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Influence of Soil Applications of Nitrogen, Phosphate, Potash, Dolomite, and Manure on the Micronutrient Content of Avocado Leaves[1]

By C. K. LABANAUSKAS, T. W. EMBLETON, and W. W. JONES,
University of California Citrus Experiment Station, Riverside, Calif.

The deficiency of micronutrients in avocado trees is often an important problem in southern California avocado orchards. This report shows some of the possible effects of fertilizer practices on the micronutrient content of avocado leaves. Specifically, some effects of soil applications of nitrogen, phosphate, potash, dolomite, and steer manure on the zinc, copper, manganese, iron, and boron contents of Fuerte avocado leaves are reported in this paper. Influence of soil applications of the above mentioned macronutrients on the macro-nutrient content of Fuerte avocado leaves from this particular experiment is a subject for a future paper.

Very little experimental evidence from field studies has been presented in the literature pertaining to avocado fertilization practices, and few data exist on the influence of soil applications of macro-nutrients on the micronutrient composition of avocado leaves. Several reports indicate that continued heavy applications of phosphorus may change the zinc, iron, and manganese nutrition of citrus trees. Reuther and Smith (15) observed that, as the rate of nitrogen and potash fertilization was increased, the incidence of mottle-leaf increased and the zinc concentration in Valencia orange leaves decreased. Camp (3) found that zinc deficiency symptoms of citrus became more prevalent as the level of nitrogen applied to the soil was increased. Chapman *et al.* (5) reported that citrus plants grown under high-nitrogen conditions in culture solution studies were more severely mottled than plants grown under low-nitrogen conditions. Ruehle (16) observed that little-leaf was especially severe on avocado trees in certain groves where nitrogen applied in the fertilizer for several years had been mainly from synthetic sources. Lynch (11) observed that die-back and ammoniation in avocados was often induced by excessive nitrogen fertilization.

Ozanne (12) found that subterranean clover plants growing in a soil low in zinc showed increased severity of zinc deficiency symptoms when the nitrogen supply was increased. Under conditions of low zinc supply, the zinc concentration in roots was found to be correlated with the percentage of protein N present. The proportion of total absorbed zinc translocated to the plant tops was also found to be related to the percentage of protein N in the roots. Ozanne postulated that increased nitrogen supply caused more of the zinc to be retained by the roots in zinc-protein complexes.

Reuther *et al.* (14) found that heavy phosphate fertilization increased accumulation of zinc and manganese and decreased accumulation of copper in orange leaves in acid

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Florida soil. Reuther and Crawford (13) observed dial heavy phosphate fertilization of a calcareous soil induced zinc deficiency symptoms in citrus in the field. Chapman (4) suggests that excessive applications of phosphate, in addition to effects on micronutrients, may reduce the efficiency of nitrogen fertilization. Bingham and Martin (2) present data from greenhouse studies indicating that large applications of phosphate to the soil induced copper and zinc deficiency symptoms and increased manganese in citrus plants. Iron was not significantly influenced.

West (21) observed that potash fertilization increased the incidence of mottle-leaf induced by heavy phosphate fertilization in citrus. In greenhouse sand-culture studies with tung, Shear *et al.* (19) found that potassium depressed the concentration of heavy metals such as manganese, copper, and probably zinc in the foliage. Beyers (1) observed a high degree of grape-leaf chlorosis in potash-treated plots, as compared with that in plots receiving no potash. He postulated that this chlorosis was caused by magnesium deficiency induced by heavy applications of potash. Potassium sulfate applications increased potassium, manganese, and iron, and decreased nitrogen, calcium, and magnesium. He also found that ammonium sulfate increased nitrogen, magnesium, and manganese and reduced potassium in the leaves.

MATERIALS AND METHODS

'This experiment was conducted in an avocado orchard in northern San Diego County, California. The orchard was on Ramona stony sandy loam, a light-textured, well-drained, shallow acid soil having a cation exchange capacity of less than 4 me per 100 grams (9). The soil was non-tilled; irrigation was by individual under-tree sprinklers; weeds under the trees were controlled with oil and herbicides.

The Fuerte avocado trees were planted in 1939 where Navel orange trees had been removed because of a condition now known to have been phosphorus deficiency (9). The avocado trees did not respond favorably to phosphate fertilization. However, Valencia orange trees on the same soil type in this orchard did respond favorably to phosphate fertilization (7, 8, 9). Prior to the establishment of the experiment, the avocado trees received 3 pounds of nitrogen per tree per year from sulfate of ammonia broadcast under the trees.

