Nutritional Deficiency Symptoms In Pistachio

CPC Funded Research

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Introduction

With many fruit crops, visual tree symptoms can often be used to help in the diagnosis and treatment of nutritional problems. The use of symptoms can make diagnosis rapid, and sometimes symptoms alone can be used if adequate information on symptoms is available. Unfortunately, in the pistachio, even though it is an ancient crop, very little nutritional information is presently available, especially on deficiency symptoms. Therefore, a project was initiated to develop mineral nutrient deficiencies in pistachio, to characterize, describe and photograph the symptoms and to study certain physiological aspects of the deficiencies.

Methods and Materials

One-year-old grafted pistachio trees (Kerman / *P. atlantica*) were obtained from a commercial nursery in the spring of 1981. The roots of the trees were washed free of soil and the plants placed into containers large enough to hold several dozen trees. They were then grown under water culture using Hoagland solution (0.5 strength) during the rest of 1981 and into midsummer of 1982 when they were transferred into individual pots in a screenhouse. The pots were 5 gallon hard-rubber containers with a polyethylene plastic bag as an inside liner. Air was continually bubbled through the solution. The solution was changed every 2 to 2½ weeks.

In late August of 1982, treatments were begun to develop separate deficiencies of 10 nutrient elements — nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe) and boron (B). In order to create a deficiency of an element, that element was omitted from the Hoagland solution. Thus, there were 11 different Hoagland solutions, 10 of which had a different element missing in each while the 11th was the complete Hoagland solution in which all the elements were present (the control). Five trees were treated with each solution. The frequency of solution change remained the same as before — every 2 to 2½ weeks.

During the growing seasons of 1983 and 1984, the development of deficiency symptoms was monitored. Photographs were periodically taken to follow changes in symptoms.

Leaf tissue samples were taken in midseason in both years. The leaf level of the element that was omitted in the root medium as well as all other elements were determined to evaluate the nutritional status of the treated trees. At the end of the 1984 season, each tree was fractionated into 8 different tissues — small-sized root, medium-sized root, large root, rootstock, '82 shoot, '83 shoot, '84 shoot, and leaf. Dry weight was determined for each fraction and chemical analysis was run for all the 10 different nutrient elements.

As for some physiological aspects of the study, net photosynthesis was monitored periodically throughout the last half of both growing seasons of 1983 and 1984. Photosynthesis was measured by a CO_2 depletion technique. The CO_2 was assessed in an infrared gas analyzer (IRGA–HORIBA VIA A 500R). Leaf area was determined by a leaf area meter (LI-COR LI-3000). Biomass of the different tissues was measured at the end of the experiment.

TABLE 1. Leaf element concentrations in nutrient-deficient and control plants during the seasons of 1983 and 1984.

	1983		1984	
Treatment	**July 16**	**Nov. 9**	**July 21**	**Oct. 4**
Minus N	1.08	0.62 %	0.69	0.60 %
Control	3.07	2.0 %	3.20	2.74 %
Minus P	0.08	0.04 %	0.05	0.02 %
Control	0.32	0.36 %	0.26	0.30 %
Minus K	0.25	0.22 %	0.34	0.29 %
Control	2.53	2.89 %	2.71	3.21 %
Minus Ca	0.04	0.04 %*	0.33	0.62 %
Control	0.88	1.08 %*	1.42	1.62 %
Minus Mg	0.04	0.04 %	0.05	0.03 %
Control	0.23	0.32 %	0.29	0.32 %
Minus B	17	13 ppm	14	24 ppm
Control	210	254 ppm	147	245 ppm
Minus Zn	13	10 ppm	12	13 ppm
Control	—	11 ppm	13	16 ppm
Minus Mn	71	45 ppm	16	17 ppm
Control	214	116 ppm	190	164 ppm
Minus Cu	2.3	2.5 ppm	2.6	2.0 ppm
Control	—	2.4 ppm	208	2.1 ppm
Minus Fe	109	158 ppm	71	108 ppm
Control	—	— ppm	94	77 ppm

*Ca leaf concentration corresponds to Aug. 21, 1983 sampling.

Results

Deficiency Symptoms

Nitrogen

Nitrogen leaf content in minus-nitrogen plants ranged from 0.85% to 0.65% N average values in 1983 and 1984, respectively, compared to 2.53% and 2.97% N in the controls (Table 1).

