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Influence of Sampling Date, Season, and Fertilization on Macronutrients in Fuerte Avocado Leaves[1]

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To make the most efficient use of leaf analysis as a diagnostic tool, one must know what factors influence the concentration of a given element in the leaves and the magnitude of the influence. This report shows the influence of sampling date, season, and fertilization on the percentages of nitrogen, phosphorus, potassium, calcium, magnesium, and chloride in Fuerte avocado leaves that expanded during the April-June period. Data on the dry weight of leaves are also given. Some of the responses of avocado trees are compared with those of orange trees growing adjacent to the avocado planting.

MATERIALS AND METHODS

The experimental orchard has been described by Labanauskas *et al.* (17). The Fuerte avocado trees were planted in northern San Diego County in 1939 on Ramona stony sandy loam, a light-textured, well-drained, shallow acid alluvial soil having a base exchange capacity of less than 4 me per 100 grams. Navel orange trees were removed from this orchard prior to the planting of the avocado trees because of a condition now known to have been phosphorus deficiency (12). Although Valencia orange trees on the same soil type on the same property responded favorably to phosphate fertilization (10, 11, 12), the avocado trees did not.

The soil was nontilled; irrigation was by individual under-tree sprinklers; and weeds under the trees were controlled by herbicides. Prior to the establishment of the experiment in 1951, the avocado trees received 3 pounds of nitrogen per tree per year in three applications of sulfate of ammonia broadcast under the trees. The last general application was 1 pound of nitrogen per tree, in the spring of 1950.

In 1951, differential fertilizer treatments were established. These treatments, summarized in Table 1, included two levels each of dolomite, nitrogen, potash, and steer manure, and three levels of phosphate. Each treatment was replicated five times with single-tree plots. The symbols used in Table 1 to represent the fertilizer treatments are the same as those used by Labanauskas *et al.* (17) in a report on another phase of this experiment. During the period of time covered in the present report the treatments with the symbol N_1, received no nitrogen fertilizer.

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

Treatment		Pounds per tree per application			
No.	Material	N	P_2O_5	K_2O	Dolomite[a]
71	N_1	—	—	—	—
72	N_1P_1	—	4.6[b]	—	—
73	N_1P_2	—	9.2[b]	—	—
74	N_2	2.0[c]	—	—	—
75	N_2P_1	2.0[c]	4.6[b]	—	—
76	N_2P_2	2.0[c]	9.2[b]	—	—
77	N_2K_1	2.0[c]	—	10.2[d]	—
78	$N_2P_2K_1$	2.0[c]	9.2[b]	10.2[d]	—
79	Steer Manure[e]	2.0	0.9	3.9	—
80	N_1Dol_1	—	—	—	50
81	$N_1P_1Dol_1$	—	4.6[b]	—	50
82	$N_1P_2Dol_1$	—	9.2[b]	—	50
83	N_2Dol_1	2.0[c]	—	—	50
84	$N_2P_1Dol_1$	2.0[c]	4,6[b]	—	50
85	$N_2P_2Dol_1$	2.0[c]	9.2[b]	—	50
86	$N_2K_1Dol_1$	2.0[c]	—	10.2[d]	50
87	$N_2P_2K_1Dol_1$	2.0[c]	9.2[b]	10.2[d]	50
88	Steer Manure[e], 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 August 1951 and 1952; source: treble superphosphate, 46% P_2O_5.
[c]Applied annually, starting August 1951, source: ammonium nitrate, 33.5% N.
[d]Applied August 1951 and 1952; source: potassium sulfate, 51% K_2O.
[e]Applied annually, starting August 1951.

On the trees in this experiment new leaves in the process of expanding could be found at almost any period during the year. However, more leaves were in the process of rapid expansion in April than at other periods of the year. In order to estimate the age of the leaves more closely for leaf sampling, many leaves on several trees were punched in an identifiable form at three different times to mark leaves whose period of most rapid expansion was in either April, May, or June. For a nine month period the punched leaves were inspected before taking leaf samples from the treated trees. It was learned that, after August, leaves that expanded in April could not be distinguished visibly from leaves that expanded in June.

