A SURVEY OF THE NUTRITIONAL STATUS OF APPLE ORCHARDS IN LEBANON

By

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NUTRITIONAL STATUS OF APPLES

KHAN

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AN ABSTRACT OF THE THESIS OF

Abdul Haq Khan for M.S. in Horticulture

Title: A survey of the nutritional status of apple orchards in Lebanon.

A preliminary survey of apple orchards was conducted in the Beqa'a Plain of Lebanon in June of 1965. Twenty orchards were visited for the collection of leaf samples during June, 1965. Leaf samples were analysed for eight elements and their levels were compared with the critical levels.

The results of this study revealed that phosphorus and magnesium among macro-nutrients and iron among micro-nutrients were in the deficiency range in the majority of the orchards.

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I. INTRODUCTION

The apple industry in Lebanon, although of recent origin, has considerable economic importance in that it is the second most important fruit after citrus (22, p. 1). It is grown extensively in the mountanous and sub-mountanous areas. A considerable portion of the production is exported to other middle eastern countries. Within recent years there have been rapid developments in the industry such as the use of commercial fertilizers as a source of nutrients and the use of new insecticides and fungicides for the control of pests. However, very few investigations have been made into the basic requirements of the crop for maintaining normal growth of the trees and continuous successful production of good quality fruit in Lebanon.

One of the factors which has been shown repeatedly to be essential for trees to be productive over a period of time is that they receive all the required nutrient-elements in proper amounts and proportions. Studies conducted by Dauok (22), Abukhalil (1), and Nasrallah (39) are insufficient to serve as a guide to apple nutrition.

In order to investigate the nutritional condition of apple orchards in the Beqa'a Plain and to evaluate their general nutritional status, a preliminary survey was conducted in June of 1965, in which leaf samples were collected from two apple varieties from 20 orchards for tissue analysis. At the same time the growers were interviewed in order to ascertain their cultural and fertilizer practices. This thesis is a report of this preliminary survey.

II. REVIEW OF LITERATURE

Chemical Analysis of Plants as a Means of Diagnosis of Nutritional Status

The use of leaf analysis as a diagnostic tool towards understanding the nutritional requirements of plants is well known. It is also known that the levels of nutrients may become inadequate for optimum growth and fruitfulness before the appearance of deficiency symptoms. Chemical analysis of plant tissue with close observations on the behaviour of trees and their general appearance, therefore, is a useful guide to fertilizing of fruit trees. According to Reuther (43, p. 76) visual symptomology is very suggestive in cases of moderate to acute boron, calcium, molybdinum, nitrogen, phosphorus, potassium, and sulphur deficiencies and moderate to acute boron, manganese, potassium sulphate, chlorine, sodium, and lithium excesses. In all cases, leaf analysis is required to "firm up" the diagnosis. Moreover, deficiencies of magnesium, manganese and copper can not be diagnosed visually in the incipient stages as specific deficiency symptoms do not develop. In addition, deficiency symptoms of nutrients like nitrogen, sulphur, and potassium are quite similar; plants deficient in any of these nutrients show a general yellowing of foliage, dieback of twigs and failure to grow. Chemical analysis of leaves makes possible a clear cut differential diagnosis in such circumstances.

Roach (45), working with agricultural and horticultural crops, found that a hidden deficiency of one or more essential nutrient-elements may reduce the yield of crops an economically important amount. In potato, he found that, although plants did not show any symptoms of calcium and magnesium deficiency, leaf analysis revealed deficiency of these nutrients. When the deficiencies were corrected, the yield increased significantly. Thompson and Roberts (57) reported that in cases of multiple deficiencies of iron, manganese, and zinc, the leaf symptoms were not enough for the diagnosis of disorder. The dull yellow color of the foliage could be associated with neither iron nor manganese deficiency with certainty, but analysis of the leaves revealed that the disorder was associated with deficiencies of iron, manganese and zinc. They suggested that visual symptomology should not be depended upon under such complex cases.

It is generally recognised in the literature that soil analysis is not always a satisfactory guide to the fertilizing of fruit crops. The nutrient uptake by plants is affected by the effect of complementary ions, ion antagonism, differential feeding power of plant roots and binding power of different types of clays for mono and divalent ions. For fruit crops, it is also difficult to obtain a representative sample of soil to the depth explored by the roots of trees (7, pp. 229-231; 46, pp. 459-464; 51, pp. 81-84). Leaf analysis based on appropriate methods of sampling and correct interpretation of data, can lead to a better assessment of the nutritional status of such perennial crops and their responses to different fertilizer treatments.

The leaf has been generally accepted to be the most appropriate for analysis not only because it can be sampled easily but also because the bulk of the plant is built up of organic compounds synthesised from raw material in the leaves. It's composition, therefore, is the only valid criterea of the nutritional status of plants (48; 59, p. 106).

Critical Levels

Macy (34, pp. 750-754), in 1936, introduced the concept of "critical nutrient percentage" in leaf dry matter. According to the author, for any given plant there exists a fixed critical percentage for each nutrient. Plant growth would be effected whenever a change in the nutrient balance occurred. He recognised three stages.

1. A narrow "minimal percentage range" in which

response increases without any change in the nutrient concentration in the plant tissue.

2. A "poverty adjustment range" where there is an increase in both response and internal concentration.
3. A "luxury consumption range" when there is little or no response but the internal concentration increases.

Ulrich (59, p. 102) in 1943, defined "critical nutrient levels" as the concentration ranges at which plant growth is restricted when compared with plants at higher nutrient levels. Plants with widely differing nutrient composition may give similar yields as long as their nutritional condition is above the critical level and properly balanced. This definition, however, ignores all upper nutrient levels at which plant growth is adversely affected as a result of nutrient excesses.

Goodall and Gregory, as reported by Bould *et al.* (7, p. 231), considered the following two sets of factors to be responsible in conditioning plant growth.

1. The external factors such as light, temperature, water, and nutrient supply.
2. The internal factors which are nutritive and hormonal.

They suggested that there is an optimum intensity level for each of these factors, at which the maximum potential growth will occur. Hence, the nutrition of plant is influenced by the whole complex of the environment and not solely by the availability of nutrients.

The establishment of critical foliar standards or levels for use in separating the conditions of nutrient sufficiency from those of deficiency or excesses requires a considerable amount of research. Such information can be obtained by growing plants in culture solutions and in field experiments conducted in such a manner as to give yield responses at varying levels of one element while maintaining constant levels of others. Information on critical levels obtained only through solution culture studies on young trees cannot be considered valid for application to the condition of mature trees because the nutrient availability in solution culture differs considerably from that in the soil. The physiological age of a mature tree is another factor contributing to making the results of studies on young plants invalid under such conditions (54, p. 572; 36).

For the interpretation of the results of leaf analysis surveys, it was necessary to establish standard values for each nutrient-element that would demarcate levels of deficiency, sufficiency and excesses. Emmert (24, p. 6), in 1955, by compiling the results of published data of foliar analysis of apple orchards surveyed by different workers in different parts of the world, arrived at a set of standards for nitrogen, phosphorus, potassium, calcium, and magnesium which he called "critical levels". He defined these critical levels as:

1. The range of nutrient concentrations below which a restriction in plant growth occurs in case of deficiencies when compared with plants at higher nutrient levels.
2. The range of nutrient concentrations above which a restriction in plant growth occurs in case of excesses when compared with plants at lower nutrient levels.

The range of concentrations in which plant growth is normal he called the desirable range, that at which plants were restricted in growth due to deficiencies he called the low range and that due to excesses he called the high range.

Emmert's critical levels (for macro-nutrients) have been accepted by many workers (6; 40, p. 6; 61; 62, p. 24) and they are approximately the same as the standard values or critical levels proposed by Kenworthy (32), Beattie and Ellenwood (4), and Thomas et al. (56, p. 9). As stated by Emmert (24, p. 7) these critical levels should not be considered to have rigid and sharp demarcations but to have areas of transition between optimum and sub-optimum conditions.

For micro-nutrients, critical levels for iron and boron have been suggested by Walker and Mason (60) and Kenworthy (32). Insufficient information is available for zinc so no critical levels have been established.

Elements Determined

Nitrogen: Nitrogen deficiencies are very common in apple orchards. In general a deficiency of nitrogen results in reduction in growth but, under conditions of severe deficiency, injury to tissue may occur. Nitrogen requirements of apple trees vary from year to year in the same orchard, in different orchards at different locations and under different systems of management (8, 39).

Phosphorus: Phosphorus fertilization is believed to be no problem in apple orchards. It has been shown that apple trees responded to phosphorus fertilizer in very few cases even when the results of leaf analysis revealed a deficiency of this element (44). Phosphorus requirements of apple trees is one tenth of nitrogen, potassium or calcium. It's deficiency is rare under field conditions because mature apple trees may store sufficient amounts of phosphorus to support normal growth for several years after the soil has become deficient in it (2, p. 113; 3; 21, p. 59; 27, pp. 174-179; 28, p. 194; 38, p. 312; 42, pp. 177-178; 44; 61, p. 23).

Potassium: Potassium deficiency is generally associated with high lime content of the soil. It also has been shown by many workers that lack of response to potassium fertilizer is due to inadequate nitrogen in the soil (2, p. 113; 15; 16, p. 62; 21, p. 55; 43, p. 65; 63). The level of potassium nutrition may vary over a wide range without any effect on tree condition and production (42, p. 179).

Calcium: Little evidence is available to show that liming the soil is of any direct benefit to fruit trees except on naturally acid soils or on soils where acid fertilizers have been used for a long time. When compared with its content in the soil, calcium requirements of apple trees is negligible. However, after nitrogen and potassium apple trees require calcium in larger quantities than any other nutrient-element. High calcium content of the soil is believed to reduce the availability of certain other elements (3; 5, p. 313; 19, p. 205; 27, p. 254; 42, p. 179).

Magnesium: Apple trees growing on acid soils of low exchange capacity usually show symptoms of magnesium deficiency (11). Leaching of magnesium on such soils is rapid and the use of excessive amounts of nitrates of soda, potash or high calcium forms of lime may accentuate the deficiency (29, p. 199; 42, p. 179).

Iron: Lack of iron in plants appears to interfere with nitrate metabolism (41). Chlorosis in plants may result from a deficiency of iron, nitrogen, magnesium and perhaps some other nutrient-elements but the effect of iron deficiency is more rapid and pronounced (27, p. 253; 49, p. 221). Increased absorption of calcium by plants growing on alkaline calcarious soils causes immobilization of iron within the plant resulting in chlorosis (37, pp. 320-332).

Boron: Various types of boron deficiencies have been described which usually appear on limestone soils, acid soils, sandy soils and on dry or extremely wet soils. Boron deficiency may show itself in the development of internal cork on the fruit in one year and external cork the following year (27, p. 195; 28, p. 200). Any soil management which affects the nitrogen supply also affects the boron content of the leaves in apples (33). Plants can absorb boron from a solution of very low concentration but there is little correlation between total boron content of the soil, its concentration in soil solution and the appearance of deficiency symptoms (27, p. 196).

Zinc: Zinc is essential for plant growth and development but is required in very small quantities. Zinc deficiency is a problem of fruit trees in arid regions and any condition that restricts root development is conducive of zinc deficiency (18, p. 643; 20, p. 49). Availability of zinc in the soil is lowest in the pH range of 5.5 to 6.5 . Replacement of native cover crops with cover crops of low zinc requirements accompanied by indiscriminate use of lime results in increasing zinc deficiency (17; 26, p. 64).

Nutrient uptake and the nutritional condition of fruit trees is influenced by the whole complex of the environment in which the plant is growing and by the physiological age of plant (51, p. 92). Beattie and Ellenwood (4) reported that there were considerable variations in all the nutrients because of wide differences in soil and climatic conditions, differences in tree age and other factors. In most cases nitrogen, potassium, magnesium, and boron values were so low as to be insufficient for most satisfactory growth. Simon (50) observed significant differences for nitrogen, calcium, magnesium, and iron in leaves of the same variety taken from different places at different height on the same tree, on different dates during the growing season and in leaves of different varieties in the same orchard. It appears from the work of Walker and Mason (63) and Smith (51, p. 93) that chemical composition of leaves from the same trees is different in different years. Moreover, they found that phosphorus and calcium were deficient in most of the orchards as indicated by leaf analysis but deficiency symptoms of neither of these nutrients were found in any of the test orchards. Mohsin Nour (40, pp. 16-20) found through leaf and soil analysis that in orchards growing on soils with high pH (more than 6.5) phosphorus was in the deficiency range in most of the cases in southern Mexico. There was an increasing trend in leaf and soil phosphorus content as the soil pH decreased towards the Northern part of the country. Potassium, calcium, and boron were in the desirable range in leaf samples from orchards growing on sandy soils while magnesium was high and iron in the low concentration range in the majority of cases. Nitrogen was deficient in almost all samples because of low organic matter content of the soil and negligence on the part of growers to add nitrogen to the soil. Emmert (25, p. 14) found that deficiencies of bases were most common in apple orchards growing on soils with a pH below 6.5.