In the first growing season (1983), bud break and shoot growth were initially normal. However, soon after, evidence of nitrogen deficiency was seen. There was a general decrease in the green color of the glossy appearing leaves. Size of the leaves was reduced also. Shoot growth stopped about early May and no more growth occurred later. Shoots were shorter and thinner than in plants well supplied with N. The bark on the basal part of shoots started to show reddening, the reddening advancing toward the tip of the shoot. As the deficiency became more severe, petioles began showing reddening which continued into the midrib

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of leaflets. A few lower leaves on spurs in the lower part of shoots showed an intense reddening, including the fine lateral veins. These leaves rapidly became chlorotic and dried out.

In early September, the lower leaves of the shoots continued to change color from a greenish yellow to a complete yellow. This early senescence of the leaves advanced upwards to leaves toward the tip of the shoots. The lateral buds in the axil of these leaves toward the end of the shoots were unusually small.

In early November, most of the leaves showed senescence. Some reddening of the lateral fine veins was also observed on senescing leaves near the terminal of the shoots.

The following spring (1984) the initiation of bud growth was slightly delayed (about a week). Shoot growth was markedly shorter and slender. Growth occurred only from the apical buds and stopped early in the season (late April). The leaves were of normal-shape but smaller. They lost their green color as the season advanced, similar to the previous year, but within a shorter time. Reddening also appeared earlier and a more severe reddening of the fine lateral veins in the leaves was evident (early July).

In late September, small dark brown spots developed on both sides of the midrib in senescing leaves. Also, the process of senescence occurred earlier than in the previous year.

The root system was drastically reduced. Lateral growth was limited and the main roots remained short, thin and sparse.

Phosphorus

Average phosphorus leaf content values of 0.06% and 0.04% P were found in minus-phosphorus plants during the 1983 and 1984 seasons, respectively, compared to control tree values of 0.34% and 0.28% P (Table 1).

The first evidence of deficiency of phosphorus was a general restricted growth with shorter shoots and internodes. The leaves were slightly smaller, otherwise normal in color and shape.

In late June, a slightly reddish color began to appear on the bark in the lower part of some of the shoots and also on the petioles. In mid-summer as the deficiency became more severe, the bright green color of the leaves turned to a dull green.

Later on (mid August), small light-brown necrotic spots, irregular in shape, started to appear mainly close to the margins of the lower leaves on the shoots. These spots became more numerous and gave to the leaflet a bronzy appearance. Enlargement and fusion of the necrotic areas occurred and sometimes involved more than one-fourth of the leaflet blade. These necrotic spots were localized mainly in the central-margin area and expanded toward the tip and midrib of the leaflets.

As the deficiency became more acute, the color of the old leaflets changed to a yellowish green. Later, the leaflets lost the green color entirely and the tissue dried up. After this, leaves shed rapidly.

Late in the fall, leaves in the upper part of some of the shoots showed a marginal chlorosis that expanded rapidly toward the midrib.

The following spring, initiation of growth was delayed. Some apical buds failed to grow. The initiation of necrotic spots on the leaves was earlier. Senescence and leaf shedding also occurred earlier.

The total root system was reduced somewhat, but lateral root growth was severely reduced.

Potassium

Minus potassium plants varied from 0.23% to 0.32% K average values in their leaf content during the season of 1983 and 1984, respectively, compared to 2.71% and 2.96% K in the control (Table 1).

Potassium deficiency symptoms appeared in 1983 as soon as shoot growth started. Many new leaves had a pale green color. Some leaves were greener and had a glossy appearance. In late May, the pale basal leaves of shoots, even though showing a slight interveinal chlorosis, began to change to a more greenish color. In mid-summer the foliage appeared dull green.

Plant growth was definitely restricted. Shoots were shorter and thinner. Leaves also were smaller. The shape was slightly roundish, especially of apical leaves. The petioles, midrib and sometimes the lateral fine veins were pale green to whitish throughout the season.

