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Effects of Irrigation Treatments and Rates of Nitrogen Fertilization on Young Hass Avocado Trees. III. Changes in Soil Chemical Properties[1]

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The cooperative experiment described by Richards, *et al.* (6) provides an opportunity for study of some irrigation-nitrogen interactions. The horticultural phases (mineral nutrition and tree appearance) arc discussed in the companion papers. A discussion of the chemical properties of the soil in its original state and some changes resulting therein from irrigation-nitrogen treatments provides the basis for the present report.

MATERIALS AND METHODS

Permanent soil sampling sites were selected in such a manner that each of the nine irrigation-nitrogen treatments was represented by three sites (trees). The same trees were sampled by Embleton, et al. (2) and Labanauskas, et al. (3) in their studies of tree nutrition. At the beginning of differential treatment, soil samples of the 0-6, 6-18, and 18-30-inch horizons were obtained; the soil beneath each of the 27 avocado trees was sampled in four places, all located at the drip line of the tree and approximately equidistant from one another.

Chemical analyses of the less than 2-mm fraction were made for the exchangeable cations, cation exchange capacity, soluble salts, water-soluble phosphorus, total nitrogen and organic carbon, and soil reaction (pH). Neutral normal ammonium acetate was used to replace the exchangeable cations; the ammonium thus absorbed was released with sodium hydroxide and subsequently distilled into boric acid. The ammonium released was taken as a measurement of the cation exchange capacity. Saturation extracts were analyzed for calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate. pH measurements were made on the saturated soil paste. Total nitrogen was determined by a Kjeldahl procedure modified to include nitrates. A wet oxidation procedure was used for organic carbon, with chromic acid as the oxidizing agent. In general, the chemical procedures outlined in the United States Department of Agriculture Handbook No. 60 (7) were used. Water-soluble phosphorus was measured in a 1:10 extract by the procedure described by Bingham (1).

Once the differential treatments were in effect, each site was sampled once a month. During 1955 and 1956, soil samples from each of the three sites were pooled by horizons prior to chemical analysis. Saturation extracts were analyzed for nitrate, chloride, and electrical conductivity.

A number of samples of the irrigation water used have been analyzed. Little seasonal

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variation in composition was noted. The water is low in salts and sodium.

RESULTS

Chemical composition of the soil at the beginning of differential treatment is given, along with irrigation water quality data, in Table 1. Only averages of the data are presented. Individual analyses were relatively uniform from one site to another.

Table 1.—Soil analysis of avocado irrigation-N plot, sampled June, 1954.

Soil horizon (inches)	pH	C %	N %	PO_4 ppm	Exchange complex				
					C.E.C.[a] me/100 gm	Ca %	Mg %	Na %	K %
0–6	7.3	0.67	0.065	2.8	9.1	73	14	2	5
6–18	7.2	0.31	0.038	1.9	8.6	81	16	2	2
18–30	7.3	0.19	0.028	1.1	8.8	.96	26	3	2

Composition of irrigation water (me/1)

Ca	Mg	Na	K	NO_3	Cl	SO_4	HCO_3
2.7	1.0	1.5	0.1	0.4	1.1	0.9	2.7

[a]C.E.C.—Cation exchange capacity.

As is common in soils of a semi-arid climate such as that at Riverside, both nitrogen and organic carbon are low, the surface soil containing 0.065 per cent nitrogen and 0.67 per cent carbon. Water-soluble nitrate values for the adjacent native brushland are likewise low (less than 5 ppm NO_3-N on a soil basis). From the standpoint of nitrogen fertility, the experimental plot is ideally low in this element and hence suited for nitrogen fertilizer evaluations. Phosphorus is not limiting, according to the high water-soluble concentrations noted (>2.0 ppm PO_4).

The exchange complex data show the soil to be typical of residual soils weathered from granite and in a semiarid climate. Briefly, the soil is base-saturated, primarily with calcium. Some free calcium and magnesium exist in the lower horizons. Although the avocado tree is especially sensitive to sodium (4, 5), the 2 per cent exchangeable sodium present would not be expected to be of any consequence. Exchangeable potassium is approximately 5 per cent; although this level is relatively low, there is enough for normal nutrition of the avocado tree. The cation exchange capacity is about 9 me/100 grams, a value which is consistent with the coarse texture (sandy loam). Examination of the saturation extracts shows the soil to be relatively salt-free (ECe = 0.2-0.3 millimhos/cm). The irrigation water is low in salts and sodium.