In Lebanon a few studies of the nutritional status of apple trees have been conducted in an exploratory fashion. Daouk (22, pp. 23-41) determined leaf nitrogen in Golden Delicious and Red Delicious apples on Malling VII, Malling IX and <u>Malus communis</u> understocks. Leaf samples were collected in intervals of 21 days between May 14 and October 18 during one season. This study indicated that average leaf nitrogen in leaves of Golden Delicious on different rootstocks varied in 1957 from 2.94 percent to 3.25 percent and in Red Delicious from 2.57 percent to 3.08 percent (22, p. 24). A comparison of the nitrogen content in the leaves from trees of the same variety on different rootstocks showed that trees on the seedling rootstocks (Malus communis) had the lowest nitrogen content on almost all sampling dates. This study was conducted on trees that had received 25 Kg of pig manure per tree in the fall followed by 15 Kg per tree of a mixture of cow, pig and goat manure in the winter, and the orchard was irrigated with water that contained pig urine (22, pp. 16-17).

Abukhalil (1, pp. 24-57), working on boron and preharvest drop in apples, analysed leaf samples of Red Delicious for different elements by taking leaf samples at monthly intervals between June 29 and October 1, 1958. The trees from which leaf samples were collected had been receiving normal management practices for the area including the use of mixed fertilizer and vetch as a cover crop. He found that nutrient-elements in the leaves sampled on June 29, were in the following concentration ranges (1, p. 137).

Nitrogen	2.34	to	2.68	percent
Potassium	1.58	to	1.96	percent
Calcium	1.05	to	1.55	percent
Phosphorus	0.166	to	0.234	percent
Magnesium	0.21	to	0.40	percent
Iron	42	to	60	ppm
Boron	48	to	62	ppm

Nasrallah (39, pp. 42-71), working on the seasonal variation in nutrient content of leaves of Golden Delicious and the effect of rootstocks on the mineral composition of scion leaves reported that differences occurred in composition during 1959 as compared with that in 1960 and that the nitrogen, phosphorus and calcium content of the leaves from trees on the understocks French Crabapple and Malling VII were on lower than those of trees on Malling II whereas the potassium and magnesium content were lower in the trees on Malling II than in trees on either of the other stocks during both years of the study. The average nutrient content of leaves sampled in the beginning of June were:

	1959	1960
Nitrogen	2.75 to 2.90	2.96 to 3.05 percent
Potassium	2.33 to 2.78	1.70 to 1.95 percent
Calcium	1.92 to 2.10	1.56 to 1.76 percent
Phosphorus	0.163 to 0.180	0.173 to 0.199 percent
Magnesium	0.33 to 0.42	0.29 to 0.39 percent
Iron	65 to 76	137 to 161 ppm

The yearly fertilizer program consisted of 5 Kg of organic compost plus 1.25 Kg of superphosphate and 0.6 Kg of Potash per tree applied in fall.

III. MATERIALS AND METHODS

Selection of Orchards

This study was conducted on orchards in the Beqa'a Plain, which is one of the major apple growing areas in Lebanon. Twenty orchards were visited between June 23 and June 30, 1965: the period during which the composition of leaves is relatively stable and mineral shifts are at a minimum (10, pp. 344-346; 20, p. 18; 25, pp. 527-540; 27, pp. 168-174; 39, pp. 42-71; 51, p. 85). In accordance with the general practice in the selection of orchards for a nutritional survey of this type, those orchards were chosen in which it was believed that the grower had been doing at least a minimum of management practices and as such their conditions represented an average nutritional condition.

Selection of Trees in Orchards

The study was conducted on orchards of Golden Delicious and Red Delicious varieties. These occupy the largest part of the area in Lebanon devoted to commercial production of apples (22, p. 1). Small orchards constituted a single block but large ones were divided into two or more blocks for the purpose of this survey. In each orchard block, five trees each of each variety were selected and contributed to two single variety composite samples (4, 32). In order to avoid large differences in soil, trees were selected which were growing in close proximity to each other, were of comparable size and vigor, and showed little or no sign of any disorders (4). All trees from which leaf samples were taken were in production and at least seven years in age. In all 90 composite samples were collected from the 20 orchards.

Information obtained through a questionaire (Appendix B) indicated that the growers were not particular in the use of rootstock. Both seedling and Malling rootstocks were used indiscriminately. No restriction on the rootstock could, therefore, be placed while selecting trees for leaf sampling. Other information about the frequency of irrigation, kinds and amounts of fertilizers used, and the spray material and the date of last spraying was obtained from the growers through the questionaire completed at the time of leaf sampling.

Leaf Sampling

Leaf sampling methods used by different workers (12; 23; 35; 52; 55; 61, p. 22; 62) vary only for the number of leaves taken from each tree or the number of trees making up a sampling unit. The method used in the present study was patterned after Kenworthy (32) as improved by Walker and Mason (60) and Moon and Hymas (38). From each tree, two mid-shoot leaves from the current season's extension growth were collected from ten different shoots around the periphery of the tree. Leaves were taken at about chest height from the ground level. Leaves which showed signs of insect or mechanical damage or were abnormal in appearance were rejected. The leaves from the five trees of the same variety from each block were combined to constitute a composite sample. Each composite sample thus consisted of 100 leaves. To avoid diurnal variation in the nutrient content of the leaves, sampling was done between 7:00 and 11:00 A.M. (14). Each sample was placed in a labled paper bag and taken to the laboratory.

Shoot Measurements

The extension shoots of the current season's growth from which leaf samples were taken were measured to the nearest centimeter at the time of leaf sampling. Average shoot length of each composite sample thus was the mean of 50 shoots measured at 10 different places on each of the five trees forming the sampling unit.

Preparation of Samples for Analysis

Leaf samples were cleaned the same day they were collected. Before and after cleaning, and before drying, the samples were stored in a refrigerator to avoid losses in dry weight through respiration. For the removal of surface contaminating substances arising from dust particles and spray residues, a number of workers (9, 12, 53) have suggested different washing techniques. The washing procedure adopted in the present work was that recommended by Taylor (53) and Bradfield and Bould (13). These workers recently examined the different cleaning methods and concluded that washing with a mild detergent solution followed by washing in running tap water and finally rinsing thoroughly with distilled water resulted in the most efficient removal of surface contaminations.

Washing was completed within 30 seconds and excess water was removed from the leaves by shaking. The leaves were then returned to the original paper bag and were dried in a forced draught oven at 70^{0}C for 48 hours. The dried material was then ground in a Wiley Mill to pass through a 40 mesh sieve (4). The ground material was stored in soft-glass jars for subsequent analysis.

Chemical Analysis

The elements determined were nitrogen, potassium, calcium, phosphorus, magnesium, iron, boron, and zinc. The results for the macro-nutrients nitrogen, potassium, calcium, phosphorus and magnesium were expressed as percentages of dry weights and that of the micro-nutrients iron, boron and zinc as parts per million. Total nitrogen was determined by the modified Kjeldahl method as described by Jackson (30, pp. 183-193) using 2.000 grams of the oven dried ground material. Boron was determined according to the method of Johnson and Ulrich (31, pp. 62-64) using 0.50 gram of oven dried ground material for ashing. For the determination of total potassium, calcium, phosphorus, magnesium, iron, and zinc 2.000 grams of oven dried ground material was digested with concentrated nitric acid and 70 percent perchloric acid as described by Toth _et al_. (58). Subsequently, phosphorus, magnesium, iron, and boron were determined colorimetrically by color reactions with stannous chloride, thiozole yellow, cucurmin-oxalic acid and o-phenonthroline, respectively, using a Beckman Model B Spectrophotometer; calcium and potassium were determined using a Beckman flame attachment to the Model B Spectrophotometer; and zinc was determined by using a Perkin-elmer Model 303 Atomic Absorption Spectrophotometer.

Comparison of Results of Foliar Analysis

Emmert's critical levels (24, p. 6; Table 1) were used for the comparison of the levels of nitrogen, potassium, calcium, phosphorus, and magnesium in the leaf samples. Boron and iron contents in the leaves were compared with the critical levels proposed by Kenworthy (32) and Walker and Mason (60). These critical levels are given in Table 1. The critical level for zinc has not been established because of insufficient data being available (60).

Since there were unequal numbers of samples collected from different orchards, the mean value of each nutrient-element was determined for each variety in each orchard; the mean values were used for comparison with the critical levels. The distribution of the mean values and their relationship with the concentration ranges is represented by means of histograms.

Table 1. Critical levels of eight nutrient-elements as suggested by Emmert, Kenworthy and Walker, and Mason.

Nutrient-element	Desirable range
Nitrogen[x]	1.9 % to 2.4 %
Potassium[x]	1.2 % to 1.8 %
Calcium[x]	1.0 % to 1.6 %
Phosphorous[x]	0.18% to 0.26%
Magnesium[x]	0.24% to 0.36%
Iron[xx]	more than 40 ppm
Boron[xx]	14 to 84 ppm
Zinc	not established

[x] Proposed by Emmert. (24).

[xx] Proposed by Kenworthy and Walker and Mason (60).

IV. RESULTS AND DISCUSSION

The results of leaf analysis for the eight elements and the distribution of levels of nutrients in different orchards according to variety in different concentration ranges are shown in Table 2 through 9 and Figure 1 through 8. Ranges used are low, desirable and high. No attempt has been made to correlate the results of the foliar analyses with the amounts and kinds of fertilizers used in different orchards, since efforts to evaluate or correlate the effect of fertilizers in influencing the chemical composition of leaves provides very little useful information unless the nutritional status of the trees in these orchards prior to the application of fertilizer, is known.

Nitrogen

Figure 1 shows the distribution of the levels of nitrogen in the orchards according to variety in the low, desirable and high ranges. From the figure it is evident that 82.5 percent of the orchards were in the desirable concentration range, 17.5 percent were in the high range and none were in the low range. Among the orchards with high levels of nitrogen, 12.5 percent were close to the desirable range having 2.5 percent nitrogen on a dry