In 1951, differential fertilizer treatments were started for the purpose of evaluating the effects of two levels each of dolomite, nitrogen, potash, and steer manure, and three levels of phosphate, on yield, fruit size and quality, tree growth, and chemical composition of leaves of avocado trees. The 18 fertilizer treatments are summarized in Table 1. Each treatment was replicated five times in single-tree plots, making a total of 90 plots. For statistical analysis, certain groups of treatments were compared in factorial combinations. By grouping treatments factorially, dolomite and nitrogen were, in effect, replicated internally 30 times, and phosphate and potash 20 times.

Table 1.—Soil treatments in Fuerte avocado fertilizer experiment in northern San Diego County, California.

Treatment	Pounds per tree per application: N	P_2O_5	K_2O	Dolomite[a]
N_1	0.5[b]	—	—	—
N_1P_1	0.5[b]	4.6[c]		
N_1P_2	0.5[b]	9.2[c]	—	—
N_2	2.0[d]	—	—	—
N_2P_1	2.0[d]	4.6[c]	—	—
N_2P_2	2.0[d]	9.2[c]	—	—
N_2K_1	2.0[d]	—	10.2[e]	—
$N_2P_2K_1$	2.0[d]	9.2[c]	10.2[e]	—
Steer manure[f]	2.0	0.9	3.9	—
N_1Dol_1	0.5[b]	—	—	50
$N_1P_1Dol_1$	0.5[b]	4.6[c]	—	50
$N_1P_2Dol_1$	0.5[b]	9.2[c]	—	50
N_2Dol_1	2.0[d]	—	—	50
$N_2P_1Dol_1$	2.0[d]	4.6[c]	—	50
$N_2P_2Dol_1$	2,0[d]	9.2[c]	—	50
$N_2K_1Dol_1$	2.0[d]	—	10.2[e]	50
$N_2P_2K_1Dol_1$	2.0[d]	9.2[c]	10.2[e]	50
Steer manure,[f] Dol_1	2.0	0.9	3.9	50

[a]Applied August, 1951, May, 1952, and August, 1952. Dolomite contained 60% $CaCO_3$ and 39% $MgCO_3$.

[b]Applied February, 1955 and 1956; source: ammonium nitrate, 33.5% N. Prior to 1955 N_1 treatments received no nitrogen.

[c]Applied August, 1951 and 1952; source: treble superphosphate, 46% P_2O_5.

[d]Applied annually, starting August, 1951; source: ammonium nitrate 33.5% N.

[e]Applied August, 1951 and 1952; source: potassium sulfate, 51% K_2O.

[f]Applied annually starting August, 1951.

Leaf samples for chemical analysis were obtained in October, 1955, from the spring and summer flushes of growth. Each sample consisted of 20 fully developed avocado leaves. The method of preparing avocado leaves for micronutrient analysis has been described elsewhere (20). Zinc and copper were determined by using 2-carboxy-2'-hydroxy-5'-sulformazylbenzene (17). Manganese was determined by the permanganate method (18), iron by the o-phenanthroline method (18), and boron by the carmine method (10). All five micronutrient elements were determined colorimetrically with a Beckman Model B spectrophotometer.

RESULTS AND DISCUSSION

Nitrogen:—The data presented in Table 2 show that leaves from avocado trees that received the high nitrogen rate (N_2) contained significantly less zinc, copper, and boron, and significantly more manganese and iron, than leaves from trees that received the low nitrogen rate (N_1).

Our observations of a reduction in copper in avocado leaves as a result of large applications of nitrogen fertilizers are in agreement with observations by Lynch (11). The effects reported here of nitrogen fertilization on avocado leaves are in close agreement with observations by Ruehle (16) on avocado, and by Camp (3), Chapman *et al.* (5), and Reuther and Smith (13), who reported that an increase in the rate of nitrogen applications to citrus was associated with an increase in zinc deficiency symptoms.

Phosphate:—Three levels of phosphorus were studied in this experiment. The data presented in Table 2 clearly indicate that when the rate of phosphate fertilization was increased, the copper and zinc contents in avocado leaves were reduced. Phosphate application increased manganese in the leaves. Although not significantly, phosphate fertilization tended to reduce the amount of boron found in the leaves.

Table 2.—Effect of soil applications of nitrogen, phosphorus, dolomite, and steer manure on the micronutrient content of avocado leaves.[a]

Application rate	Parts per million in dry leaves				
	Zn	Cu	Mn	Fe	B
N_1	34	4.1	538	48	38
N_2	31	3.7	653	52	27
F value	**	*	**	**	**
P_0	35	4.2	528	50	37
P_1	33	4.0	655	49	28
P_2	30	3.5	603	50	32
F value	**	**	**	NS	NS
K_0	31	3.7	619	53	27
K_1	33	5.0	651	51	30
F value	NS	**	NS	NS	NS
Dol_0	32	3.6	637	52	32
Dol_1	31	4.2	553	52	32
F value	NS	**	**	NS	NS
Steer manure	41	5.8	366	51	41
Ammonium nitrate	32	4.0	570	52	31
F value	**	**	**	NS	*

[a]NS indicates that the differences between means are not statistically significant.
*F value significant at the 5% level.
**F value significant at the 1% level or higher.