After early June the lower leaves on some shoots showed a marginal fading of the leaflets which advanced toward the midrib. Some interveinal chlorosis was also apparent. In general, the loss of color of the leaf margin was followed by darkening and later, necrosis of the tissue. In a few cases, there appeared numerous small necrotic spots throughout the blade which became larger in size with time. The marginal chloro-

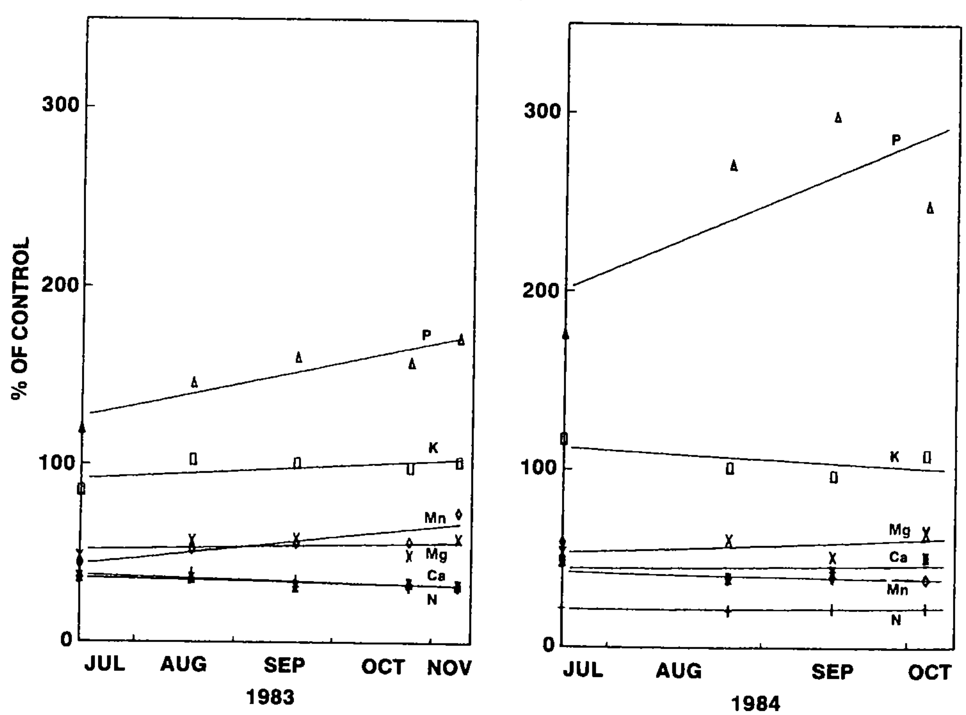

FIGURE 1. Effect of minus-nitrogen on the leaf contents of several ions during 1983 and 1984.

sis and necrosis developed throughout the summer in most of the lower leaves and eventually in the upper leaves. Frequently, a severe marginal scorching was accompanied by the leaf being bowed downward with the scorched edges curled down sharply.

In the next season (1984) the symptoms were more severe and appeared earlier. Foliage was initially quite pale with a general interveinal chlorosis in the blades. The new leaves that formed later may have been slightly greener but were still faded.

Plant growth was markedly restricted in shoot and internode length. Leaf size was also smaller. In early May, marginal scorch on leaflets developed rapidly in the lower shoots, often without the prior appearance of a marginal chlorosis. Later, leaf scorching also appeared in the middle leaves of lower shoots and with the tip of the leaflet curled downward. Finally in late August, marginal chlorosis and necrosis of leaflets were generally present in most of the leaves, but especially in the lower part of shoots.

Calcium

Minus-calcium plants had leaf Ca contents that averaged 0.04% and 0.48% Ca in 1983 and 1984, respectively, while the controls averaged 0.98% and 1.52% Ca (Table 1).

Early in the 1983 season, top growth was severely reduced. Shoots were scarce, short and slender. Leaves were sparse, thin, small and roundish with short and thin petioles.

The youngest leaves at the shoot tips showed the first symptoms. The tips of leaflets became chlorotic and curled upward and later became necrotic. Also, growth ceased and the terminal buds became dormant. Later, the basal leaves showed tip chlorosis and scorching that progressed over the whole blade with the leaves eventually shedding. In mid-season the plant was almost defoliated and most of the leaves that remained had a chlorotic and wilted appearance. Some dieback and lateral bud drop occurred.

The following season, as the deficiency became more acute, the symptoms were more severe. A pronounced dieback was present in some plants. New shoot growth was severely restricted and the leaves appeared wilted. The symptoms were so severe that there was fear that the trees may not survive. Thus, beginning in late May, a very small amount of Ca was added to the root medium to keep the plants alive.

Partial recovery was soon seen in shoot and root growth in some plants. Leaves were larger and thicker, glossier and darker green. Later on, however, deficiency symptoms appeared again. Shoots ceased to grow and some of the leaflet tips became necrotic and curled upward. The dark green color of the leaves, however, remained.

