and the pH values at the field moisture content are lower than those obtained in the wetter area. The pH values of the soil in orchard no. 4 were determined *in situ* and also in auger samples (7). All of the samples were acid at the field moisture content. When a soil is quite acid, losses of plant food the more readily may occur and control of soil moisture and depth of fertilizer penetration is essential. It should be of interest in later studies to determine the calcium content of these acid soils.

The pH values of the soil in all of the avocado orchards, no. 5 to 11 inclusive, were determined in the field and in general were found to be acid at the field moisture content. The light soils from orchard no. 12 were near their highest moisture content and had stood in closed soil containers several days enroute to and in the laboratory. At the field moisture content their pH values were 7.33, 7.13, 7.42 and 7.71 respectively. As a result of many tests with soils, it was found that upon standing in closed soil containers the pH values at the field moisture content frequently though not always increased.

Even though the pH values at the field moisture percentage in orchard no. 14 are for the most part somewhat acid, they are, however, sufficiently close to neutrality as to make it increasingly difficult for the roots in obtaining an adequate supply of the so-called minor elements such as iron, zinc, manganese or copper. With citrus pH studies it was possible to predict fairly close to the soil pH values by careful inspection of the tree or leaf condition or deficiency symptoms.

In orchard no. 15 the moisture percentage decreased with depth and the pH values became more acid with increased depth. This is not the usual condition, however, for in most citrus and avocado orchards the soils become increasingly alkaline with increased depth.

Samples of soil from two avocado orchards in Santa Barbara County were sent in closed soil containers to Riverside where the pH determinations were made. In such cases the results may lose some of their significance because of possible changes in the soil in the tightly sealed containers but in the absence of other samples the data are given for what they may be worth. In the samples from orchard no. 20 the first foot of soil was quite wet, being close to the moisture equivalent or approximately the field capacity. The pH values at the field moisture content were high, being 7.38, 7.26, 6.66, 7.04, and 7.17 respectively. At depths of 1 to 2 feet, the soil was acid at the field moisture content. As previously mentioned, the leaves of such trees may be deficient in one of the minor elements, probably manganese.

Table 1

pH of soils in avocado orchards in various counties of Southern California

Orchard no. and soil type	Sample depth in feet*	Tests in orchard: pH of soils at field moisture content (in beaker)	Tests in laboratory: pH of soils at 1-5 soil-water ratio	Tests in laboratory: Moisture percentage	Tests in laboratory: Moisture equivalent
San Diego County					
No. 1 Vista sandy loam	0.5	4.65	5.27	10.4	
	1.0	4.98	5.42	7.8	9.5
	2.0	5.25	5.71	8.6	9.0
	3.0	5.57	6.35	8.6	8.6
	4.0	6.07	6.67	8.9	8.1
No. 2 Sierra sandy loam	0.5	4.44	4.35	13.0	
	1.0	4.88	5.47	11.8	11.4
	2.0	5.67	6.60	11.7	15.0
	3.0	5.68	6.90	7.0	11.9
	3.5	5.80	6.75	5.8	
No. 3a Sierra sandy loam (moist area)	0.5	6.21	6.74	14.6	
	1.0	6.15	6.99	12.2	12.0
	2.0	6.39	7.33	11.2	11.4
	3.0	6.58	7.43	10.6	11.0
	4.0	6.57	7.57	9.8	7.7
No. 3b Sierra sandy loam (dry area)	0.5	5.65	6.90	8.9	
	1.0	5.91	7.20	6.3	
	2.0	5.95	7.50	6.2	
	3.0	5.97	7.61	6.5	
	4.0	6.05	7.68	6.5	
No. 4a Sierra sandy loam (tested *in situ*)	0.5†	5.80	6.90	9.7	
	1.0†	6.04	7.23	11.0	
	2.0†	6.32	7.50	11.4	
No. 4b Sierra sandy loam (not tested *in situ*)	0.5	5.11	5.27	10.8	
	1.0	5.63	6.50	10.0	
	2.0	5.95	7.13	9.4	
	3.0	5.82	7.22	6.5	
	3.5	5.93	7.47	6.8	
	4.0	5.67	7.16	7.2	
No. 5 Greenfield sandy loam	1.0	6.69	6.92	12.1	
	2.0	6.60	7.05	11.7	
	3.0	6.67	7.19	11.8	
	4.0	6.51	7.11	10.2	
No. 6 Greenfield sandy loam	0.5	5.84	6.98	10.2	17.0
	1.0	6.05	7.35	10.2	16.7
	2.0	6.73	7.61	11.6	16.6
	3.0	6.73	7.52	12.5	18.2

* Soil tube or auger sample consisted of the soil column extending from the base of the previous sample to the depth indicated in the table.