Analyses of the saturation extracts (NO_3-N, Cl, salinity) for the year 1956 are summarized in Tables 2, 3, and 4. The concentrations pertain to the entire 0-30-inch profile, and each figure represents the average of three consecutive monthly samples, beginning with January.

The nitrate data in Table 2 show NO_3-N levels of 5 ppm or less for the Zero-N treatment. The Low-N treatment consisted of ¼ pound N per tree as calcium nitrate. Apparently, this level of fertilization sufficed for the tree, as judged by the maintenance of 10 to 15 ppm NO_3-N throughout the soil profile. Concentrations of 3- to 4-fold this level were found where 1¾ pounds N had been used.

Table 2.—Nitrate concentration, ppm NO_3-N, soil basis, in the 0–30-inch soil horizon, 1956.

Treatment		Irrigation treatment (Maximum soil suction)		
		1/2 bar ppm	1 bar ppm	10 bars ppm
Zero-N	Jan.–Mar.	2	7	3
	Apr.–June	4	4	4
	July–Sept.	2	5	4
	Oct.–Dec.	3	4	5
	Average	3	5	4
Low-N	Jan.–Mar.	12	24	16
	Apr.–June	16	15	25
	July–Sept.	10	13	15
	Oct.–Dec.	4	9	9
	Average	11	15	16
High-N	Jan.–Mar.	35	35	49
	Apr.–June	38	57	53
	July–Sept.	42	60	105
	Oct.–Dec.	37	50	46
	Average	38	51	63

For example, the treatment of ½-bar suction—High-N resulted in an average of 38 ppm NO_3-N. The same quantity of nitrogen with less frequent irrigation (1 bar and 10 bars) resulted in higher levels in the soil, indicating interaction of irrigation on soil nitrates.

The chloride data given in Table 3 show a build-up of chloride under the treatment of frequent irrigation. The irrigation water contains approximately 1 me Cl/liter, whereas the soil irrigated according to ½-bar suctions contains approximately double the quantity expressed as me Cl/liter of the saturation extract. In general, the dry irrigation schedule (10 bars) produced concentrations of approximately 0.93 me Cl/liter. In addition, the chloride analyses show a general increase with the progression of the irrigation season.

Measurements of the conductivity of the saturation extract indicate that salinity is primarily controlled by the fertilizer rate (Table 4). Possibly, at the high rate, frequent irrigation modifies the salinity somewhat.

Table 3.—Chloride concentration, me/l, in saturation extract of the 0–30-inch soil horizon, 1956.

Treatment		Irrigation treatment (Maximum soil suction)		
		1/2 bar me/l	1 bar me/l	10 bars me/l
Zero-N	Jan.–Mar.	1.31	0.78	0.45
	Apr.–June	1.43	1.22	0.82
	July–Sept.	2.09	2.22	1.30
	Oct.–Dec.	3.35	1.10	1.02
	Average	2.05	1.33	0.90
Low-N	Jan.–Mar.	1.40	2.29	0.88
	Apr.–June	1.67	1.16	0.86
	July–Sept.	2.16	1.03	0.75
	Oct.–Dec.	1.62	1.40	1.46
	Average	1.71	1.72	0.99
High-N	Jan.–Mar.	0.84	0.68	0.63
	Apr.–June	1.68	0.92	0.68
	July–Sept.	2.44	1.07	1.20
	Oct.–Dec.	1.90	1.24	1.06
	Average	1.72	0.98	0.89

Table 4.—Electrical conductivity, millimhos/cm, of saturation extract of 0–30-inch soil horizon, 1956.