Root growth was dramatically curtailed with lack of Ca. Most of the fine and medium sized roots showed dieback. The roots became stubby with reduced amounts of live tissue.

Magnesium

Minus-magnesium plants had about 0.04% Mg in the leaves in both 1983 and 1984 compared to about 0.3% Mg in the controls (Table 1).

The early foliage of the affected plants had a dull, pale green color. Leaves were thick and severely curled downward. A light tip or marginal fading appeared in the leaflets of the lower-most leaves on the shoots. Interveinal chlorosis or yellow mottling appeared in these areas and eventually resulted in a bronze or a light brown scorched area along the apical and lateral margins of the leaflets. The scorch progressed inward toward the midrib leaving an inverted green "V" area at the base of the leaflets.

A striking symptom of magnesium deficiency was the appearance of necrotic lateral veins within the scorched areas prior to the actual scorching. The pattern of scorching of the lateral margins of the leaflets may appear similar in both Mg and K deficiencies but in K deficiency necrosis of the fine lateral veins cannot be seen prior to scorching.

In advanced stages of scorching, the lateral areas of the blade were covered with small dark brown spots before the death of

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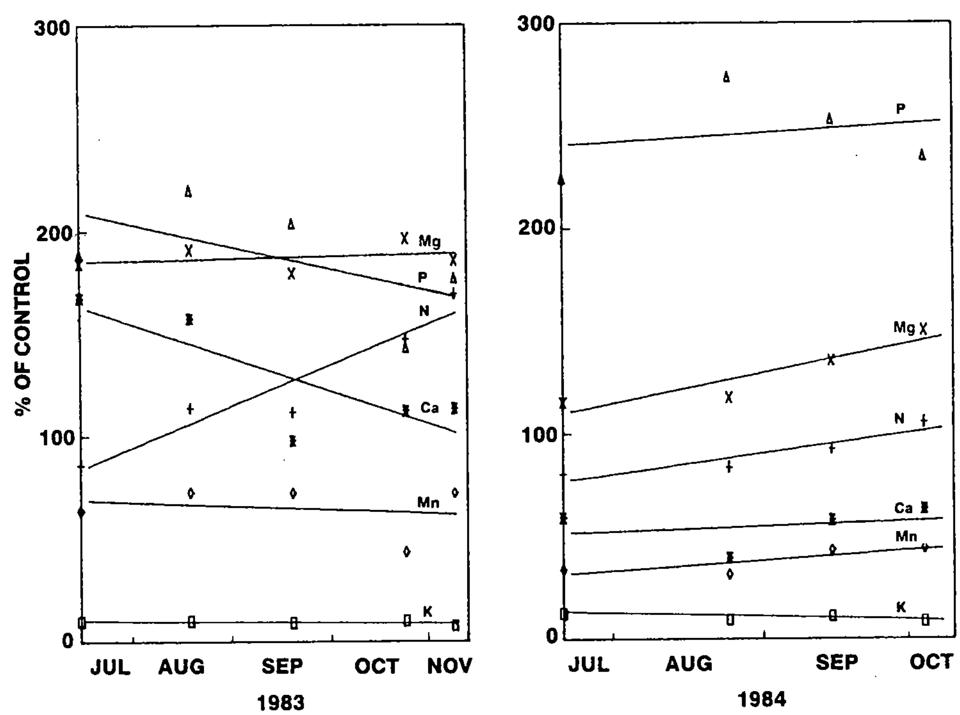

FIGURE 2. Effect of minus-potassium on the leaf contents of several ions during 1983 and 1984.

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the whole leaflet. Once the leaves were fully scorched, they became brittle and shed. Mg deficiency symptoms appeared initially in the basal leaves and then in the leaves above them.

Some dieback was noticed, mainly in some of the upright shoots.

In the next season, growth was severely delayed. At bud break buds showed a temporary red color that disappeared as the shoots grew. New shoots were extremely stunted, sparse, thin and rosetted. Leaves were small, roundish, and of pale green color. Early dieback occurred in some shoots. Scorching of the lateral margins of leaflets occurred earlier and were more rapid in development. Sometimes the scorch was randomly distributed.

In late summer the shoots were quite defoliated.

The root system was severely reduced. New growth was scarce and some dieback of the roots was evident during the season.

Boron

Boron leaf content in minus-boron plants averaged around 15 ppm and 19 ppm B in 1983 and 1984, respectively, compared to 232 ppm and 196 ppm B in the controls (Table 1).