† At these depths the pH values also were obtained in the soil in its natural position or location (in situ) in the orchard and the pH values (in situ) were found to be 5.72, 6.01 and 5.60 respectively.

Table 1 (continued)

Orchard no. and soil type	Sample depth in feet*	Tests in orchard: pH of soils at field moisture content (in beaker)	Tests in laboratory: pH of soils at 1-5 soil-water ratio	Tests in laboratory: Moisture percentage	Tests in laboratory: Moisture equivalent
San Diego County					
No. 7	0.5	6.70	7.03	10.4	11.1
Vista sandy	1.0	6.46	7.10	9.3	9.9
loam	2.0	6.73	7.33	10.4	12.1
	2.5	6.99	7.92	10.7	12.2
No. 8	0.5	5.95	7.32	12.2	16.4
Merriam sandy	1.0	6.20	7.22	13.5	17.3
loam	2.0	6.12	7.23	15.6	18.8
No. 9	0.5	5.87	7.30	5.4	9.8
Sierra sandy	1.0	6.66	7.40	7.1	10.4
loam	2.0	6.63	7.50	9.8	11.8
	3.0	7.12	7.73	10.8	14.3
No. 10	0.5	6.80	6.85	15.2	13.0
Vista sandy	1.0	6.36	7.01	8.5	11.6
loam	2.0	6.34	7.40	7.4	11.3
	3.0	6.43	7.66	7.6	11.8
No. 11	0.5	6.55	6.61	20.4	18.9
Sierra sandy	1.0	6.66	6.77	13.6	13.9
loam	2.0	6.18	6.92	10.9	13.6
	3.0	6.24	7.30	8.4	12.3
No. 12	0.5		7.43	6.2	4.7
Kimball sandy	1.0		7.52	6.5	5.4
loam	2.0		7.60	8.5	7.0
	3.0		7.66	10.0	7.8
No. 13a§	0.5	6.22	7.42	10.1	12.0
Vista sandy	1.0	6.40	7.27	7.6	10.0
loam	2.0	6.60	7.02	7.4	9.8
	3.0	6.76	7.18	7.8	9.9
No. 13b§	0.5	6.52	6.50	7.3	10.2
Vista sandy	1.0	6.29	6.52	8.2	10.3
loam	2.0	6.60	7.01	9.4	10.0
	3.0	6.39	7.47	11.7	12.4
Los Angeles County					
No. 14	0.5	6.28	7.38	8.3	11.4
Hanford stony	1.0	6.45	7.80	7.2	8.6
sandy loam	2.0	6.72	7.47	7.1	8.1
	3.0	7.02	7.50	7.1	7.1

* Soil tube or auger sample consisted of the soil column extending from the base of the previous sample to the depth indicated in the table.

§ No. 13a: Orchard soil; No. 13b: Virgin soil with natural sage-brush vegetation and adjoining No. 13a.

TABLE 1 (concluded)

Orchard no. and soil type	Sample depth in feet*	Tests in orchard: pH of soils at field moisture content (in beaker)	Tests in laboratory: pH of soils at 1-5 soil-water ratio	Tests in laboratory: Moisture percentage	Tests in laboratory: Moisture equivalent
Orange County					
No. 15 Ramona clay loam	0.5	6.34	7.40	19.1	19.4
	1.0	6.25	7.40	17.8	21.2
	2.0	5.89	6.94	15.6	21.0
	3.0	5.72	7.03	12.8	21.0
	4.0	5.66	6.94	10.4	21.6
No. 16 Altamont clay loam	1.0	6.62	8.35	25.1	26.2
	2.0	6.69	8.05	22.0	25.9
	3.0	6.70	7.55	19.5	25.2
No. 17 Altamont gravelly loam	0.5	5.82	7.87	19.8	
	1.0	6.19	8.09	18.5	21.5
	2.0	6.69	8.50	17.5	19.5
	3.0	6.60	8.53	16.7	24.1
No. 18 Altamont gravelly loam	0.5	6.67	7.75	14.9	
	1.0	6.54	8.11	16.0	21.4
	2.0	6.34	8.62	17.4	21.0
	2.5	6.70	8.72	16.8	20.8
No. 19a‡ Ramona clay loam	0.5	6.50	8.20	22.2	33.1
	1.0	6.31	8.53	21.4	33.2
	2.0	6.69	8.66	21.3	33.2
	3.0	6.78	8.65	21.3	30.9
No. 19b‡ Ramona clay loam	0.5	5.91	7.67	20.1	32.9
	1.0	5.92	8.37	20.0	33.4
	2.0	6.26	8.61	21.2	34.1
	3.0	6.60	8.94	21.2	38.9
Santa Barbara County					
No. 20	0.5		7.90	17.3	17.7
	1.0		7.81	14.9	15.6
	2.0		7.55	9.1	15.8
	3.0		7.50	8.5	13.3
	4.0		8.54	5.2	8.6
No. 21	0.5		6.50	6.9	15.1
	1.0		6.60	7.6	15.3
	2.0		6.44	9.3	14.2
	3.0		6.20	8.7	13.7
	4.0		6.05	10.9	13.4

* Soil tube or auger sample consisted of the soil column extending from the base of the previous sample to the depth indicated in the table.