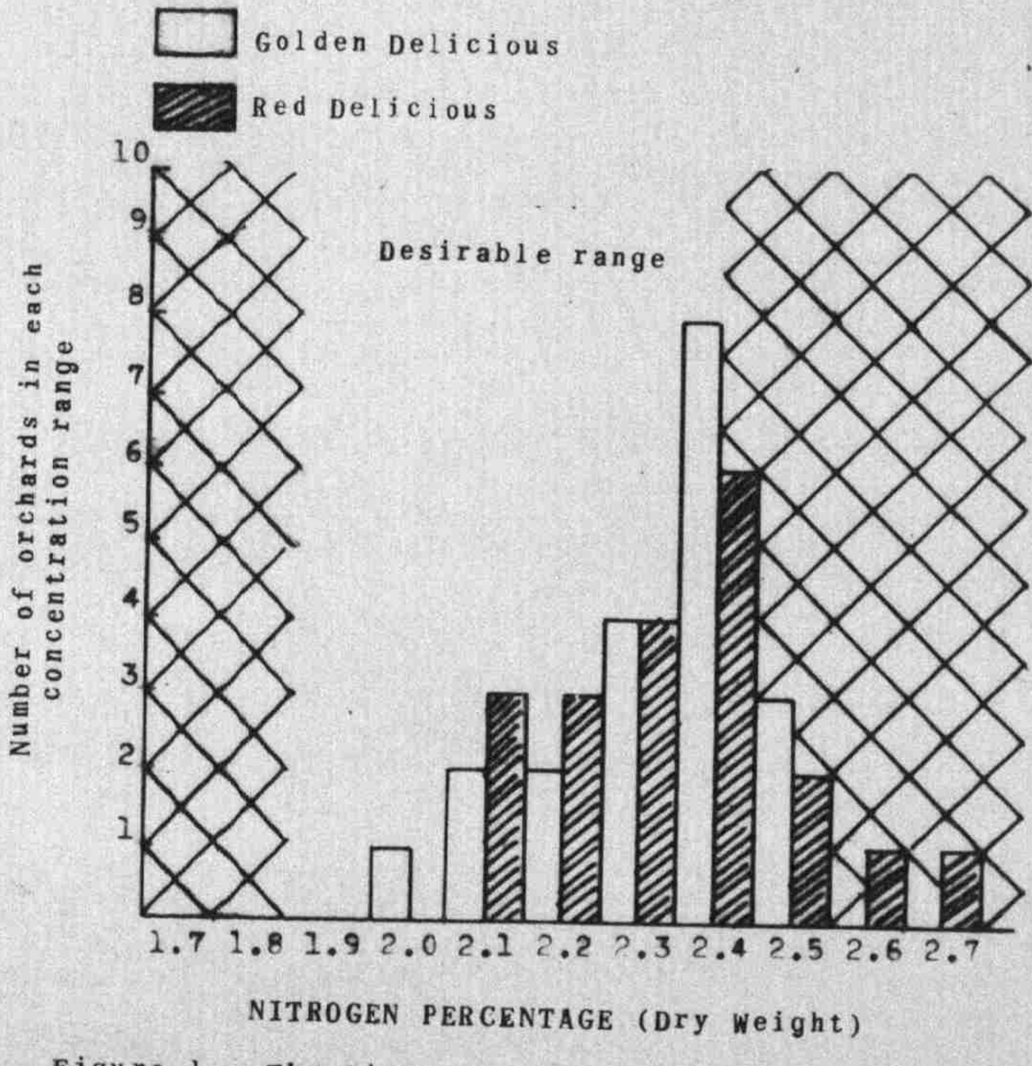

Figure 1. The Nitrogen percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

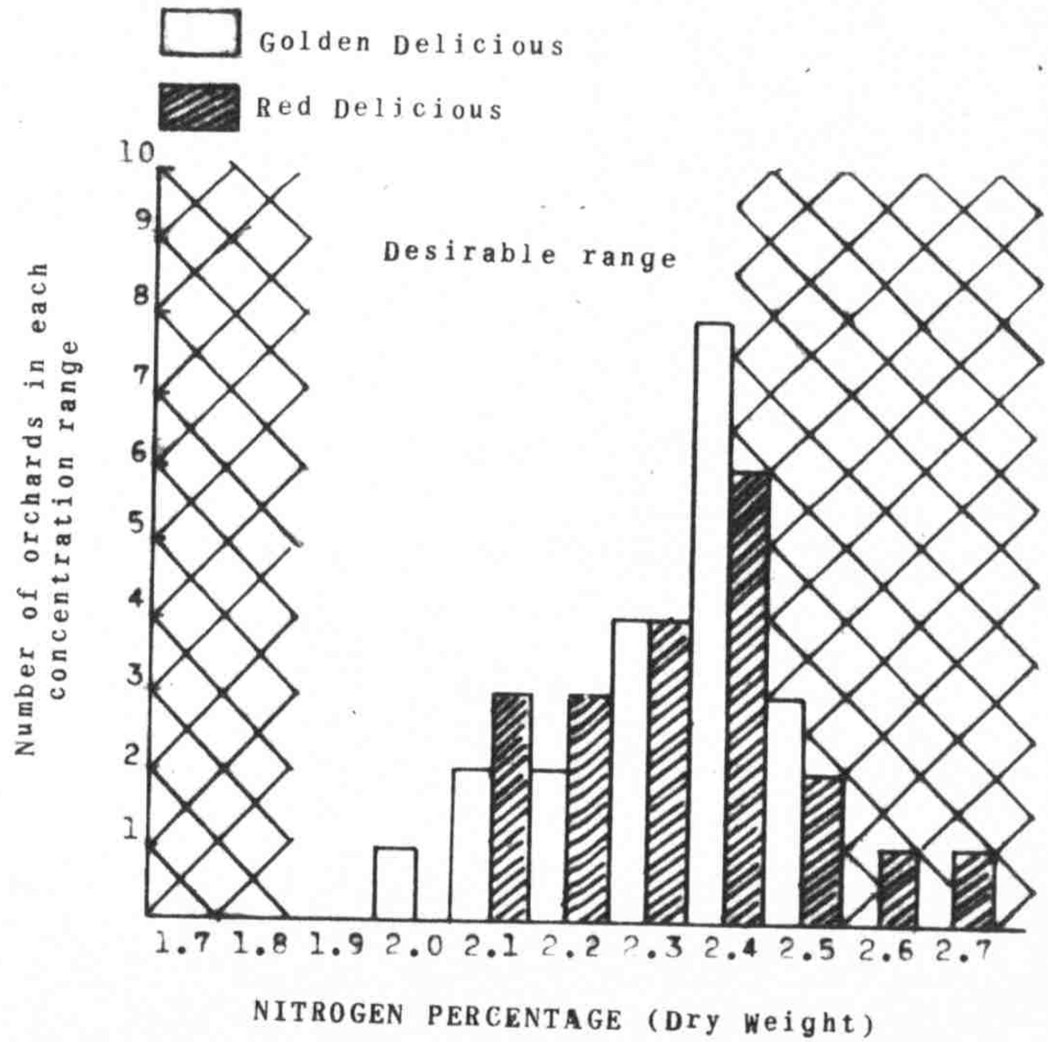

Figure 1. The Nitrogen percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

weight basis. Since these critical levels are considered areas of transition between optimum and sub-optimum or above optimum conditions, it can be concluded that only 5 percent of the orchards (having more than 2.5 percent nitrogen) had nitrogen contents well above the optimum range, while 95 percent of the orchards were within the desirable range.

The nitrogen content in the leaves of the two varieties in different orchards ranged between 2.0 and 2.5 percent for Golden Delicious with an average of 2.33 percent, and between 2.1 and 2.7 percent for Red Delicious with an average of 2.34 percent (Table 2). Daouk (22, p. 36) found that the average nitrogen content ranged between 3.41 and 3.53 percent in the leaves of Golden Delicious and between 2.99 and 3.15 percent in the leaves of Red Delicious sampled on 25th of June. Nasrallah (39, pp. 43-45) reported that nitrogen in the leaves of the Golden Delicious variety, on different rootstocks, when sampled during June varied from 2.75 to 2.90 percent with an average of 2.83 percent in one year and from 2.96 to 3.0 percent with an average of 2.99 percent in the second year. Abukhalil (1, p. 137) observed that nitrogen in the leaves of Red Delicious, sampled on June 29, was 2.55 percent on the average.

The average nitrogen content in the leaves of Golden Delicious and Red Delicious as reported by these

Table 2. Nitrogen content (% dry weight) in the leaves of Golden Delicious and Red Delicious apples, in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	2.5	2.5
2	2.3	2.4
3	2.2	2.7
4	2.4	2.3
5	2.4	2.2
6	2.2	2.4
7	2.3	2.4
8	2.4	2.4
9	2.5	2.1
10	2.4	2.4
11	2.5	2.5
12	2.1	2.4
13	2.4	2.3
14	2.1	2.2
15	2.3	2.2
16	2.4	2.3
17	2.0	2.1
18	2.3	2.1
19	2.4	2.6
20	2.4	2.3
Mean	2.33	2.34

workers are high as compared with those observed during the present study (Table 2). The possible explanation for these differences are discussed later in this chapter because it will be seen that such differences occur in case of all nutrient-elements.

Nitrogen is one element that is generally regarded by the growers as necessary to be applied annually. Informations obtained from the growers as presented in Appendix A indicates that most of the growers whose orchards were visited used nitrogen either in the form of commercial fertilizer or as animal manure or mixed. There were, however, a few who did not use any manure or fertilizer. It is, therefore, not surprising that the nitrogen status of the majority of orchards was satisfactory.

Potassium

Potassium content of apple leaves and the levels of potassium in different orchards according to variety in different ranges are shown in Table 3 and Figure 2, respectively. It is evident from the figure that 17.5 percent of the orchards were low in potassium, 72.5 percent in the desirable range and 10 percent were high in potassium. In the leaves of Golden Delicious, potassium ranged between 1.1 and 1.9 percent with 1.5 percent on the average. In Red Delicious it was between 0.9 and 2.4 percent with 1.5 percent on the average. These values are

Table 3. Potassium content (% dry weight) in leaves of Golden Delicious and Red Delicious apple in different orchards in Beqa'a Plain, surveyed during June, 1965.*

Orchard No.	Golden Delicious	Red Delicious
1	1.3	1.3
2	1.5	2.0
3	1.6	2.4
4	1.4	1.5
5	1.5	1.4
6	1.2	1.3
7	1.5	1.5
8	1.4	1.4
9	1.4	2.3
10	1.1	1.6
11	1.7	1.3
12	1.1	1.2
13	1.6	1.3
14	1.7	1.6
15	1.3	1.7
16	1.4	0.9
17	1.8	1.6
18	1.9	1.3
19	1.5	1.8
20	1.6	1.2
Mean	1.48	1.53

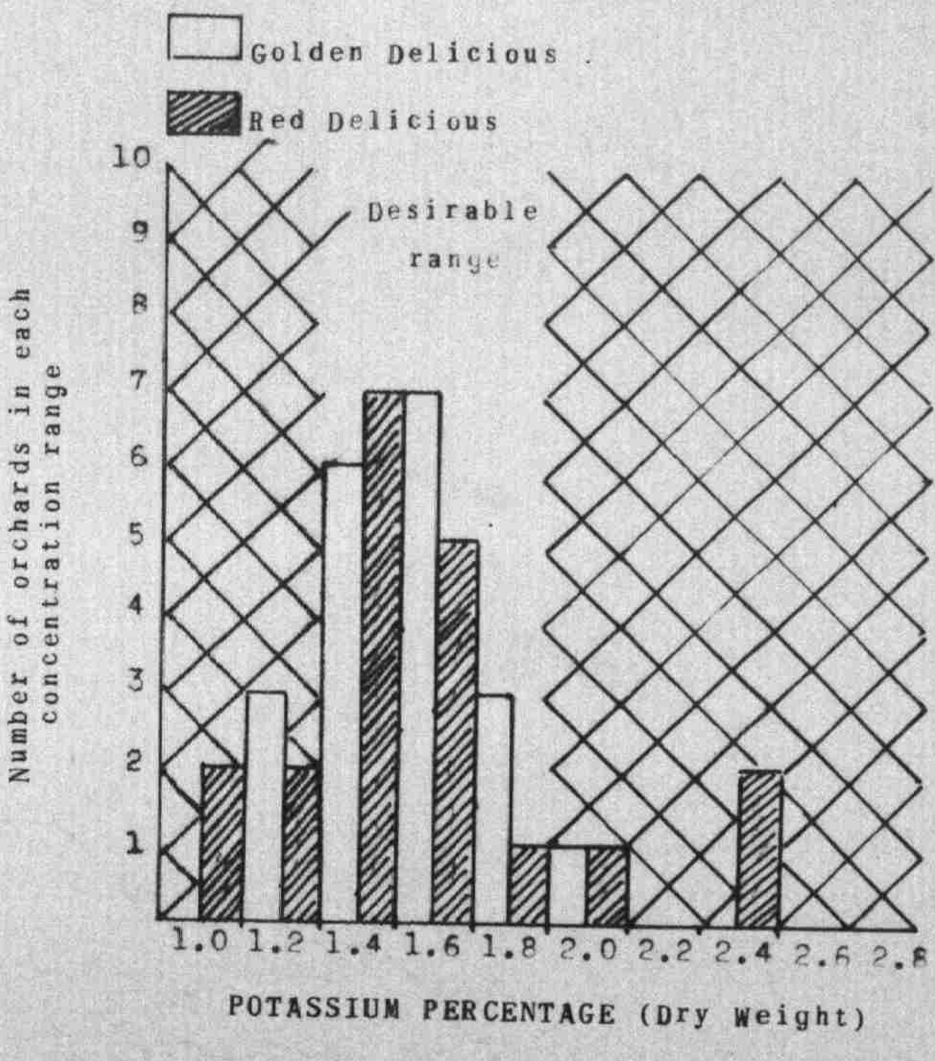

Figure 2. The Potassium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

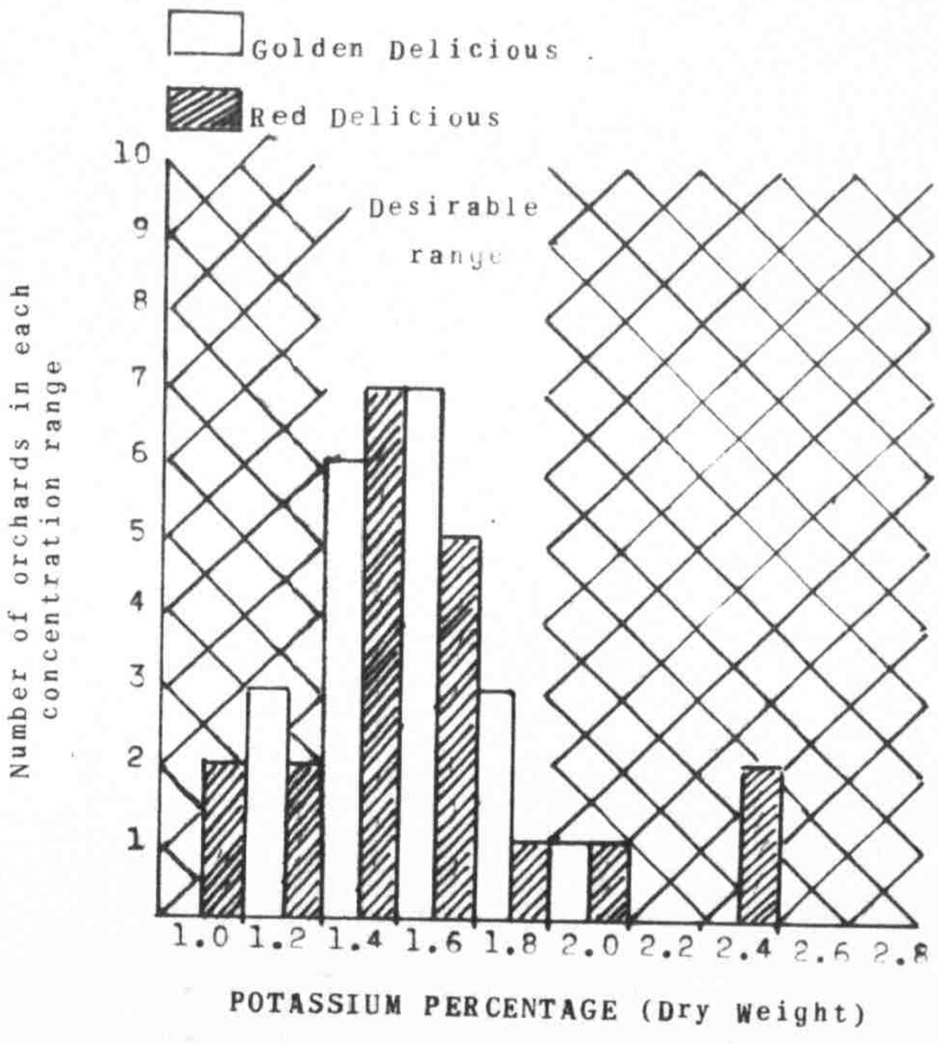

Figure 2. The Potassium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

slightly less than those reported by Abukhalil (1, p. 137). He found that in the leaves of Red Delicious potassium was in the range of 1.6 and 2.0 percent with 1.8 percent on the average. Nasrallah (39, pp. 153-156) reported still higher values. He found that potassium in the leaves of Golden Delicious sampled in June, 1959, was in the range of 2.3 and 2.8 percent, and 1.7 and 2.0 percent when sampled in June, 1960, with an average of 2.5 and 1.8 percent, respectively, during the two consecutive years of his study.