In this study, leaves were sampled at monthly intervals over a two-year period. Samples taken in June, July or August were leaves that expanded during April. From August until the leaves dropped the following spring the samples consisted of leaves that expanded in the period April through June because of reasons previously mentioned.

It would have been highly desirable to sample and analyze leaves separately from each plot for each sampling date. This task would have been too burdensome because of the large number of analyses involved. Therefore, it was decided to obtain leaf samples at monthly intervals for two years, and on each sampling date composite the leaves from the five replications of each treatment into one sample. From each tree on each sampling date, ten outside leaves of the desired age from around the tree were selected at a height of from four to six feet from the ground from shoots that were not fruiting and did not have a cycle of leaves younger than those sampled. Thus, each composite sample consisted of 50 leaves.

Analytical results were averaged so that the number of trees represented in the mean for each value in Figs. 1—14 was as follows: no nitrogen (N_1) and nitrogen (N_2), 30 trees each; no phosphate (P_0) and high phosphate (Pa), 20 trees each; no potash (K_0) and potash (K_1), 20 trees each; no dolomite (Dol_0) and dolomite (Dol_1), 40 trees each; manure, 10 trees. The numbers of the treatments that were used to obtain the means were as follows (Table 1): no nitrogen, treatments 71, 72, 73, 80, 81, 82; nitrogen—74, 75, 76, 83, 84/85; no phosphate—71, 74, 80, 83; phosphate—73, 76, 82, 85; no potash —74, 76, 83, 85; potash—77, 78, 86, 87; no dolomite—71 through 78; dolomite—80 through 87; manure—79, 88. The values for the intermediate level of phosphate (P_1) were not plotted.

The samples included both the petioles and the blades of the leaves. Methods of preparing leaf samples for analysis and of analyzing the leaves for nitrogen, phosphorus, potassium, magnesium and calcium were the same as those used by Embleton *et al.* (11). Chloride was determined by the method of Brown and Jackson (2), using a Beckman electrotitrimeter.

RESULTS AND DISCUSSION

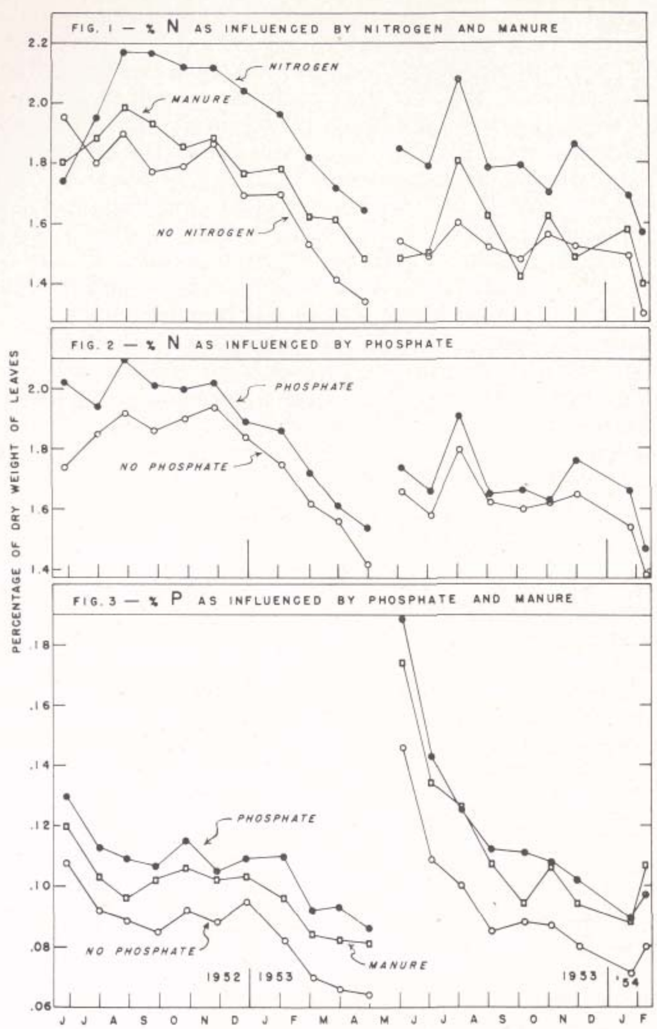
The influence of soil applications of nitrogen, phosphate, potash, dolomite, and manure on the seasonal trends of the percentages of nitrogen, phosphorus, potassium, magnesium, calcium, chloride, and sodium in the leaves and on the dry weight of the leaves was determined. However, only the data which show meaningful influences are presented here.

