SOME POSSIBLE CAUSES OF CITRUS DECLINE IN SOUTH LEBANON

By
HAMEED MAZHAR SHEIKH

A THESIS

Submitted to the
AMERICAN UNIVERSITY OF BEIRUT

In partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE IN
AGRICULTURE
September 1966

SOME POSSIBLE CAUSES OF CITRUS DECLINE IN SOUTH LEBANON

By

HAMEED MAZHAR SHEIKH

Approved:

Ramzi Khalidy

Ramzi M. Khalidy: Associate Professor of Sub-Tropical Horticulture. In Charge of Major.

Franz Nienhaus

Franz J. Nienhaus: Associate Professor of Plant Pathology.

E. E. Barnard /ww.

E.E. Barnard: Associate Professor of Horticulture.

Adib T. Saad

Adib T. Saad: Assistant Professor of Plant Pathology.

W. W. Worzella

W.W. Worzella: Professor and Chairman of Graduate Committee.

Date Thesis is presented: August 29, 1966.

CITRUS DECLINE IN LEBANON

SHEIKH

ACKNOWLEDGEMENTS

The author wishes to express his deep appreciations and indebtedness to Dr. Ramzi M. Khalidy, Associate Professor of Sub-Tropical Horticulture, for his guidance, supervision and generous help received during the course of this study and for his hard labor in the preparation of this manuscript.

Thanks are due to Mr. A.K. Tabbarah, for his co-operation and permission to conduct this experiment in his orchard.

Thanks are also due to Mr. Abbas Fadil Al-Jamali, Graduate Assistant in Horticulture, for his help in the analytical work.

AN ABSTRACT OF THE THESIS OF

Hameed Mazhar Sheikh for M.S. in Horticulture

Title: Some possible causes of citrus decline in South Lebanon.

Studies on some of the possible causes of declining yields in citrus were conducted during 1965-66, on two orchards located at Adloun, South Lebanon.

Leaf samples were collected during July 1965 from Valencia orange trees budded on sour orange root stock. The leaf tissue was analysed for N, P, K, Ca, Mg, Na, Fe, Mn, B, and NO_3^-.

The results of the leaf inorganic chemical analysis, indicated that all the four blocks of the two orchards were below the standard values required for normal and healthy growth of the trees, in N, P, K, and Mg contents. Calcium content of the leaves was found to be in the "excess" range. Iron, Mn, B, and Na contents were in the satisfactory range.

Leaf N, P, K contents of orchard A were comparatively higher than orchard B, but low in Ca content. Orchard B was found to be comparatively more sufficient in its leaf Mg, Fe, Mn, and B contents. Orchard A produced more fruits per tree than orchard B. This could be due to the greater amounts of N, P, and K in the tissue of the former orchard.

Soil depth of both the orchards was shallow and drainage was also found to be poor. Nematode population was not found very high in soil samples collected during winter.

Decline in both orchards could be due to insufficient and unbalanced nutrition as well as shallow soil and poor drainage.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

I. INTRODUCTION

The orange is considered to be one of the oldest cultivated fruit in the world (3, p. 2367). The first known reference to oranges occurs in the second book of the "Five Classics" which appeared in China around 500 B.C. (43, p. 142).

The native habitat of citrus is not definite, but it appears that orange culture spread from Malay Archipelago to Indo-Pakistan Sub-Continent, the East Coast of Africa and from there to the Eastern Mediterranean region (51, p. 1021).

The existence of citrus fruits in the Middle Eastern countries is traced back to the ninth century A.D. (74, p. 6).

In Lebanon citrus fruits ranks first as to planted area and tonnage of production. In 1965, the total area under citrus fruits was 10,000 hectares with a total production of 232,000 metric tons. A major portion of the crop was exported out of the country (28, pp. 12-24).

Although, citrus fruits are of great commercial importance to the country and have been growing for such a long time, yet only a limited amount of research has been carried out on its nutritional and cultural aspects.

Complaints of declining yields have been received from established citrus areas for some time. The causes of low yields and decline are manifold (22, pp. 138-142). Some important causes are imbalanced nutrition, shallow soils, poor drainage, damage to roots by soil borne diseases and insects, and poor management practices.

The purpose of this investigation was to determine the nutritional status of the leaves in two citrus orchards, and study the over all growing conditions of the trees in order to determine the causes of decline in these two citrus groves.