Calcium

Investigations by Salib (47, p. 65) into the chemical and physical properties of soils in the Beqa'a Plain indicate that the soils are alkaline calcareous in nature. The pH ranges between 8.0 and 8.3 while the calcium carbonate content ranges between 34.7 and 71.1 percent. Figure 3 presents the distribution of the levels of calcium in orchards according to variety in different ranges and Table 4 shows the average calcium content in the leaves in different orchards. Among the five major elements, calcium was found in most of the orchards in fair condition. Of the orchards 92.5 percent were in the desirable range with 7.5 percent high in calcium and none in the low range.

The average calcium content in samples from

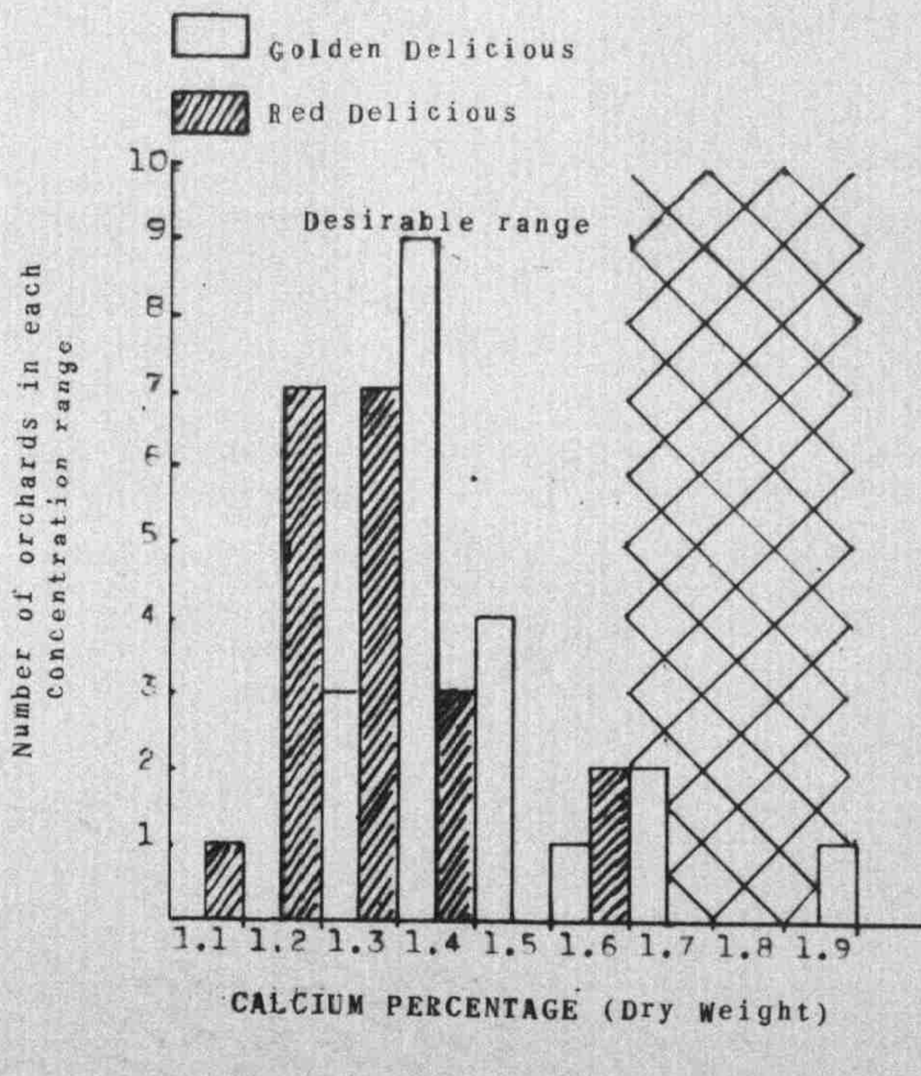

Figure 3. The Calcium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

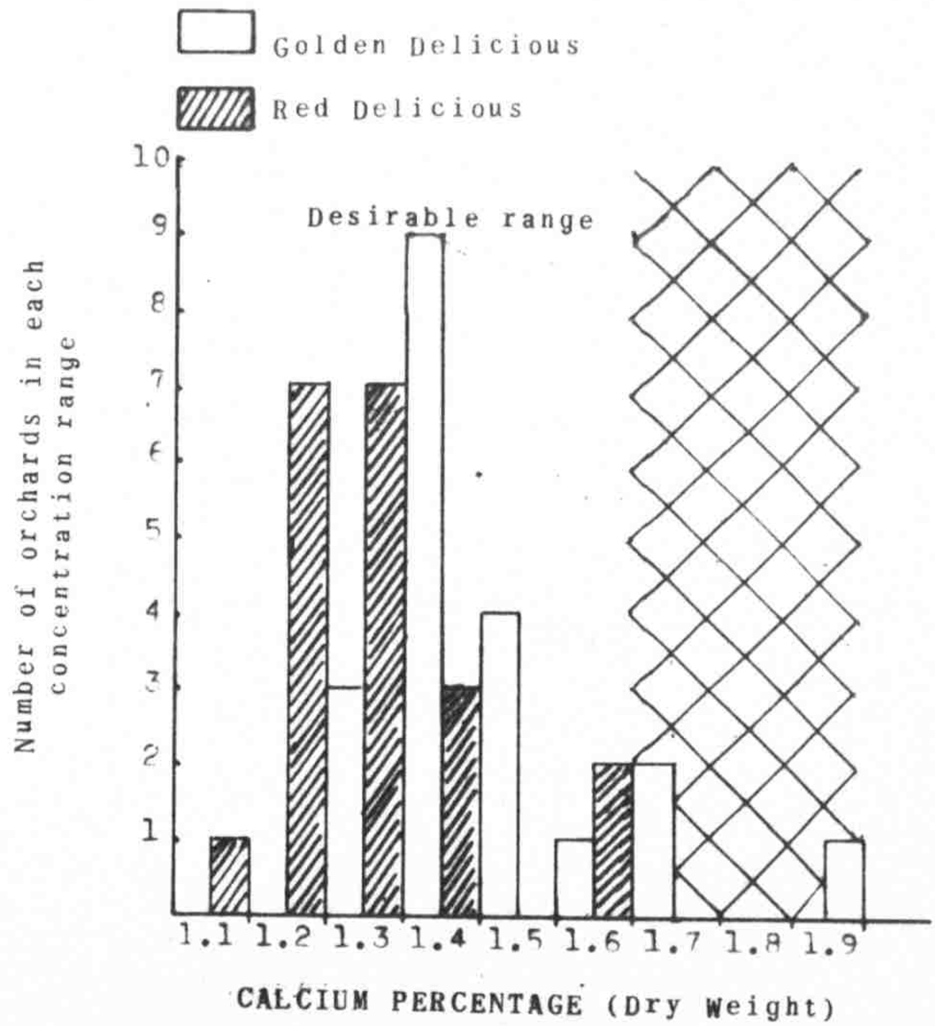

Figure 3. The Calcium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

Table 4. Calcium content (% dry weight) in leaves of Golden Delicious and Red Delicious apple in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	1.5	1.3
2	1.4	1.3
3	1.3	1.4
4	1.5	1.3
5	1.5	1.2
6	1.9	1.3
7	1.4	1.2
8	1.4	1.4
9	1.4	1.2
10	1.7	1.6
11	1.6	1.6
12	1.4	1.2
13	1.4	1.3
14	1.4	1.2
15	1.3	1.1
16	1.4	1.2
17	1.4	1.3
18	1.5	1.4
19	1.7	1.3
20	1.3	1.2
Mean	1.5	1.3

different orchards ranged between 1.3 and 1.9 percent in the leaves of Golden Delicious and 1.1 and 1.6 percent in the leaves of Red Delicious. The average calcium content in the 20 orchards was 1.5 percent in the leaves of Golden Delicious and 1.3 percent in the leaves of Red Delicious. These results are close to those reported by Abukhalil (1, p. 137) but are less than those reported by Nasrallah (39, pp. 60-64). The latter worker found that in the leaves of Golden Delicious the calcium content was from 1.92 to 2.10 percent with an average of 2.04 percent in one year and from 1.6 to 1.8 percent with an average of 1.7 percent in the second year.

Phosphorus

The percentage of phosphorus in the leaves and the distribution of the levels of phosphorus in orchards according to varieties in different categories are shown in Table 5 and Figure 4, respectively. Of the orchards 75 percent were low in phosphorus, 25 percent in the desirable range and none in the high range. Phosphorus content in the leaves of Golden Delicious ranged between 0.122 and 0.192 percent with an average of 0.166 percent and in the leaves of Red Delicious between 0.117 and 0.200 percent with an average of 0.169 percent. These values are lower than those reported by Abukhalil (1, p. 137) and Nasrallah (39, pp. 46-51). For Red Delicious Abukhalil reported

Table 5. Phosphorus content (% dry weight) in leaves of Golden Delicious and Red Delicious apples, indifferent orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	0.180	0.136
2	0.179	0.180
3	0.165	0.164
4	0.122	0.188
5	0.154	0.147
6	0.158	0.155
7	0.169	0.138
8	0.192	0.198
9	0.187	0.188
10	0.165	0.172
11	0.161	0.171
12	0.181	0.200
13	0.166	0.184
14	0.144	0.144
15	0.174	0.174
16	0.158	0.133
17	0.178	0.199
18	0.144	0.200
19	0.177	0.198
20	0.158	0.117
Mean	0.166	0.169

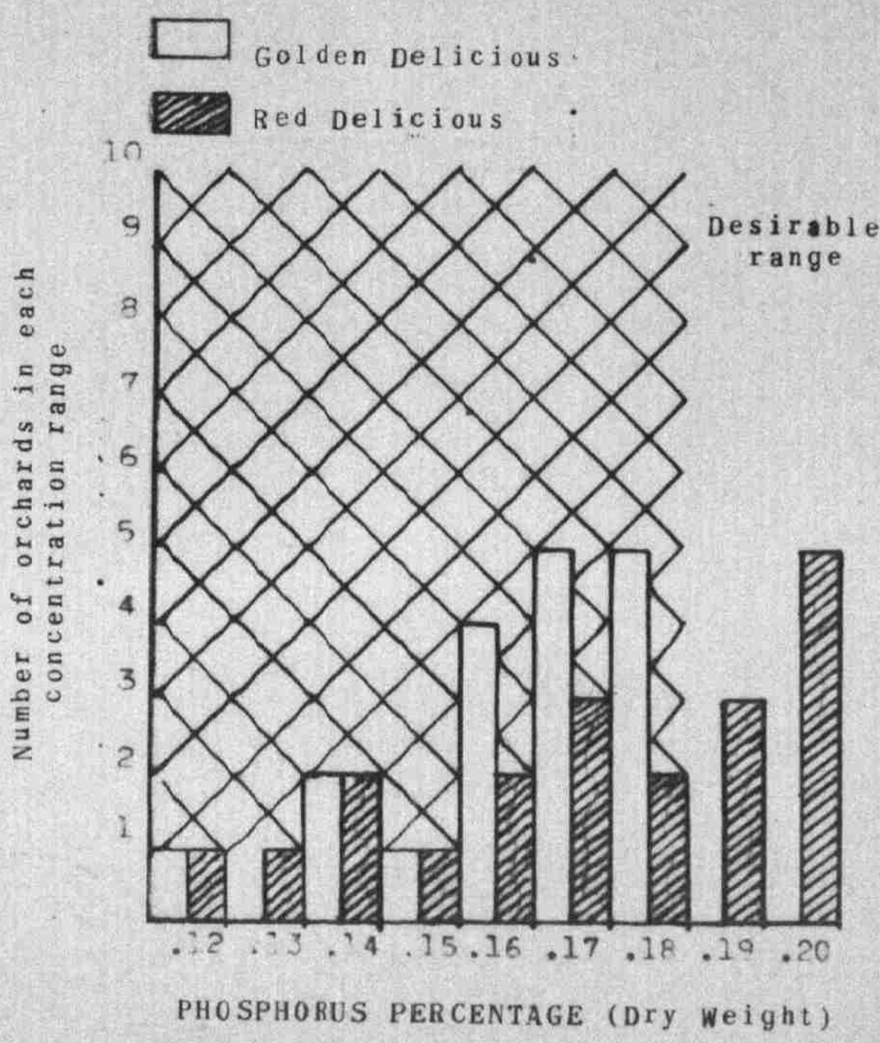

Figure 4. The Phosphorus percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