Because of the extreme variability in avocado yields (15), the critical levels of the above elements in the leaves, in relation to yield, are not well known. Some information, is available on nitrogen levels in Fuerte avocado leaves as related to yield (9).

Nitrogen:—The withholding of nitrogen fertilizers after the spring of 1950 resulted in considerably lower nitrogen percentages in the leaves during 1952 and 1953, in. comparison with results from trees receiving 2 pounds of nitrogen annually (Fig. 1). This difference has important implications. In 1953 and 1954, the 30 no-nitrogen trees produced 54 per cent and 25 per cent, respectively, more fruit in pounds per tree, than did the 30 trees receiving 2 pounds of nitrogen annually (9). The fruit from the no-nitrogen trees was significantly larger both years and had a higher percentage of oil in the fruit pulp in 1953 than the trees receiving the 2 pounds of nitrogen (9).

In this nontilled orchard 2 pounds of nitrogen from manure applied as a mulch resulted in nitrogen values in the leaves that were, in general, not much higher than the values in the leaves of trees receiving no nitrogen (Fig. 1). Presumably, part of the nitrogen from the manure mulch was lost in gaseous form, possibly as ammonia, and was, therefore, not available to the trees. It was observed that in nontilled citrus and avocado orchards, manure was less efficient than commercial inorganic forms of nitrogen in supplying nitrogen to the trees (8).

The data in Fig. 2 show that, in this experiment, phosphate applications resulted in a consistently higher percentage of nitrogen in the leaves. Citrus, on this same property and on the same soil type, responded to phosphate applications with a markedly lower percentage of nitrogen in the leaves (12). Lynch *et al.* (18), working with the Lula avocado in Florida, found no consistent influence of phosphate applications on the level of nitrogen in the leaves.



Figs. 1–3. Relation of sampling date, season, and fertilization to the composition of Fuerte avocado leaves as per cent of dry weight: Fig. 1—Effect of nitrogen and manure on percentage of nitrogen. Fig. 2—Effect of phosphate on percentage of nitrogen. Fig. 3—Effect of phosphate and manure on percentage of phosphorus.

The seasonal trends for the percentage of nitrogen in. the leaves are different for the two years studied (Figs. 1, 2). In general, the percentage of nitrogen in the leaves increased to about August, when the leaves were three to lour months old, and then decreased gradually until December to February, after which there was a rather sharp decrease. The period from the beginning of September to the end of November appears to be the most stable period for nitrogen concentration in. the leaves. This would probably be the most desirable time to sample leaves to be used for nitrogen studies. At other periods the nitrogen level in the leaves changes more rapidly and makes it more difficult to evaluate results. This does not preclude the possibility that the nitrogen level in the leaves at other periods of the year may be more important in influencing production, than in the September to November period. For two seasons, Cameron and Bialoglowski (3) followed the nitrogen level in the leaves of two trees in relation to bearing and nonbearing and found appreciable differences between trees and between seasons. Their data also show a sharp drop in the percentage of nitrogen in the leaves after December.

Phosphorus:—Total phosphorus concentrations of less than 0.10-0.11 per cent in orange leaves three to seven months old would suggest phosphorus deficiency (4, 5, 16). Valencia orange trees adjacent to the experimental avocado planting responded markedly to phosphate application (10, 11, 12). In the present avocado experiment, the levels of phosphorus in the leaves of the no-phosphate trees were below 0.10 per cent for most of the year. Phosphate applications increased the level of phosphorus in the leaves markedly (Fig. 3), but no beneficial effect on yield or fruit quality was observed. In. Florida, Lynch *et al.* (18) observed no increase in avocado yield or tree growth from increases of phosphorus in the leaves.