The symptoms of boron deficiency were manifested in many different ways.

Initially, the first 3 or 4 nodes in some shoots grew normally and a complete leaf developed from each node. Shoot growth later became progressively weaker with small, deformed leaves on short petioles and, finally, as B became limiting, only rudimentary leaves were formed. Usually the shoot tip became necrotic and the terminal bud died. Sometimes, the killing of the growing point in the shoot stimulated the growth of lateral buds below it, producing shoots that eventually were also restricted in growth, causing a bushy type of appearance.

On many of the shoots, irregular sunken and raised (blister-like) areas developed on the bark, initially in the upper part of the shoot. Later these areas developed into necrotic lesions with the surface often cracked.

An important symptom of B deficiency in early growth was leaf deformation. Leaves became twisted, cupped, puckered, crinkled or irregular in shape. Size was usually reduced. Some leaves showed veins that stood out prominently. Leaves were dark green with a glossy luster.

As these leaves matured, the foliage became pale green and deformities became more obvious and various other symptoms appeared. The different symptoms were not all present on any one plant but could be found scattered over several of the B-deficient plants.

Some leaves showed interveinal chlorosis or a yellow mottling near the lateral margins. In some cases these symptoms extended to the midrib, thus covering most of the blade. Some leaves had a leathery appearance, some were rough, thick, curled, and brittle. Petioles also became thicker, brittle and sometimes with cracks on the surface.

The next season, growth was severely delayed. All the shoot tips were dead from the previous season. New shoots were arising mainly from wood below the dieback. The length of the terminal part of the shoots that died varied from an inch to over a foot. Even some shoots from lateral buds were killed soon after emergence. The shoot dieback phenomenon can be considered to be one of the most important symptoms of B deficiency.

The new foliage was again initially dark green and glossy. Soon after, however, the same deficiency symptoms in the shoots, bark, growing points and leaves as described for 1983 appeared in 1984.

The root system in B deficient plants was severely damaged. Very poor root growth occurred and dieback of the fine and medium sized roots was observed during the growing seasons.

Zinc, Copper, Manganese and Iron

The omission of these elements from the root media did not produce visual deficiency symptoms in the plants during the two years of the trial. The reason for the lack of symptoms becomes clear when the leaf concen-

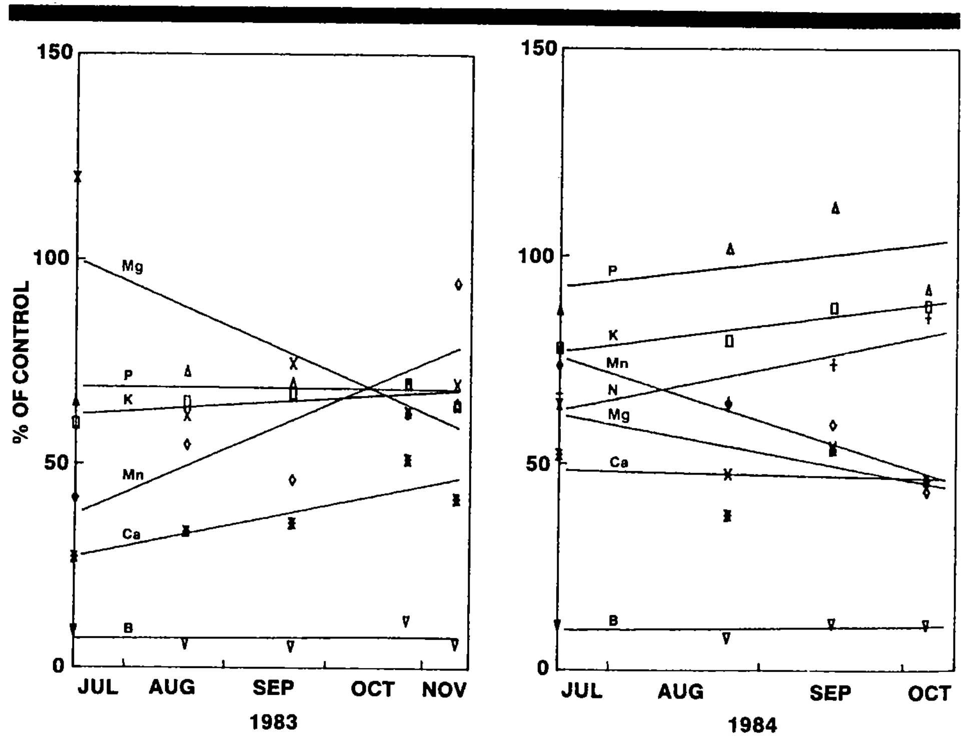

FIGURE 3. Effect of minus-boron on the leaf contents of several ions during 1983 and 1984.

trations in the treated trees are considered (Table 1).