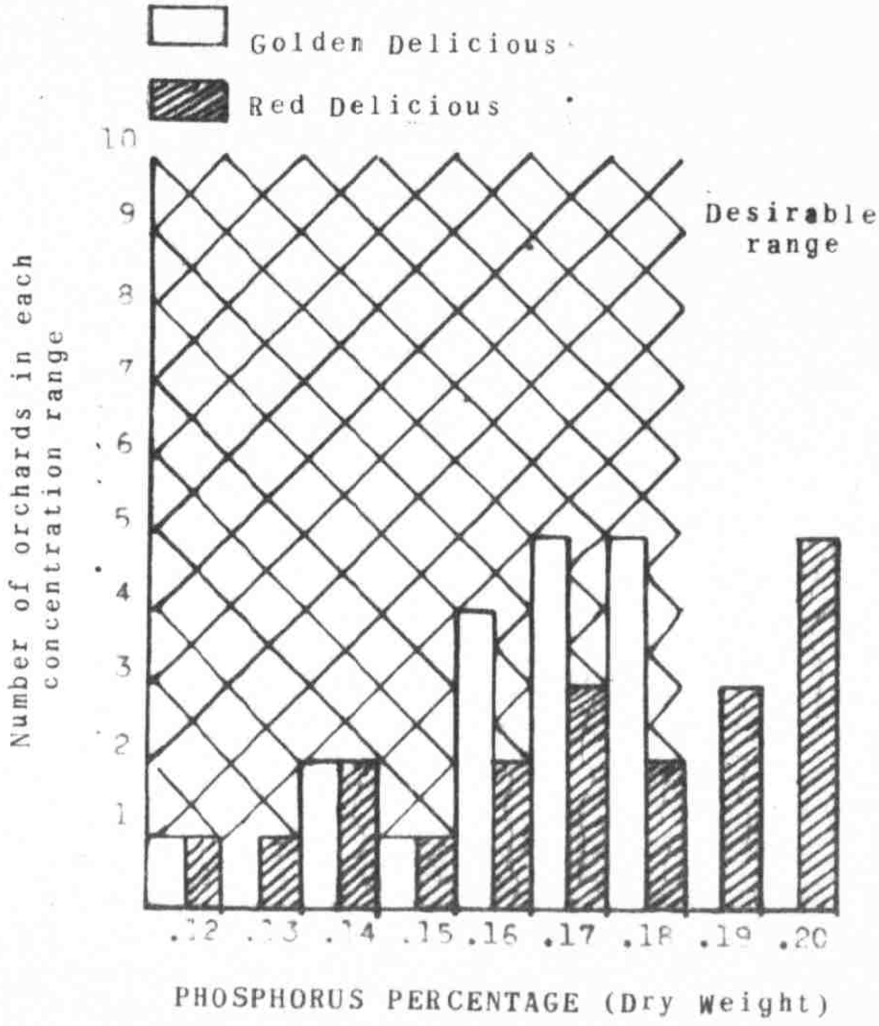

Figure 4. The Phosphorus percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

that the phosphorus content in the leaves ranged between 0.166 and 0.234 percent with an average of 0.200 percent, while for Golden Delicious Nasrallah found that it was from 0.163 to 0.180 percent with an average of 0.174 percent in one year and from 0.173 to 0.199 percent with an average of 0.189 percent in the second year.

Magnesium

The concentration of Magnesium in the foliage was found below the critical level in the majority of the orchards. As shown in Figure 5, 82.5 percent of the orchards were low in magnesium, 17.5 percent in the desirable range and none in the high range. The average magnesium content in the leaves of Golden Delicious ranged between 0.158 and 0.298 percent with an average of 0.221 percent and in the leaves of Red Delicious between 0.150 and 0.283 percent with an average of 0.222 percent as shown in Table 6. In the studies conducted by Nasrallah (39, pp. 56-60) magnesium content in the leaves of Golden Delicious was from 0.33 to 0.42 percent with an average of 0.36 percent in one year and from 0.29 to 0.39 percent with an average of 0.32 percent in the second year. For Red Delicious Abukhalil (1, p. 137) reported that it ranged between 0.21 and 0.40 percent with an average of 0.30 percent. The average values reported by these workers are higher when compared with 0.22 percent found in the present

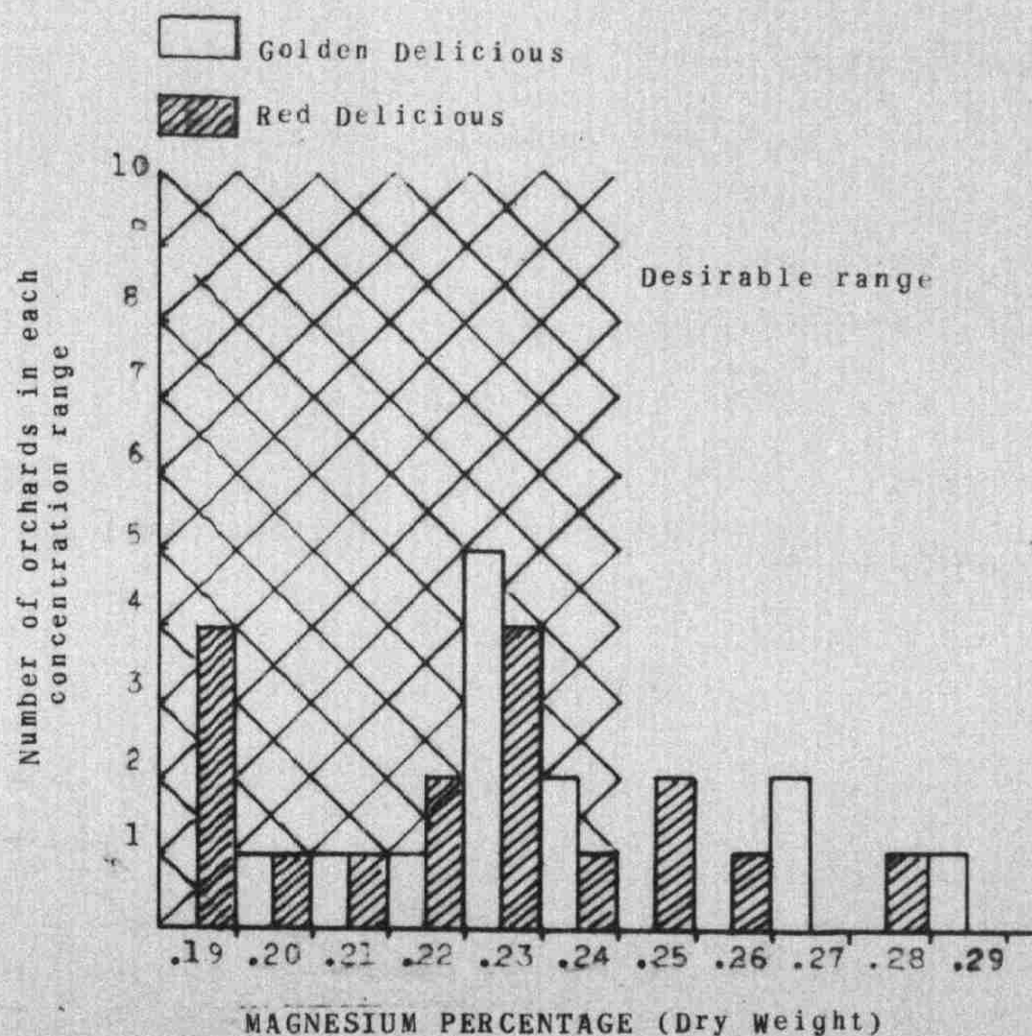

Figure 5. The Magnesium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

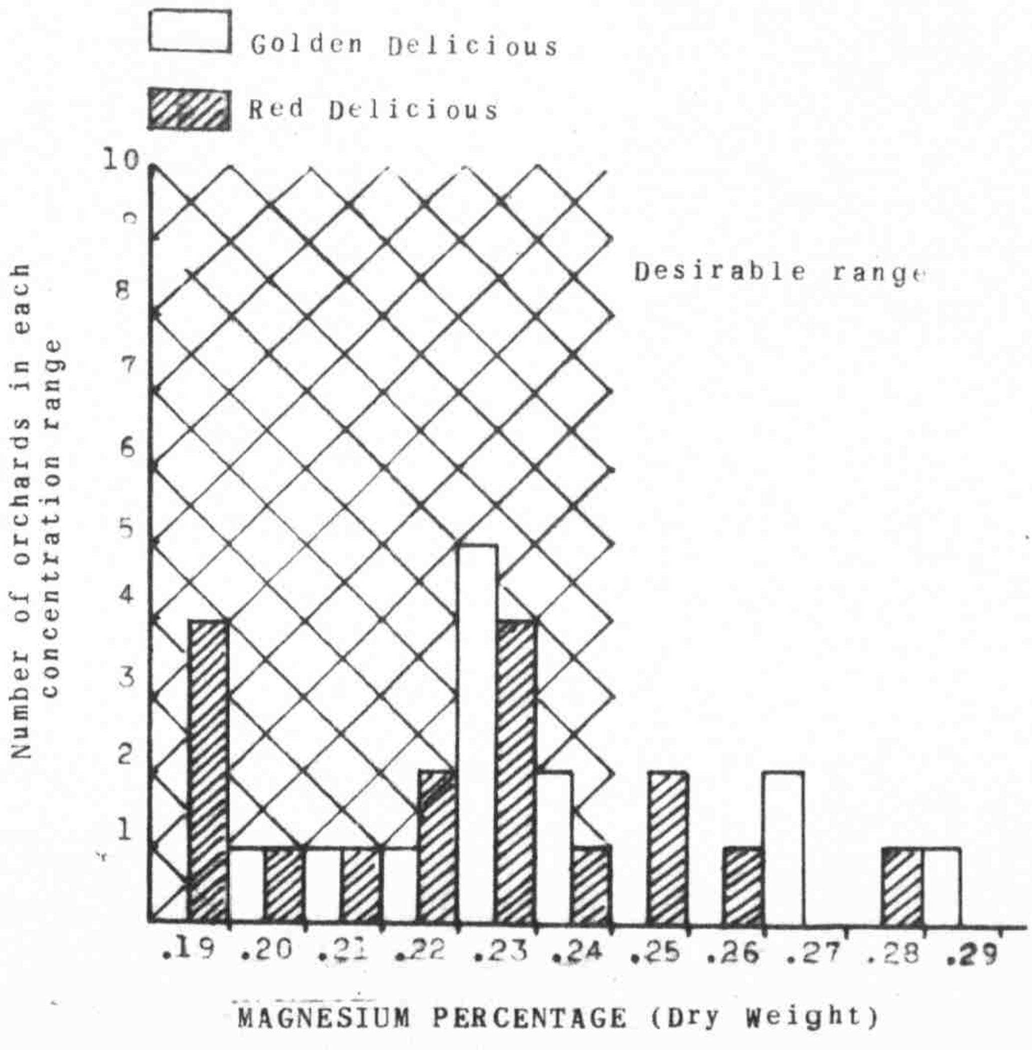

Figure 5. The Magnesium percentage in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

Table 6. Magnesium content (% dry weight) in leaves of Golden Delicious and Red Delicious apple in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	0.190	0.278
2	0.233	0.228
3	0.210	0.240
4	0.215	0.250
5	0.230	0.248
6	0.190	0.195
7	0.298	0.230
8	0.241	0.259
9	0.270	0.230
10	0.231	0.206
11	0.158	0.150
12	0.175	0.185
13	0.212	0.216
14	0.175	0.205
15	0.220	0.178
16	0.227	0.220
17	0.200	0.283
18	0.230	0.185
19	0.240	0.230
20	0.268	0.218
Mean	0.221	0.222

study.

Iron

When compared with the critical levels proposed by Kenworthy (32), the levels of iron in different orchards according to variety were found low in 75 percent of the orchards as shown in Figure 6. Whether this is due to the calcareous nature of the soil or not cannot be decided because of certain evidences in the literature (37, 43) that plants growing on alkaline calcareous soils are able to absorb as much iron as those growing on non-calcareous soils; and that there is not too much difference in the iron content between leaves of healthy plants and those showing lime-induced chlorosis.