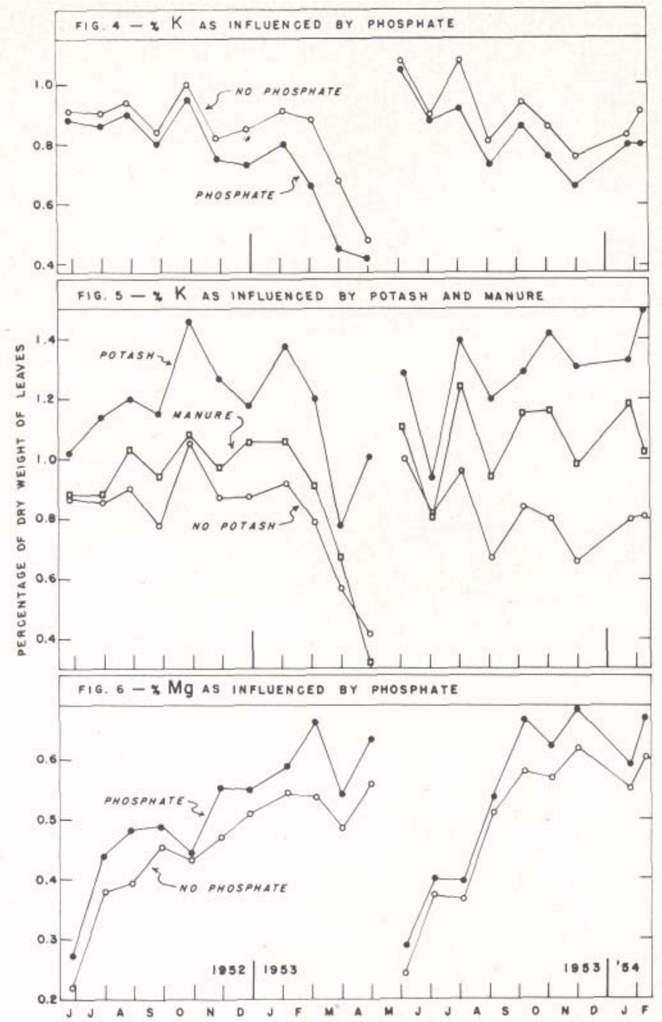
The application of manure as a mulch served as an efficient source of phosphate (Fig. 3). The total amount of P_2O_5 applied in manure was much less than that applied in treble superphosphate (Table 1). By the 1953-54 season the level of phosphorus was practically the same in the leaves of the trees receiving manure as in those of the trees receiving the high rate of treble superphosphate.

The trend for the percentage phosphorus in the leaves was generally downward as the age of the leaf increased, with some stability in the August-to-December period (Fig. 3). Fullmer (13) found a similar trend for acetic acid-soluble phosphate-phosphorus in the blades of Fuerte avocado leaves, but in the petioles he found a general downward trend throughout the season, with no period in which the phosphate level was stable.

These studies suggest that, for comparative purposes, leaf samples should be taken in the August-to-December period. Since the acetic acid-soluble phosphate-phosphorus in the leaf petioles drops rather rapidly during the August-to-December period (13), perhaps one should consider using only the leaf blade for analysis. However, Fullmer (13) concluded that analysis of the leaf petiole gave results that were more indicative of the phosphorus status of the plant, than analysis of the leaf blade.

Potassium:—The authors are not aware of any potassium deficiency in avocados growing in the field. Potash variables were incorporated in (his experiment to attempt to influence the oil content in the fruit. Potash .fertilization did not have a detectable effect on oil content in the fruit. Potash and manure applications both increased I he potassium found in the leaves, the manure treatments being intermediate between the no-potash and potash treatments (Fig. 5). Less potash was applied in the manure application than in the regular potash application (Table 1). Also the phosphate in the manure may have resulted in reducing the amount of potassium found in the leaf (Fig. 4, Table 1). Phosphate applications consistently reduced the percentage of potassium in the leaves (Fig. 4). Similar influences were observed in an adjacent orange fertilizer experiment (12). Fullmer (13) observed that phosphate applications increased the potassium in Fuerte avocado leaves in the presence of potash applications but reduced the potassium in the leaves in the absence of potash applications.

No consistent seasonal trend was observed in the potassium level in the leaves except that it dropped sharply after February (Figs. 4, 5). Where potash was not applied, the potassium level in the leaf remained about the same or dropped slightly from June to February. Where potash was applied, the trend was for potassium in the leaf to increase from June to February. Fullmer (13) showed a reduction in the potassium level in Fuerte avocado leaves as the leaves became older.