In the minus-Zn plants, the leaf Zn concentration was 12 ppm and 13 ppm in 1983 and 1984, respectively, while the controls averaged 11 ppm and 14 ppm Zn. The Zn levels in both treatments were the same.

The same was true with Cu. The minus Cu and the control plants both averaged about 2.4 ppm Cu in the two years.

In the case of manganese, the minus-Mn plants showed a considerable reduction in leaf Mn (58 ppm) but was not low enough in 1983 to produce symptoms. Even a further drop in 1984 to 17 ppm Mn did not produce symptoms. Perhaps if the trial had been carried on another year, the Mn level would have declined further and become low enough to produce symptoms.

In the iron treatment, there was no difference in leaf Fe levels between the minus-Fe plants and the controls. Perhaps a third year of trial was necessary in all four of these minor element treatments.

Nutrient Interaction

The absence or presence of an element in the root medium can affect the level of that element in the plant. We have seen that a deficiency of an element has resulted in a very low concentration of that element in the leaf. However, the absence of an element may affect the uptake and distribution of other elements in the plant. This effect is termed ion interaction which is defined as the enhancing or depressing effect of one ion in a tissue on the accumulation of other ions in that tissue.

Clear ion-interaction effects have been detected when certain nutrient elements were removed from the nutrient solution.

When nitrogen was deficient, Ca was the most depressed ion (Fig. 1). Mg and Mn were also depressed to some extent (Fig. 1). P, on the other hand, accumulated tremendously, reaching levels 3 times that in the control.

Omission of potassium from the root medium resulted in low contents of Mn and Ca. However, Mg and P levels were considerably increased. At the end of the 1984 season, P leaf content was 2.5 times that of the control (Fig. 2).

When boron was omitted from the nutrient solution Ca was again the element that was most reduced (Fig. 3). Mg, Mn, K and N were also significantly depressed.

TABLE 2. Net photosynthetic rate — August 1, 1983

Treatment	(nmol $CO_2 \cdot cm^2 s - 1$)	Relative to Control (%)
Minus N	0.41	61
Minus P	0.58	87
Minus K	0.60	90
Minus Ca	0.13	19
Minus Mg	0.39	58
Minus B	0.38	57
CONTROL	0.67	100

TABLE 3. The effect of nutrient deficiencies on whole plant and root dry matter accumulation at the end of 1984

Treatment	Whole Plant (grams)	Relative to Control (%)	Root (grams)
Minus N	126	24	31
Minus P	225	42	52
Minus K	169	32	31
Minus Ca	85	16	16
Minus Mg	109	21	19
Minus B	118	22	24
CONTROL	531	100	113

Influence on Photosynthesis and Dry Matter Accumulation

Photosynthesis

Photosynthetic measurements made in midsummer of 1983 showed that nutrient-deficient trees, no matter what the deficient element, have reduced capacity for photosynthesis (Table 2). There was only a slight reduction in the minus-K and P plants, considerable, in the minus-N, Mg and B, and a very severe reduction in the minus-Ca plants. Photosynthesis is necessary for the normal growth of the plant and the production of dry matter. Thus a reduction in photosynthesis can lead to less growth and smaller trees. This is borne out by the data on dry matter accumulation (Table 3).

Dry matter accumulation

The deficiency of any of the nutrient elements reduced dry matter accumulation (Table 3). The reduction in dry matter production followed very closely the reduction in photosynthetic capacity of the plants (Table 2). The greatest reduction in the weight of the whole plant occurred in the minus-Ca trees just as did the photosynthetic capacity. Minus-N, Mg and B plants showed a considerable reduction in plant weight. Photosynthetic capacity in these treatments was also reduced considerably.

With roots, the greatest reduction in weight occurred in the minus-Ca, Mg, and B treatments. Leaf weight was mostly reduced in the minus-Ca, Mg, B and N treatments.

NOTE: Since colored photos of deficiency symptoms could not be put into this report, they will appear in another publication.