The average iron content in different orchards are shown in Table 7 and the distribution of levels of iron in the orchards according to variety in different categories is presented in Figure 6. Iron content in the leaves of Golden Delicious varied from 22 to 60 ppm with an average of 35 ppm. In the leaves of Red Delicious it varied from 15 to 68 ppm with an average value of 39 ppm. Data on iron content in the leaves of Red Delicious as reported by Abukhalil (1, p. 37) show that it varied from 42 to 60 ppm with an average of 45 ppm. These values are close to those found in this study. Nasrallah (39, pp. 64-67) found that iron content in the leaves of Golden Delicious varied from 65 to 76 ppm in one year and from

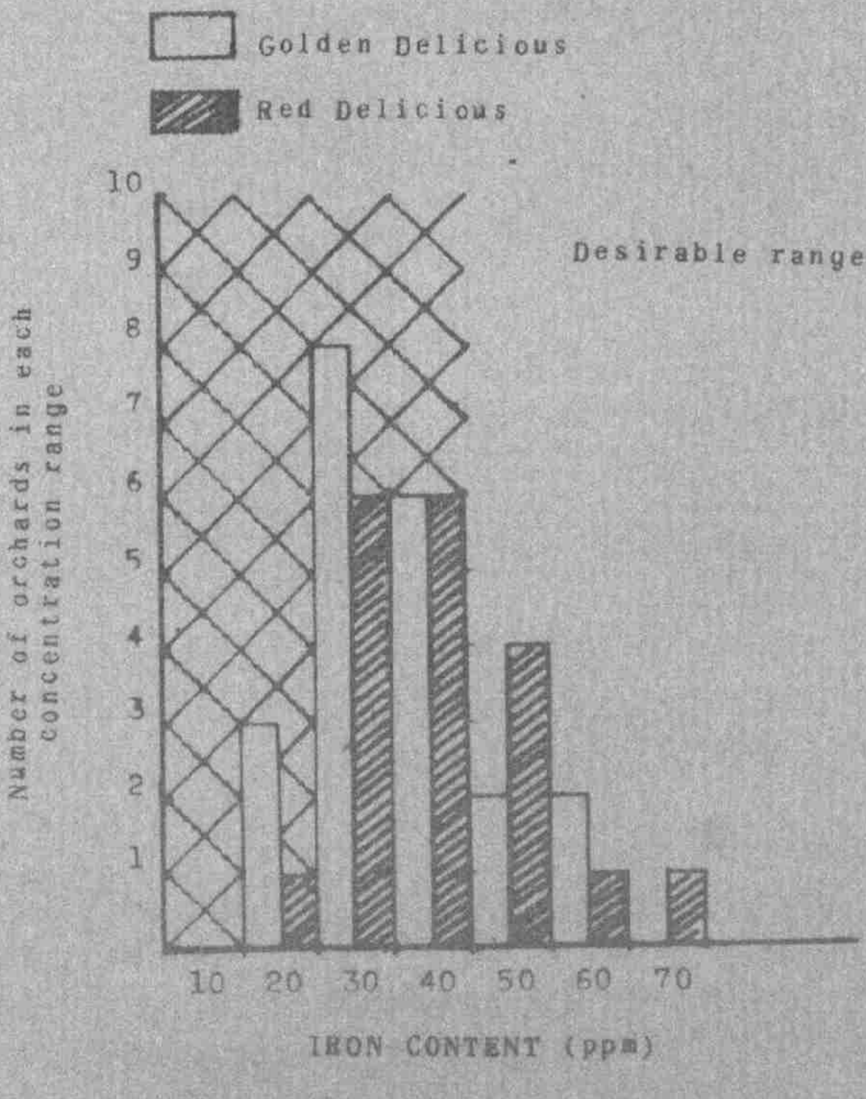

Figure 6. The Iron content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

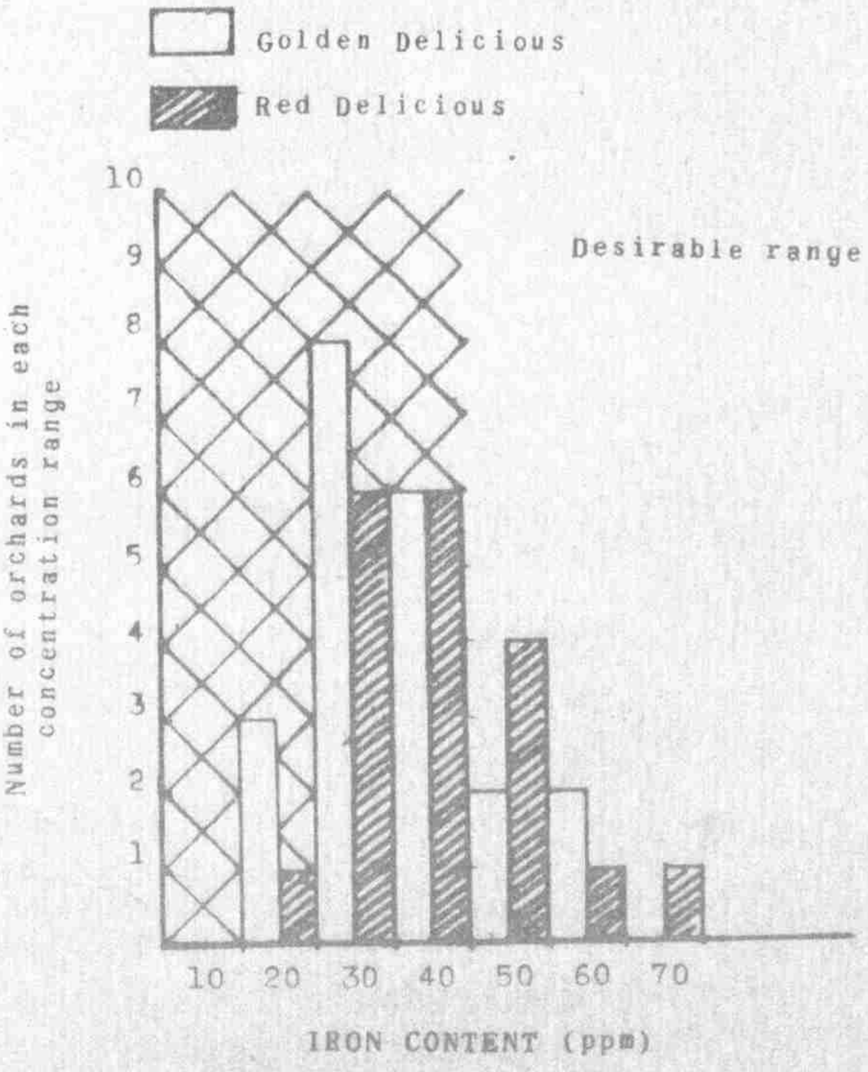

Figure 6. The Iron content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

Table 7. Iron content (ppm) in leaves of Golden Delicious and Red Delicious apple in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	56	68
2	42	53
3	48	45
4	46	29
5	27	51
6	27	27
7	33	38
8	36	38
9	24	60
10	34	39
11	35	37
12	22	15
13	26	27
14	60	30
15	46	35
16	38	32
17	26	32
18	24	42
19	26	49
20	34	27
Mean	35	39

137 to 161 ppm in the second year. The average iron content during 1959 and 1960 was 72 and 152 ppm, respectively. These values are higher than those found in the present study.

Boron

Concentration of boron in the leaves in different orchards according to variety and their distribution in different categories are compared with the critical levels proposed by Walker and Mason (60). On the basis of these critical levels, as illustrated in Figure 7, boron was the only one of eight elements in all the orchards the level of which was found in the desirable range. As shown in Table 8, boron content in the leaves of Golden Delicious varied from 24 to 60 ppm with 42 ppm on average. In Red Delicious it varied from 18 ppm to 67 ppm with an average of 47 ppm. These values do not agree with those reported by Abukhalil (1, p. 137) for Red Delicious. He found that the concentration of boron in the samples ranged between 49 and 62 ppm with 55 ppm on the average.

Zinc

Literature on zinc nutrition of apple trees is scanty. Because of non-availability of sufficient information on this element the critical levels have not been established (60). Table 9 indicates that average

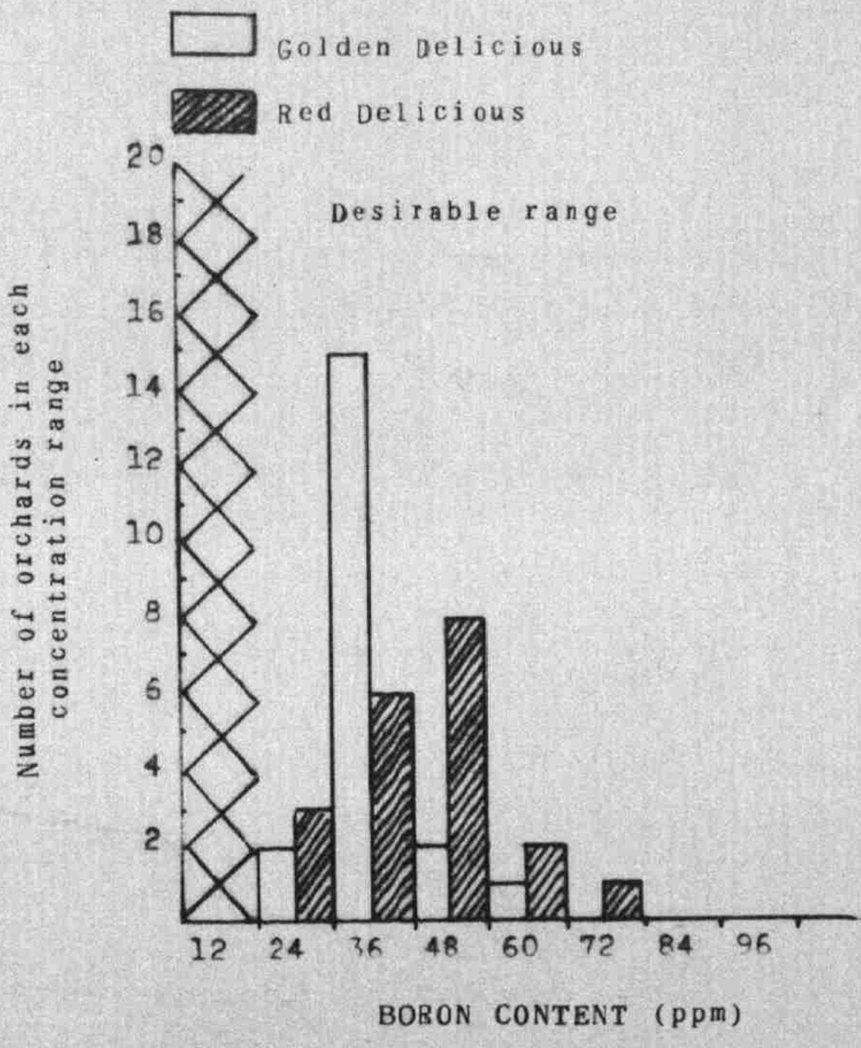

Figure 7. The Boron content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

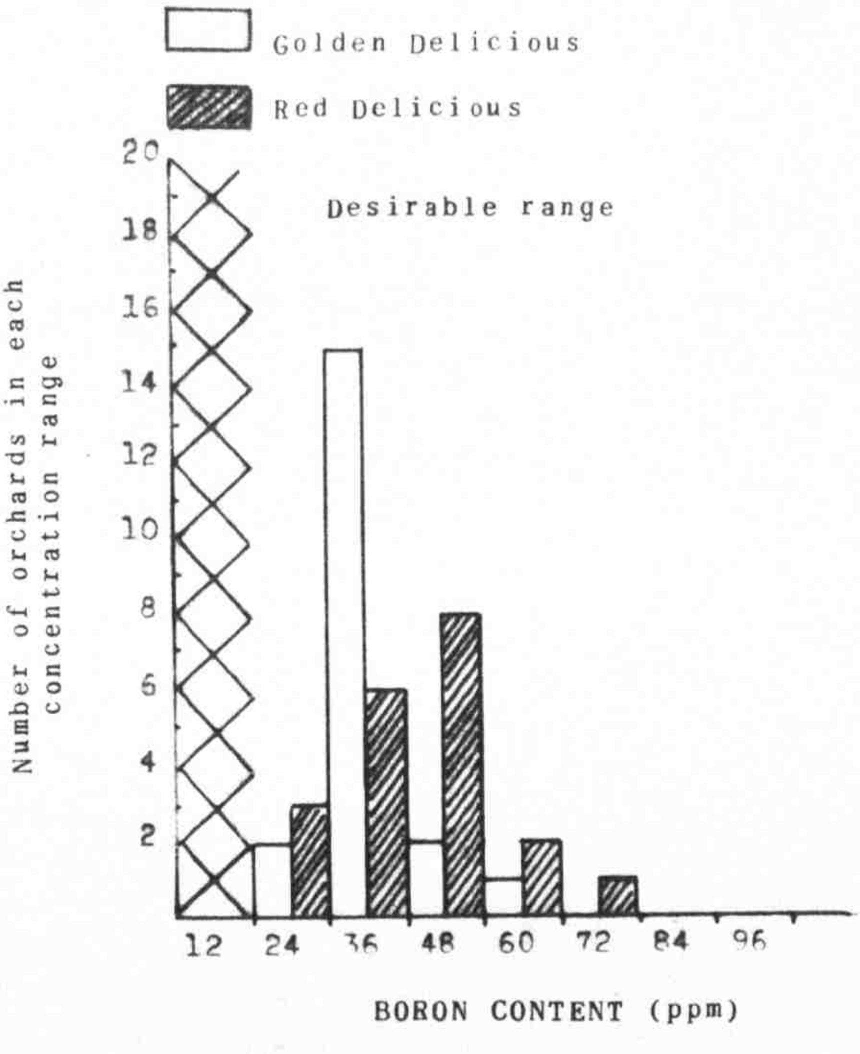

Figure 7. The Boron content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

Table 8. Boron content (ppm) in leaves of Golden Delicious and Red Delicious apple in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	49	45
2	39	52
3	45	32
4	47	54
5	40	53
6	44	76
7	43	55
8	36	41
9	24	27
10	45	53
11	40	50
12	60	34
13	43	49
14	45	67
15	50	53
16	47	30
17	39	42
18	47	62
19	24	18
20	41	44
Mean	42	47

Table 9. Zinc content (ppm) in the leaves of Golden Delicious and Red Delicious apples in different orchards in the Beqa'a Plain, surveyed during June, 1965.