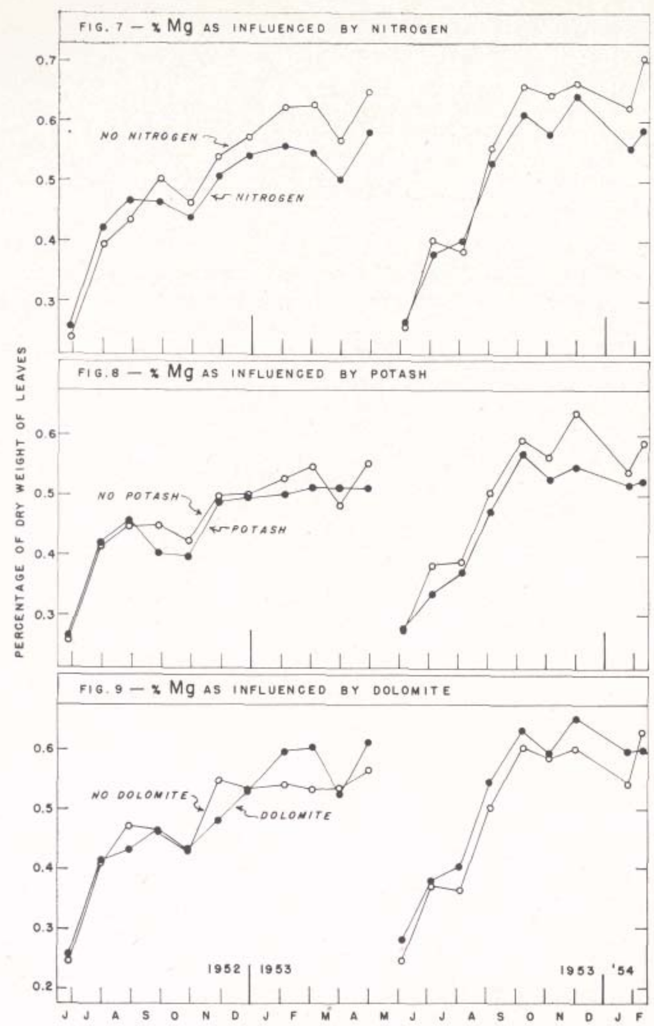
Figs. 4–6. Relation of sampling date, season and fertilization to the composition of Fuerte avocado leaves as per cent of dry weight: Fig. 4—Effect of phosphate on percentage of potassium. Fig. 5—Effect of potash and manure on percentage of potassium. Fig. 6—Effect of phosphate on percentage of magnesium.

Magnesium:—Dolomite applications on this nontilled acid soil showed a slight tendency to increase the amount of magnesium found in the leaves (Fig. 9). The magnitude of the increase was not enough to be of practical importance, however. Thus far, dolomite (39 per cent $MgCO_3$) has not been very effective in increasing the magnesium in the leaves.

Phosphate applications increased the amount of magnesium in avocado leaves (Fig. 6) as in orange leaves (11). After October each year less magnesium was found in the leaves of trees that had received nitrogen (Fig. 7). Nitrogen applications generally increased the amount of magnesium found in citrus leaves (4, 19). Our unpublished data show that nitrogen applications increased the amount of magnesium found in the leaves of Valencia orange trees adjacent to the avocado experiment, both in the presence of and in the absence of phosphate applications. This implies that, if other factors were equal, nitrogen applications would aggravate magnesium deficiency in avocado and reduce the deficiency conditions in citrus.

Potash applications showed a weak tendency to reduce the level of magnesium in the avocado leaves (Fig. 8). In many plants, including citrus (11), potash has a much stronger influence in reducing the magnesium level in the leaves.