‡ No. 19a: Orchard soil; No. 19b: Virgin soil with natural sage-brush vegetation and adjoining No. 19a.

Table 2

Notes on sampled orchards in various counties of Southern California

Orchard No.	Date of sampling	Location	Orchard Description
		San Diego County	
1	1939 Nov. 2	Mt. Helix area	Age 11; Fuerte avocado trees; 2 lbs. K and P twice a year; 2 lbs. nitrogen per tree four times per year; ammonium sulfate, potassium sulfate, triple superphosphate; unit plantings; 160 lbs. yield per tree per year.
2	Nov. 3	Escondido	Age 14; Fuerte avocado trees; excellent growth; lacks a productive strain; wilting points 5.4 and 6.1 at 30 inches and 10 inches respectively.
3	Nov. 3	Escondido	Age 26; seedlings, topworked to Fuerte; 3 lbs. nitrogen, 8-8-4 fertilizer last 10 years, no manure; 16-20, ammonium phosphate; ammonium sulfate; no cultivation; low sprinklers; a show place.
4	Nov. 3	Escondido	Age 12; excellent Fuerte and Nabal avocado trees; manure prior to 3 years ago; 6 lbs. ammonium sulfate; average, 180 lbs. fruit per tree per year.
5	1940 Jan. 16	Pala	Part of 165 acres; 81 Fuerte avocado trees; 135 lbs. yield per tree, 1939.
6	Mar. 20	Vista	Age 11.
7	Mar. 20	Vista	Age 10.
8	Mar. 20	Escondido	Dense subsoil.
9	Mar. 21	Winterwarm	
10	Mar. 21	Fallbrook	Basin irrigated; near top of slope; large acreage.
11	Mar. 21	Fallbrook	15 acres; age 13; basin irrigated.
12	Apr. 4	Carlsbad	Samples obtained several days before pH tests; soil light.
13a	Mar. 20	Vista	Age 10; fairly good trees.
		Los Angeles County	
14	1940 Mar. 19	Pasadena	Orchard not examined.

TABLE 2 (Concluded)

Notes on sampled orchards in various counties of Southern California

Orchard No.	Date of sampling	Location	Orchard Description
		Orange County	
15	1939 Nov. 27	La Habra	Large thrifty trees; care given soil moisture; sprinklers.
16	1940 Jan. 17	San Juan Capistrano	Slope on west side of canyon; excellent Fuerte avocado trees.
17	Feb. 20	Puente Hills Brea	Age 20; road separates orchards; sampling locations comparable; No. 17, dairy plus ammonium phosphate; No. 18, ammonium phosphate and sulfate, gas ammonia.
18	Feb. 20	Puente Hills Brea	
19a	May 11	Brea	Age 10; manure, ammonium phosphate; soil tight and sticky; trees not at their best.
		Santa Barbara County	
20	1940 June 6	Goleta	Orchards not examined.
21	June 6	Carpinteria	

The pH values for the soil from avocado orchard no. 21 were 5.83, 6.32, 6.08, 5.72, and 5.60 respectively at the field moisture content at the various depths. All samples, even at the 1-5 soil-water ratio were acid. Here the moisture percentages at the time of sampling were not close to the moisture equivalent nor to the water-holding capacity of the soil. It is of interest that the soil samples from near a large avocado tree in highly organic soil in Guatemala were quite acid at the 1-5 soil-water ratio: the pH values at 6 in. intervals of depth at the 1-5 soil-water ratio were 6.76, 6.69, 5.93, 6.32, 6.41 and 6.24 in soils, the moisture equivalents of which were 48.5, 45.8, 47.8, 48.2, 51.9, and 51.7 per cent respectively.

The moisture content of the soil is related to the pH of the soil which, in turn, is associated with the availability of nutrient elements such as iron, zinc, manganese, etc., but it is also related to the oxygen content of the soil and its availability to the roots. Excessive soil moisture in orchards (5) is brought about in large part by dense compacted layers, however thin, of heavy soil or by marked changes in pore space at varying depths.