Treatment		Irrigation treatment (Maximum soil suction)		
		1/2 bar millimhos/cm	1 bar millimhos/cm	10 bars millimhos/cm
Zero-N	Jan.–Mar.	0.63	0.72	0.49
	Apr.–June	0.70	0.65	0.64
	July–Sept.	0.93	0.91	0.72
	Oct.–Dec.	1.10	0.65	0.62
	Average	0.84	0.73	0.62
Low-N	Jan.–Mar.	0.88	1.28	0.88
	Apr.–June	1.04	0.87	1.01
	July–Sept.	1.09	0.86	0.86
	Oct.–Dec.	0.66	0.86	0.73
	Average	0.92	0.97	0.87
High-N	Jan.–Mar.	1.29	1.48	1.59
	Apr.–June	1.57	2.12	1.71
	July–Sept.	1.80	1.94	3.13
	Oct.–Dec.	1.52	1.99	2.34
	Average	1.55	1.88	2.19

Linear regressions were calculated for the relation between treatments, season, and nitrate, chloride, and electrical conductivity of the saturation extract. According to the F values for the above, soil nitrates were related to fertilizer rate, season, and their interaction; chlorides were related to irrigation; whereas, electrical conductivity was related to the fertilizer rate. The above relationships were all significant to the 0.01 per cent level, as judged by their respective F values.

In July, 1957, each of the sites was sampled for cation analysis of the saturation extract. The interesting feature of these data is the accumulation of calcium and the effect that irrigation has on the level for any one fertilizer rate (Table 5). For example, the High-N treatment has values of 6.4, 13.5, and 17.5 me/liter of calcium for the ½-, 1-, and 10-bars irrigations, respectively.

DISCUSSION

The maintenance of nitrate differentials is verified by soil analyses. The nitrate level is dependent upon rate of fertilization, as well as upon irrigation management and winter rains. Even though these data are preliminary, they illustrate the necessity for considering the joint effect.

Table 5.—Cation concentrations, me/1, in saturation extract of 0–30-inch soil horizon, July, 1957.

Treatment		Irrigation treatment (Maximum soil suction)		
		1/2 bar me/1	1 bar me/1	10 bars me/1
Zero-N	Ca	2.0	3.4	1.9
	Mg	0.1	0.1	0.2
	Na	2.6	2.8	2.0
	K	0.9	1.6	0.5
Low-N	Ca	2.6	2.5	2.2
	Mg	0.6	0.4	0.5
	Na	2.7	2.9	2.3
	K	1.4	1.8	1.5
High-N	Ca	6.4	13.5	17.5
	Mg	1.4	1.2	1.2
	Na	4.0	3.2	3.1
	K	0.6	2.1	2.5

Perhaps at first the trends in chloride buildup are surprising, for frequent irrigations are ordinarily associated with leaching. However, the irrigation technique is important too. In the above experiment, irrigation was managed in such a manner as to avoid excessive leaching. Fifty-three, 31, and 21 surface-inches of water were applied to effect the ½-bar, 1-bar, and 10-bars treatments, respectively. The application of 2½ times as much chloride to the ½-bar irrigated soils as to the 10-bars irrigated soils accounts for the higher chloride level in the ½-bar irrigated soils. Some leaching occurred, judging by the nitrate and conductivity data, yet the net accumulation of chloride in the ½-bar irrigated soils can only be the result of the greater quantity of water applied. Had leaching been less, higher chloride values would have prevailed, possibly to the extent of being harmful to the tree.

The poorest growth occurred under the High-N-10-bars treatment. See Richards, *et al.* (6), Tables 5 and 6. Examination of the nitrate data reveals no unusually high concentrations which could account for retarded growth. Although the avocado tree is especially sensitive to salt, the poor growth cannot be related to excessive chloride concentrations in the soil. Actually, more chloride is present under frequent irrigations, a condition favoring good growth. Total salinity, as expressed by the electrical conductivity of the saturation extract, may be a factor related to the retarded growth. Higher conductivity values were associated with the High-N-10-bars treatment. Electrical conductivity values of 6 to 7 millimhos/cm were occasionally noted for the saturation extracts of surface samples collected in late summer or early fall, which might account for the reduced growth.

Specific relationships between treatments, soil analysis, and tree nutrition are covered in more detail in the companion paper by Embleton, *et al.* (2).

SUMMARY

Irrigation and nitrogen management jointly control the level of salinity and nitrate maintained in the soil. Frequent irrigations produce higher chloride levels and lower nitrate levels. In general, total salinity is controlled by the rate of fertilizer application.

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