Orchard No.	Golden Delicious	Red Delicious
1	106	110
2	128	157
3	103	89
4	71	96
5	108	80
6	57	63
7	67	69
8	74	82
9	73	64
10	79	89
11	68	68
12	49	54
13	49	50
14	97	108
15	86	102
16	70	99
17	65	79
18	40	50
19	56	62
20	37	43
Mean	74	81

zinc content in the leaves of Golden Delicious in different orchards ranged between 37 and 128 ppm and in Red Delicious between 43 and 157 ppm with 75 and 81 ppm as average values for both varieties, respectively. Figure 8 shows the levels of zinc in different orchards according to variety and their distribution. The results as shown in Table 9 and Figure 8 indicate that zinc level in all orchards is above the marginal level of 5 ppm at which appearance of zinc deficiency symptoms were reported by Walker and Mason (60).

Shoot Length

Table 10 shows the average shoot length to the nearest centimeter. Each measurement is an average of 50 measurements taken at 10 different places on each of the five trees forming a sampling unit. Comparison between nitrogen content of the leaves (Table 2) and average shoot length reveals that nitrogen content in the leaves has no direct relationship with shoot length. The average shoot length as shown in Table 10, was greatest (being 59.7 and 50.7 cm) in orchard number 14 followed by orchard number 5 and 6; it was lowest in orchard number 18 (being 15.3 and 19.8 cm) followed by orchard 3, 2, and 1. On the other hand the nitrogen content in the leaves from trees in these orchards was 2.3 percent and 2.2 percent in the first case and 2.3 and 2.1 percent in the second case.

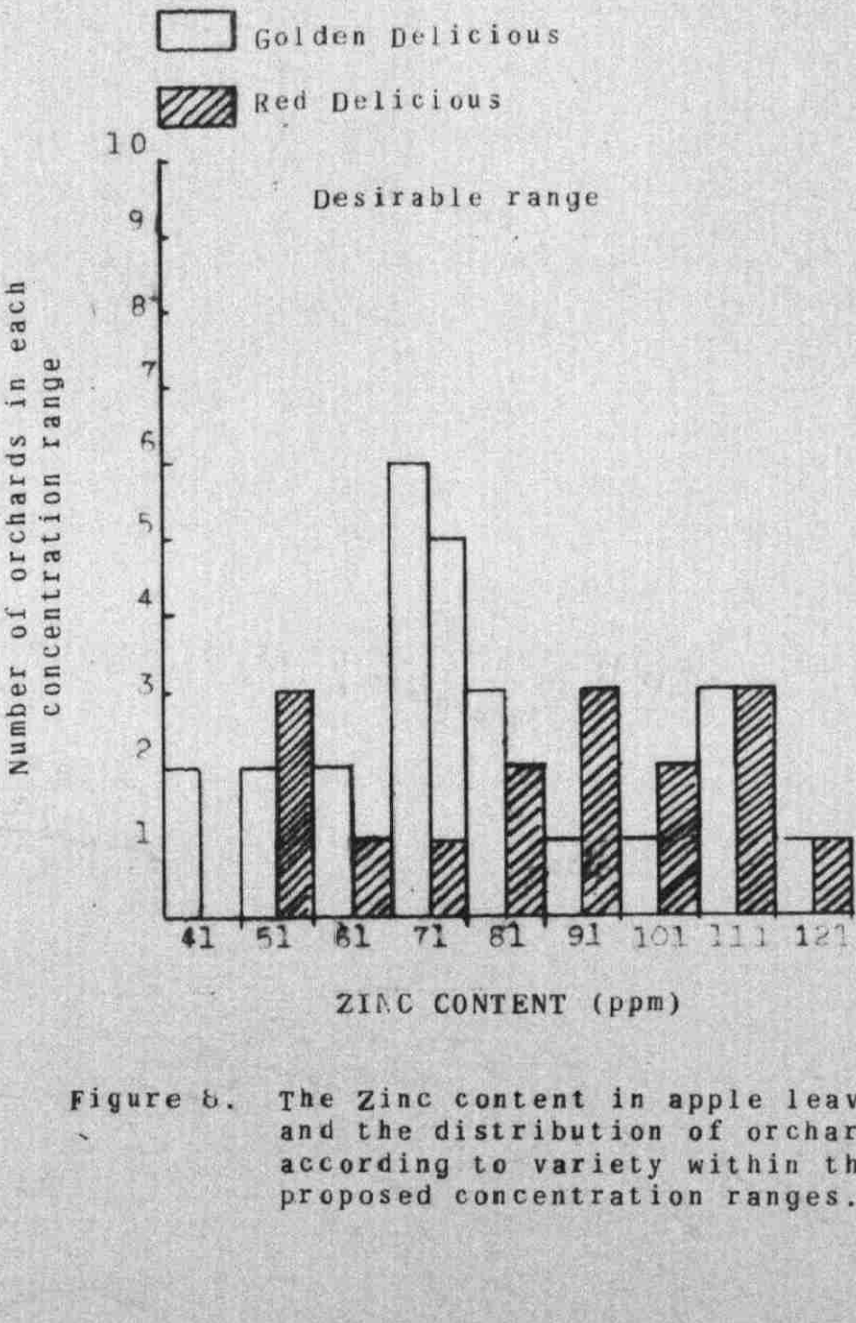

Figure 6. The Zinc content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

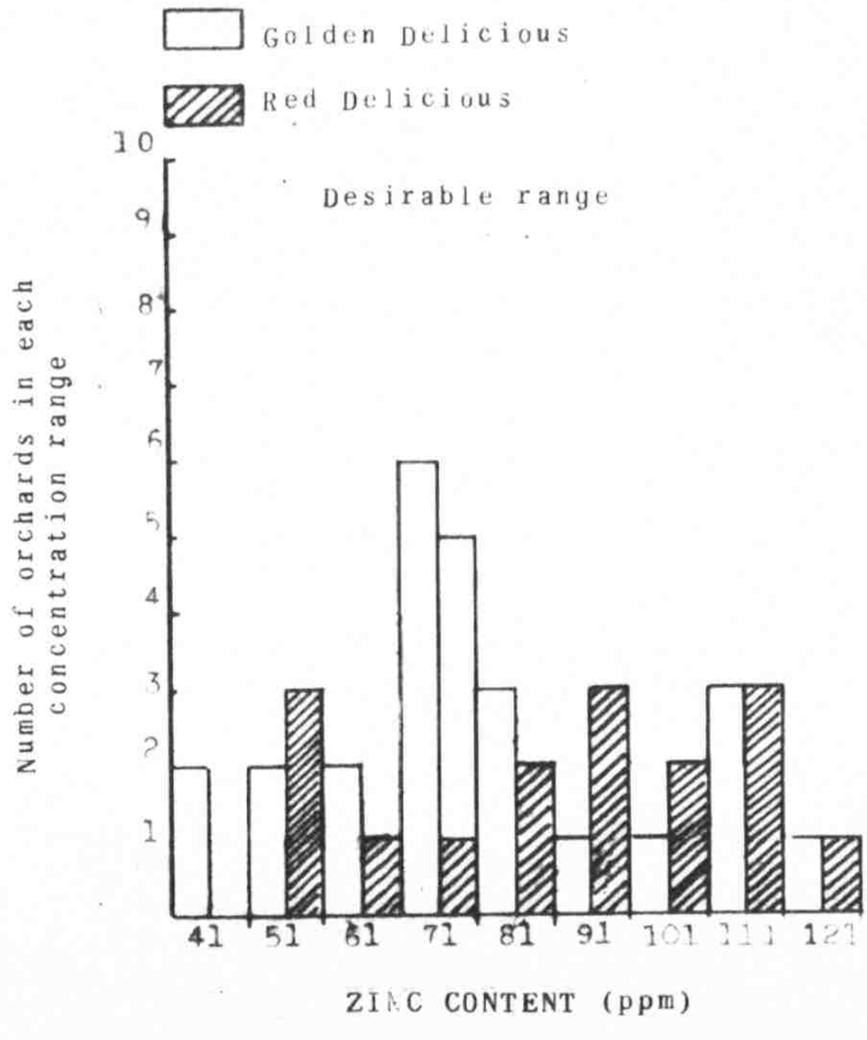

Figure 6. The Zinc content in apple leaves and the distribution of orchards according to variety within the proposed concentration ranges.

Table 10. Mean shoot length (to the nearest centimeter) of trees from which leaf samples were collected during June, 1965, for nutritional survey of apple orchards in the Beqa'a Plain.

Orchard No.	Golden Delicious	Red Delicious
	cm	cm
1	28.10	25.3
2	25.13	26.0
3	25.00	23.0
4	35.1	34.8
5	47.2	47.8
6	47.7	47.2
7	40.6	44.2
8	47.4	45.9
9	46.4	41.0
10	37.9	42.6
11	38.7	38.7
12	41.6	44.4
13	35.7	45.2
14	59.7	50.7
15	36.3	36.6
16	39.0	35.5
17	44.6	38.5
18	15.3	19.8
19	38.6	38.7
20	25.1	40.0

These results agree with those reported by Mason (36) who found that different nitrogen treatments had no effect on terminals. The present observations also confirm other reports (20, p. 18) that the nitrogen content of the leaves has no direct bearing on growth of terminal shoots and that shoot growth depends to a great extent upon stored food from the previous year and that the amount of crop may nullify the effect of nitrogen on shoot growth.

Results of the foliar analyses as discussed in the preceeding pages indicates the existence among the levels of each nutrient-element of differences between those reported by previous workers and those observed through the present study. There are, however, a few exceptions in which results agree to some extent. Possible explanations for such differences are numerous among which physiological age of the plants, soil fertility, and the availability of nutrients to plants, the effect of root-stock on the nutrient uptake, the effect of different systems of management followed and other unknown factors that comprise the whole complex of the environment of plants are some that may account for such differences.

Studies conducted by Abukhalil, Nasrallah, and Daouk were restricted to one block in an orchard so that differences in soil fertility and other effects inherent to soil properties were at a minimum. The trees that were the subject of their studies received uniform applications of fertilizer, irrigation, spraying and green manuring. On the other hand in the present study leaf samples were collected from orchards that were spread over the Beqa'a Plain and, therefore, reflected the influences of different types of soils, management practices and other unknown factors that have been operating through the growth cycle of the trees. In discussing foliar diagnosis Thomas (54, pp. 572-573) maintained that the chemical composition of morphologically homogenous leaves of the same species and variety is influenced by the medium of growth (soil and meteorological factors), fertilizer treatments and stage of development of the leaves. The magnitude of variation in the composition is subject to the resultant of meteorological factors acting in each particular season.

Results reported by Daouk (22, p. 36) are good evidence of the effect of differential fertilizer treatments on chemical composition of leaves. He reported the highest levels of nitrogen (3.5 percent) occurred in the leaves of trees that received 6 tins (25 Kg) of pig manure in the fall followed by 15 Kg of a mixture of cow, goat and pig manure in winter. In addition these trees were irrigated with water that contained pig urine (22, pp. 15-17).

The influence of rootstocks on the chemical composition of leaves of a scion variety as reported in the literature was also recognised by Daouk (22, pp. 33-63).

Comparing the nitrogen content in the leaves of Golden Delicious and Red Delicious on three different rootstocks, he found that the nitrogen content of the leaves from scion variety on Malling IX was lowest. Similar results were reported by Nasrallah regarding the differential feeding power of different rootstocks.

V. SUMMARY AND CONCLUSIONS

A nutritional survey of apple orchards in Lebanon was conducted in June of 1965. Leaf samples of Golden Delicious and Red Delicious varieties were collected from 20 orchards in the Beqa'a Plain between June 23 and June 30. At each location or in each orchard block five trees of comparable size and vigor were selected from each variety. From each tree two mid-shoot leaves from current season growth were taken at ten different places around the periphery of the tree. Each sample thus consisted of 100 leaves.