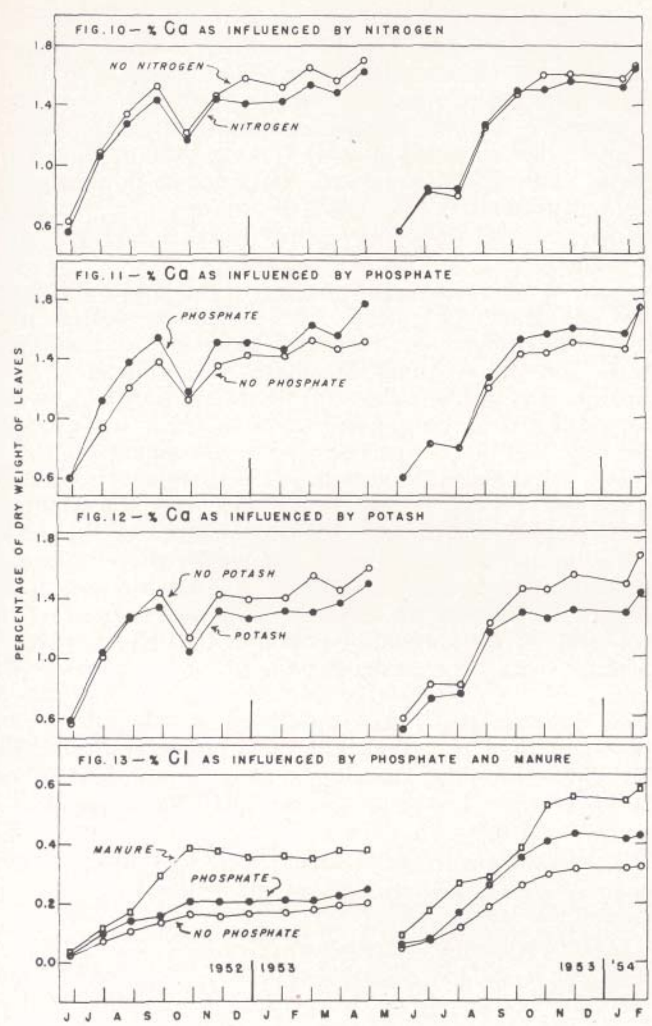
Seasonal trends for magnesium differed slightly for the two years (Figs. 7-9), but during both years the magnesium level in the leaves increased as the age of the leaves increased.



Figs. 7–9. Relation of sampling date, season and fertilization to the composition of Fuerte avocado leaves as per cent of dry weight: Fig. 7—Effect of nitrogen on percentage of magnesium. Fig. 8—Effect of potash on percentage of magnesium. Fig. 9—Effect of dolomite on the percentage of magnesium.

Calcium:—Nitrogen applications caused slight reductions, and potash applications greater reductions, in the percentage of calcium in the leaves. The influence was greater in the older leaves (Figs. 10, 12). Phosphate applications increased slightly the calcium found in the leaves (Fig. 11). The effects of potash and phosphate on composition of avocado leaves were similar to those found in citrus leaves (11).

Calcium in the leaves increased sharply until about the first of October. After that, the increase was slight (Figs. 10-12).



Figs. 10–13. Relation of sampling date, season, and fertilization to the composition of Fuerte avocado leaves as per cent of dry weight: Fig. 10—Effect of nitrogen on percentage of calcium. Fig. 11—Effect of phosphate on percentage of calcium. Fig. 12—Effect of potash on percentage of calcium. Fig. 13—Effect of phosphate and manure on percentage of chloride.

Chloride:—An excess of chloride is common in avocado leaves in California and Texas (1, 6, 14). The avocado is more sensitive to chloride excess than is citrus (6). Tipburn of avocado leaves may appear if the chloride in the leaf exceeds 0.25 per cent (6, 14). Therefore, any factor which has any appreciable influence on the level of chloride in avocado leaves is of commercial interest.

Applications of steer manure resulted in a great increase in the chloride in the leaves (Fig. 13). The manure contained from 0.85 to 1.24 per cent chloride on a dry-weight basis. From 1 to 1.5 pounds of chloride was applied per tree annually in. the manure. The leaves of trees receiving manure had more tipburn than had those of any of the other treatments. Haas (14) reports that manure from one source, used in an avocado orchard, contained 23 pounds of chloride per ton of dry manure. Therefore, if tipburn is a problem in an avocado orchard, the use of any manure likely to be high in chloride is open to question.