In the Covina Highlands area marked chlorosis of avocado trees occurred on a heavy clay loam soil with a moisture equivalent of 37.7 per cent. Outcroppings and an abundance of calcium carbonate occurred in the soil and the pH values at 1-5 soil-water ratio ranged close to 8.1 or above. By the judicious use of irrigation water the chlorosis was overcome in one season, for the reduction in the moisture content of the soil was probably accompanied by an increase in soil acidity and in iron availability.

Soil Moisture Control Important

In an avocado orchard on Fallbrook fine sandy loam near Vista, the pH values of the soils at 0.5, 1, 2 and 3 foot depths were 5.92, 5.88, 6.10 and 6.00 respectively when the field moisture percentages were 5.6, 7.5, 9.9 and 12.4. At the 1-5 soil-water ratio the pH values ranged from 6.90 to 7.68. The trees were in excellent condition. The moisture equivalent of the soil gradually increased with depth, being 10.3, 12.7, 16.0 and 20.7 per cent respectively. Compare these values with the abandoned portion of the orchard lying slightly lower and about 200 feet away. At the same depths as in the healthy tree area the pH values were 6.37, 6.64, 6.41 and 5.97 respectively at the field moisture percentages of 10.9, 8.8, 9.1 and 14.1. No doubt during the wet season these values increase considerably as is shown by the fact that the pH values at the 1-5 soil-water ratio ranged from 6.80 to 8.88. The moisture equivalent percentages were 12.9, 12.2, 35.9 and 30.2 respectively. Obviously the heavy soil at a depth of 2 to 3 feet, at times brought about the accumulation of excessive soil moisture in the upper depths and a deficiency of oxygen as well as unavailability of other nutrient elements. The control of soil moisture is one of the most potent means of controlling soil pH and nutrient availability.

In avocado orchards certain materials are from time to time being added to or eventually reach the soil, such as dusts and sprays, fertilizer, cover crops, salts in irrigation water, weed or rodent eradicators, etc., while other materials are being lost to the soils through absorption, erosion, drainage, etc. The nature of the balance is not always evident. While large numbers of soils in citrus orchards were being compared with adjacent virgin soils of about the same soil moisture percentage, a few avocado orchards were later similarly compared with adjacent virgin soils. The soil in orchard no. 13a at the field moisture percentage is increasingly more alkaline with depth, while the virgin soil no. 13b shows no uniformity. At the 1-5 soil-water ratio the orchard soil shows greater pH values in the upper areas than does the virgin soil. The virgin soil shows very little change in the pH values to a depth of 1 foot, regardless of the dilution of the soil sample.

In the other orchard cited (orchard no. 19) the pH values at the field moisture percentages are definitely higher in the orchard soil (no. 19a) than in the virgin soil (no. 19b). At the 1-5 soil-water ratio again the pH values in the orchard soil are higher in the shallow depths than in the corresponding depths in the virgin soil. In both no. 13 and 19 the pH values of the virgin soils at the 3 foot depth are higher at the 1-5 soil-water ratio than those at the same depth in the orchard soils.

In making such comparisons of pH in orchard as compared with adjoining virgin soil at the field moisture percentage, it is essential that the soil moisture percentages be comparable. In our Southern California orchards such a condition occurs principally during the rainy season when the pH values are close to their peak values. Many pH comparisons in the past have been made in soils at varying distances from the tree trunks and conclusions have been drawn without taking into account the variable factor of soil moisture even within the orchard itself.

Summary

The soils of excellent avocado orchards are predominantly acid. In most orchards not most favorably situated there are times during the season when some depths of soil are acid and it is this acidification even if temporary that permits the fair growth that is often attained. Soil moisture bears an important relationship to the pH and to the oxygen supply and these to nutrient availability. Orchard practices may affect the pH of virgin soils once they are planted to avocado trees.

1. pH is a term used to denote active acidity. At pH7 a solution is said to be neutral Above pH7, solutions are increasingly alkaline, while the farther below pH7 the more acid they are. A solution of acetic acid (vinegar) may contain the same total acidity as a solution of sulfuric acid and yet be less acid as regards pH on account of the lower active acidity.
2. Huberty, M.R. and A.R.C. Haas. The pH of soil as affected by soil moisture and other factors Soil Sci. 49, no. 6: 455-478, 1940.
3. Haas, A.K.C. The pH of soils at low moisture content. Soil Sci. 61:17-39, 1941.
4. Haas, A.R.O. and O.C. Compton. The pH of irrigated orchard soils. Soil Sci 52 (4): 309-333 1941.
5. Haas, A.R.C. Lime-induced chlorosis of citrus in relation to soil factors. Plant Physiol (In press).
6. Haas, A.E.G. Effects of pH on the growth of avocado seedlings. Yearbook Calif. Avo. Assn., 1939: 110-112.
7. Unless the pH determination was made "in situ," it was made on auger or soil tube samples.