Sampling was done in the forenoon between 8:00 and 11:00 A.M. and the leaves were washed and placed in the oven for drying within 24 hours after sampling. The dried samples were ground and stored in glass jars for subsequent analysis. The elements determined were nitrogen, potassium, calcium, phosphorus, magnesium, iron, boron, and zinc.

Nitrogen was determined by the modified Kjeldahl method while other inorganic elements were determined by using Beckman Model B spectrophotometer with flame attachment and Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer.

Results for nitrogen, potassium, calcium, phosphorus, and magnesium were expressed as percentages of dry weight and for iron, boron, and zinc as parts per million. Comparison of the results of foliar analysis were made with the critical levels suggested by Emmert (24, p. 5), Kenworthy (32), and Walker and Mason (60). The distribution of levels of nutrients according to variety in the low, desirable and high ranges were represented with the help of histograms.

The present data was also compared with the results reported by previous workers. It was found that magnesium and phosphorus among the macro-nutrients and iron among micro-nutrients was below the optimum level in majority of the orchards in both the varieties. The levels of nitrogen, potassium, and calcium were in the desirable range except for a few orchards that were in the high range. The levels of boron and zinc were in the desirable range. (Table 11).

Table 11. Proposed critical levels and mean values of each nutrient-element in apple (Golden Delicious and Red Delicious) leaves sampled during June, 1965, and the percentage of orchards in each concentration range.

Nutrient-element	Level of each nutrient in the leaves		Percentage of samples in each concentration range		
	Proposed critical level	Sample mean on dry weight basis	Low	Desirable	High
Nitrogen[x]	1.9 to 2.4 %	2.33 %	-	82.5%	17.5%
Potassium[x]	1.20 to 1.80 %	1.45%	17.5	72.5%	10.0%
Calcium[x]	1.00 to 1.60 %	1.40 %	-	92.5%	7.5%
Phosphorus[x]	0.18 to 0.26 %	0.124%	75.0	25.0%	-
Magnesium[x]	0.24 to 0.36 %	0.22 %	82.5	17.5%	-
Iron[xx]	More than 40 ppm	37 ppm	75.0	25.0%	-
Boron[xx]	14 to 84 ppm	45 ppm	-	100%	-
Zinc	Not established				

x Critical levels suggested by Emmert. (24).

xx Critical levels suggested by Kenworthy (32) and Walker and Mason (60).

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APPENDICES

APPENDIX A

The amounts and kinds of different fertilizers and spray materials used in different orchards.

Orchard No.	Amount and kind of fertilizer used	Spray material used
1.	6 Kg complete fertilizer	Parathion, lead arsinate
2.	One burlap bag cow manure + 2.5 Kg ammonium sulfate per tree	Parathion, lead arsinate
3.	Nothing	Nothing
4.	Nitrofoska	Parathion, dumol
5.	2 Kg of complete fertilizer per tree	Gusathion A
6.	8 Kg BTS + 2 Kg ammonium sulfate per tree	Winter wash, sulfur and agidon
7.	1 can goat manure + 1.5 Kg ammonium sulfate	Amidon
8.	Nitrofoska	Gusathion, parathion and winter wash
9.	Nothing	Parathion, folidol and cupporovite
10.	Kamka 1 Kg + TVS + 20-20-0	Amidon, winter wash and sulfur dust
11.	Kamka 1 Kg + TVS + 20-20-0	Amidon, winter wash and sulfur dust
12.	Nothing	Parathion, folidol and cupporovite

Orchard No.	Amount and kind of fertilizer used	Spray material used
13.	1 can chiken manure	Parathion, dimol, sulfur dust and folidol
14.	Superphosphate	Parathion
15.	Cow manure	Karathion, DDT, sulfur dust and winter wash
16.	2 Kg superphosphate + 4 Kg nitromonkal	Perfesion and sulfur dust
17.	Cow manure + 2 Kg Kamka	Akarose, DDT, and parathiol
18.	Goat manure	Sulfur dust
19.	Ammonium sulfate	Phospherno
20.	Superphosphate and potash	707 powder, 707 solution, deflion and winter wash

APPENDIX B

Questions to the Growers

1. Sample number
2. Grower's name
3. Grower's address
4. Date of sampling
5. Root stock
6. Average yield per tree
7. Frequency of irrigation
8. Date of last irrigation
9. Does he consider his water supply   High Average Low
10. Fertilizer application: Kind Amount
11. Spray material used
12. Date of last spray
13. General appearance of orchard   Good Average Poor

APPENDIX C

Locations of Orchards from which
Leaf Samples were Collected

Place	Orchard Number
Haush ul Ghanam	1, 2
Tamnine	3, 4
Dalhamieh	5, 9, 12
Duris	6, 7
Rayak	8
Istable	10, 11, 14, 15, 16
Marj	13
Anjar	17
Beit Shama	18
Zoubdoul-Chtora	19
Haush Kaisar	20

APPENDIX D

Concentration of nutrient-element in the leaves of Golden Delicious and Red Delicious apples in different orchards in the Beqa'a Plain surveyed during June, 1965.

Orchard No.	Sample No.	N		K		Ca		P		Mg		Fe		B		Zn	
		V1[x]	V2[xx]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
1	1	2.4	2.5	1.3	1.7	1.4	1.4	.180	.158	.175	.265	46	90	48	72	69	119
	2	2.6	2.4	1.2	0.9	1.6	1.3	.180	.115	.205	.270	67	46	49	19	142	102
	Average	2.5	2.5	1.3	1.3	1.5	1.3	.180	.136	.190	.278	57	68	49	45	106	110
2	1	2.3	2.4	1.6	2.5	1.3	1.2	.203	.180	.215	.205	38	60	46	75	125	143
	2	2.3	2.3	1.4	1.5	1.5	1.3	.154	.180	.250	.250	46	46	31	29	131	170
	Average	2.3	2.4	1.5	2.0	1.4	1.3	.179	.180	.233	.228	42	53	39	52	128	157
3	1	2.6	2.7	1.7	2.4	1.5	1.4	.169	.170	.205	.215	60	49	48	41	135	65
	2	1.8	2.6	1.5	2.4	1.2	1.3	.162	.158	.215	.265	24	40	41	23	71	114
	Average	2.2	2.7	1.6	2.4	1.3	1.4	.165	.164	.210	.240	42	45	45	32	103	89

Appendix D continued.

Orchard No.	Sample No.	N		K		Ca		P		Mg		Fe		B		Zn	
		V1[x]	V2[xx]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
4	1	2.4	2.3	1.4	1.5	1.5	1.3	.122	.188	.215	.250	46	29	47	54	71	96
5	1	2.4	2.0	1.5	1.2	1.6	1.2	.180	.129	.215	.265	24	42	35	43	107	84
	2	2.3	2.4	1.5	1.5	1.4	1.2	.129	.125	.230	.230	30	60	45	72	109	76
	Average	2.4	2.2	1.5	1.4	1.5	1.2	.154	.147	.233	.248	27	51	40	53	108	80
6	1	2.1	2.5	1.11	1.3	1.8	1.2	.147	.137	.175	.215	30	24	38	72	53	72
	2	2.3	2.3	1.2	1.3	1.9	1.4	.169	.133	.205	.175	24	29	49	79	61	55
	Average	2.2	2.4	1.2	1.3	1.9	1.3	.158	.155	.190	.195	27	27	44	76	57	63
7	1	2.4	2.4	1.4	1.4	1.3	1.2	.169	.154	.226	.230	42	40	31	38	55	67
	2	2.2	2.3	1.5	1.5	1.5	1.2	.129	.122	.270	.230	24	35	54	72	78	70
	Average	2.3	2.4	1.5	1.5	1.4	1.2	.169	.138	.298	.230	33	38	43	55	67	69
8	1	2.6	2.6	1.5	1.2	1.5	1.3	.177	.198	.265	.240	29	40	27	27	58	66
	2	2.2	2.5	1.5	1.2	1.4	1.5	.162	.198	.205	.265	60	42	42	68	62	110
	3	2.1	2.3	1.6	1.7	1.3	1.4	.169	.198	.230	.265	30	35	42	29	110	89
	4	2.5	2.3	0.9	1.3	1.5	1.4	.180	.200	.265	.265	24	35	49	41	66	74
	Average	2.4	2.4	1.4	1.4	1.4	1.4	.192	.198	.241	.259	36	38	36	41	74	82

Appendix D continued.

Orchard No.	Sample No.	N		K		Ca		P		Mg		Fe		B		Zn	
		V1[x]	V2[xx]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
9	1	2.5	2.1	1.4	2.3	1.4	1.2	.187	.188	.270	.230	24	60	24	27	73	64
10	1	2.4	2.4	1.4	1.4	1.8	1.4	.177	.162	.270	.145	30	42	45	72	98	97
	2	2.4	2.5	1.2	1.2	1.9	1.9	.122	.195	.230	.215	42	29	29	43	115	121
	3	2.4	2.6	1.3	2.4	1.5	1.4	.203	.187	.230	.215	24	30	41	75	60	57
	4	2.3	2.1	1.2	1.7	1.7	1.3	.147	.177	.215	.215	19	40	72	43	70	85
	5	2.4	2.5	1.2	1.8	1.7	1.5	.203	.162	.215	.230	60	49	47	50	80	105
	6	2.4	2.5	0.5	1.2	2.0	1.9	.140	.150	.230	.215	30	44	38	36	48	66
	Average	2.4	2.4	1.1	1.6	1.7	1.6	.165	.172	.231	.206	34	39	45	53	79	89
11	1	2.5	2.4	1.2	1.7	1.9	1.9	.158	.169	.045	.040	24	30	48	54	53	66
	2	2.6	2.7	0.8	1.0	1.5	1.4	.165	.147	.265	.205	42	40	29	34	76	58
	3	2.5	2.5	1.2	1.2	1.4	1.4	.169	.198	.265	.205	38	40	41	62	75	79
	Average	2.5	2.5	1.7	1.3	1.6	1.6	.161	.171	.158	.150	35	37	40	50	68	68
12	1	2.1	2.4	1.1	1.2	1.4	1.2	.181	.200	.175	.185	22	15	60	34	49	54

Appendix D continued.

Orchard No.	Sample No.	N		K		Ca		P		Mg		Fe		B		Zn	
		V1[x]	V2[xx]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
13	1	2.0	2.5	1.8	1.6	1.4	1.3	.147	.200	.230	.205	22	30	39	72	33	58
	2	2.5	2.5	1.5	1.5	1.3	1.0	.177	.200	.215	.205	26	29	45	31	33	57
	3	2.6	1.8	1.5	1.7	1.3	1.4	.180	.198	.230	.185	30	24	43	67	44	36
	4	2.4	2.4	1.5	0.4	1.6	1.3	.158	.137	.175	.270	22	26	45	24	85	50
	Average	2.4	2.3	1.6	1.3	1.4	1.3	.166	.184	.212	.216	26	27	43	49	49	50
14	1	2.1	2.2	1.7	1.6	1.4	1.2	.144	.144	.175	.205	60	30	45	67	97	108
15	1	2.0	2.0	1.4	1.9	1.5	1.2	.119	.188	.240	.175	32	32	50	34	72	87
	2	2.6	2.3	1.5	1.4	1.1	1.1	.122	.180	.270	.185	60	90	48	88	89	102
	3	2.3	2.3	1.1	1.7	1.4	1.0	.180	.154	.145	.175	46	44	54	36	98	119
	Average	2.3	2.2	1.3	1.7	1.3	1.1	.174	.174	.220	.178	46	35	50	53	86	102
16	1	2.3	2.4	0.7	1.4	1.4	1.1	.169	.137	.230	.270	29	35	27	75	73	89
	2	2.5	2.3	1.8	0.8	1.3	1.3	.137	.133	.265	.240	46	30	75	36	50	65
	3	2.3	2.3	1.8	0.5	1.4	1.2	.169	.129	.185	.145	38	30	38	78	87	142
	Average	2.4	2.3	1.4	0.9	1.4	1.2	.158	.133	.227	.220	38	32	47	30	70	99

Appendix D continued.

Orchard No.	Sample No.	N		K		Ca		P		Mg		Fe		B		Zn	
		V1[x]	V2[xx]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
17	1	2.0	2.0	1.8	1.9	1.4	1.2	.169	.200	.215	.240	26	35	47	21	63	81
	2	2.0	2.1	1.8	1.2	1.4	1.4	.188	.198	.185	.325	26	29	31	62	66	78
	Average	2.0	2.1	1.8	1.6	1.4	1.3	.178	.199	.200	.283	26	32	39	42	65	79
18	1	2.3	2.1	1.9	1.3	1.5	1.4	.144	.200	.230	.185	24	42	47	18	40	50
19	1	2.4	2.6	1.5	0.8	1.7	1.3	.177	.198	.240	.230	26	49	24	62	56	62
20	1	2.5	2.2	1.6	1.9	1.2	1.1	.158	.115	.265	.205	30	24	48	18	39	44
	2	2.3	2.1	1.5	0.5	1.3	1.2	.158	.119	.270	.230	38	49	33	26	35	42
	Average	2.4	2.3	1.6	1.2	1.3	1.2	.158	.117	.268	.218	34	27	41	44	37	43

x Golden Delicious
xx Red Delicious