Phosphate applications also increased the amount of chloride found in the leaves (Fig. 13). The phosphate-treated trees had definitely more tipburn on the leaves than the trees not receiving-phosphate. The treble superphosphate used contained 0.009 per cent chloride. It is unlikely that this small amount of chloride could have had much influence on the level of chloride in the leaves. The influence is probably due directly to the phosphate.

The level of chloride in the leaves was higher in the 1953-54 season than in the 1952-53 season. This may account for the greater amount of tipburn during the 1953—54 season. In this season the leaves on some trees were so badly burned by the end of February that leaf sampling was discontinued. The lower amount of chloride in the leaves in. the 1952-53 season may be due to the fact that the winter of 1951-52 was the only wet winter that has occurred in this area in many years. Therefore, more leaching of chloride probably took place.

Chloride accumulated very rapidly in the leaves until about November and then the level remained rather constant (Fig. 13). Cooper (7) presents data showing a three- to six-fold increase in chloride in avocado leaves of several varieties during the period Iron) June *2* to August 17, 1951.

Sodium:—Results of sodium analyses were variable, and no apparent influences were noted. In this experiment no excess of sodium was observed.

Dry Weight of Leaves:—Potash applications resulted in a lower dry weight per leaf during both seasons (Fig. 14). Smith *et al.* (20) found that the percentage of dry matter in citrus leaves decreased with increase in the amount of potassium applied. Data not reported show that, in the present experiment, nitrogen applications also resulted in a reduction in the dry weight per leaf, but the magnitude was not as great as that from potash applications.

The first samples taken in 1952 had reached a relatively stable dry weight. However, the first sampling in 1953 was taken before the leaves had reached a stable dry weight (Fig. 14). This accounts for some of the differences in concentrations of elements in the leaves at the beginning of each season, especially in the percentage of phosphate (Fig. 3). From July to February the dry weight of the leaves fluctuated very little. There appeared to be a slight increase in the dry weight of the leaves during the latter part of February and dining March and April of 1953 (Fig. 14).

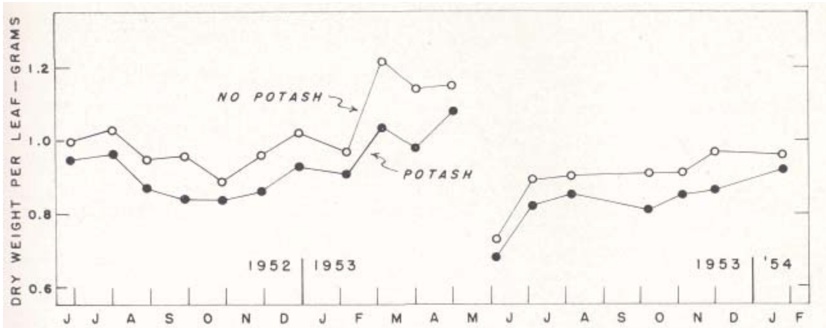


Fig. 14. Relation of sampling date, season, and potash applications to dry weight, in grams, per Fuerte avocado leaf.

SUMMARY

In a Fuerte avocado fertilizer experiment in northern San Diego County, California, leaves that expanded in the period April through June were sampled at monthly intervals during two years. The effects of applications of nitrogen, phosphate, potash, dolomite, and manure on the composition and dry weight of leaves were determined.

Nitrogen applications increased the percentages of nitrogen and phosphorus and reduced the percentages of calcium and magnesium in the leaves, and the dry weight per leaf.

Phosphate applications increased the percentages of phosphorus, calcium, magnesium, and chloride, and reduced the percentage of potassium in the leaves.

Potash applications increased only potassium in the leaves and reduced calcium and the dry weight per leaf. Potash reduced magnesium only slightly.

Dolomite applications increased only slightly the percentage of magnesium in the leaves.

Manure applications resulted in an increase in the concentrations of nitrogen, phosphorus, potassium, and chloride in the leaves.

The percentages of magnesium, calcium, and chloride in the leaves increased, while phosphorus decreased, as the leaves became older.

The percentages of nitrogen in the leaves increased until August, decreased slightly until December to February and then decreased sharply.

The trend for potassium was not consistent, except that the percentage dropped sharply after February.

The dry weight per leaf increased until about July first, leveled off until about February, and then increased slightly thereafter.

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