The data presented in Table 2 are in close agreement with findings of Bingham and Martin (2) on citrus in greenhouse studies. They report that heavy applications of phosphate fertilizers markedly reduced copper and zinc contents and tended to increase manganese content in lemon leaves. Reuther and Crawford (13) observed that heavy phosphate fertilization induced zinc deficiency symptoms on citrus in the Coachella Valley, but they did not present foliage analyses for zinc. In the present experiment many of the trees which received the high rates of phosphate and nitrogen fertilizers showed zinc deficiency patterns. The degree of the incidence of zinc deficiency symptoms agrees closely with the data obtained from leaf analysis.

Potash:—Potash fertilization increase the copper in the avocado leaves significantly and increased manganese slightly but not significantly (Table 2). Potash fertilization had no significant influence on zinc, iron, or boron in the leaves. On citrus, Reuther and Smith (15) observed that potash fertilization increased the incidence of zinc deficiency patterns. Beyers (1) observed that potassium sulfate applications increased manganese and iron contents in grape leaves.

Dolomite:—Dolomite applications significantly increase the copper and significantly reduced the manganese content in the avocado leaves (Table 2). Zinc, iron, and boron in the leaves were not significantly influenced by dolomite applications. The mean averages for the dolomite treatments do not include those dolomite treatments which receive potash fertilizers. There was a significant interaction between dolomite and potash on copper content in the leaves. This interaction is discussed below.

Manure:—In this nontilled orchard application of 2 pounds of actual nitrogen per tree annually from steer manure resulted in significantly more zinc, copper, and boron, and significantly less manganese, in the leaves than 2 pounds of nitrogen per tree annually from ammonium nitrate (Table 2). The zinc, copper, and boron in the steer manure may partly account for the increase of these three elements in trees treated with manure. However, Embleton and Jones (6) show that the nitrogen in the leaves of the manure-treated trees was much lower than that in the leaves of trees receiving ammonium nitrate. It appears that the higher nitrogen in the ammonium nitrate-treated trees may have had a strong influence in reducing the zinc, copper, and boron in the leaves. The root system of avocado trees treated with steer manure was more extensively developed in the surface soil and in the mulch than was that of trees receiving ammonium nitrate.

Interactions:—The interaction of the effects of dolomite and phosphate applications on the manganese content in the leaves is shown in Table 3. At the P_0 and P_1 levels dolomite applications reduced manganese in the leaves, but at the P_2 level dolomite applications slightly increased manganese in the leaves.

Table 3.—Interaction of effects of dolomite and phosphate soil applications on manganese content of avocado leaves.

Treatment	Manganese in dry leaves (ppm)		
	P_0	P_1	P_2
Dol_0	627	712	572
Dol_1	428	598	634
Interaction F value		**	

**Statistically significant at 1% level.

The interaction of the effects of dolomite and potash applications on the copper content in the leaves is shown in Table 4. In treatments receiving no potash, dolomite applications increased slightly the copper found in the leaves. Where potash was applied, dolomite applications reduced the amount of copper found in the leaves.

Table 4.—Interaction of effects of dolomite and potash soil applications on copper content of avocado leaves.

Treatment	Copper in dry leaves (ppm)	
	K_0	K_1
Dol_0	3.4	5.5
Dol_1	4.0	4.5
Interaction F value	*	

*Statistically significant at 5% level.

The data presented in this paper indicate that soil applications of several fertilizers have complicated effects on the micronutrients in avocado leaves. By applying nitrogen, phosphorus, or potassium to avocado trees, one not only increases directly or indirectly that particular element in the plant tissue, taut also affects the micronutrient content and induces side reactions.

SUMMARY

The effects of soil applications of nitrogen, phosphate, potash, dolomite, and steer manure on the zinc, copper, manganese, iron, and boron contents of leaves on Fuerte

avocado trees have been studied.

1. Heavy nitrogen fertilization significantly reduced the zinc, copper, and boron content of avocado leaves and significantly increased the manganese and iron content.
2. Heavy phosphate fertilization reduced the zinc and copper contents of avocado leaves, increased the manganese content, and reduced boron slightly. Iron content was not affected by phosphate applications.
3. Potash applications increased the copper in the leaves but had no effect on zinc, manganese, iron, or boron.
4. Dolomite applications increased copper, reduced manganese, and had no significant influence on zinc, iron, and boron in the leaves.
5. Trees treated with steer manure contained significantly more zinc, copper, and boron in the leaves, and significantly less manganese, than trees that received ammonium nitrate. These differences could be associated with the marked lower nitrogen in the leaves of trees that received steer manure.

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