II. REVIEW OF LITERATURE

Fruit Tree Nutrition

Balanced fruit tree nutrition is important for maximum yields and long life of trees, and work on this aspect is of prime importance in areas where fruit trees enjoy economic importance. Nicholas (46, p.63) in 1961 reported that 16 elements were required for the growth of a plant. Some of these elements are used in large quantities while others in smaller amounts. It has been known that absorption and accumulation of each nutrient ion is dependent on the absorption and accumulation of every other ion (62). It has also been found that when one element necessary for normal tree development is lacking in sufficient quantities, there is a tendency for another to increase in amounts to make up for the deficiency (2). According to Shear et al. (61) plant growth was a function of the two variables of nutrition i.e., intensity and balance. If all other factors were constant, maximum growth and yield was only possible upon the coincidence of optimum intensity and balance in the elements of a plant. Any change in the accumulation of one or more elements not accompanied by appropriate changes in all of the other nutrient elements, will result in an imbalanced nutrition which will be reflected in decreased growth, yield, and appearance of leaf deficiency symptoms. Tissue analysis frequently show reciprocative effects between pairs of anions or pairs of cations. A few examples of such reciprocative effects are as follows:

Nitrogen: The importance of proper balance between N and other elements has been pointed out by a number of workers. Reuther and Smith (58) while working on a fertilizer experiment on oranges found that as N fertilization increased, P, Zn, and K concentrations of the leaves decreased with a consequent increase in N, Ca, and Mg. Boynton and Compton (10, pp. 346-350) in an experiment on fruit trees observed an inverse relationship between N and K, and a positive relationship between N and Mg in the leaf samples. Labanauskas et al. (37) working with Valencia orange to find the effect of N on micronutrients reported that trees which received ammonium sulphate or ammonium nitrate contained more Mn and less B, than the check trees, while concentrations of Zn, Cu, and Fe remained unaffected. Weeks et al. (75) found that in the leaves of trees of McIntosh apples with a high amount of N, the trees required more K than trees with low N levels. They also found that P was a limiting factor with high rate of application of inorganic N.

Phosphorous: As regards interactions of P with other elements, Labanauskas et al. (38) found that heavy application of P fertilizers reduced Cu and increased Mn and Fe concentrations in Valencia orange leaves. Bingham and Martin (4) reported that P application reduced Zn concentration in the leaves while there was a slight increase in Mn. They further found no effect on Fe uptake. Investigations of Reuther *et al*. (57) showed that heavy P fertilization was associated with increased accumulation of P, Zn, Mn, and Ca in orange leaves and a decrease in the accumulation of Cu and Mg. They found no significant effect of P fertilization on N, K, Na, B or Fe in the leaf tissue. However, Embleton *et al*. (23) reported that high P values in the leaves were associated with high Ca values and a corresponding decrease in N and K. Chapman and Vanselow (21) attributed P deficiency to many causes, of which excessive lime in the soil was a major factor. Lime was found to buffer the nutrient medium in such a way that plant roots were not able to extract sufficient P.

Potassium: Leaf K was found to be affected by almost any change in the amounts of other elements in the leaf (63, p. 98). Potassium absorption by plants is usually decreased by the presence of high concentration of other cations in the solution. Chapman and Brown (18) in an experiment using various nutrient media, recorded that plants with low K in their nutrient solution have an increased Ca, Mg and Na absorption. Lack of K also resulted in increased N content of the leaves. Results of an experiment on oranges by Reuther and Smith (58) show that as the rate of K fertilization increased there was a decrease in the concentration of Zn, Ca, and Mg with an increase of K in the leaves. No consistent trend was found in the concentrations of either N or P as effected by K. According to Reitz and Long (54) K content of the leaves was strongly correlated with Ca content. They found that where Ca was low K was relatively high and vice versa. The above authors suggested that calcarious soils make the K absorption more difficult.

Similar results were reported by Gauch and Wadligh (29, p. 151), and Shear *et al*. (62).

Calcium: Reitz and Long (54) from a survey carried out on the mineral composition of Valencia orange leaves from the Indian River area of Florida, reported that as Ca in the leaves increased, N, P, K, and Mg concentrations decreased. Sodium was not found to be correlated with the Ca content of the leaves. From an experiment conducted by Jacoby (33) it was shown that high Ca and not the low Mg was the cause of the marked reduction in the Mg uptake. He observed that severe Mg deficiency symptoms appeared in the presence of excess Ca, but none in its absence. Boynton and Compton (9) in a differential fertilization experiment using different doses of ammonium sulphate, to find its effect on the chemical composition of McIntosh apple leaves, found an increase in K and P values with a decrease in the amount of N applied. There was an increase in leaf Mg and Ca with increasing N fertilization. In a similar type of experiment, but using superphosphate as a differential media. Smith _et al_. (67) found that leaf Ca increased with increased rate of superphosphate, but a decrease in K, and Mg resulted on the other hand. High P doses caused about 20% increase in leaf Ca and a 12% and 5% decrease in K and Mg respectively.

Magnesium: Magnesium is influenced not only by its availability in the soil but also by the relative availability of other ions, particularly cations such as Ca and K (59, p. 259). Pratt and Harding (50) found out that the use of K fertilizers increased the uptake of K and reduced the uptake of Mg in the trees. Deficiency symptoms of Mg were more pronounced at a high level of K in the nutrient solution than at adequate level of K without a change in the level of Mg (59, p. 259). Bingham _et al_. (5) observed that Mg deficiency occurred when the level of soil Mg was low or when K was applied. They were of the opinion that antagonism between K and Mg was fairly common throughout the world.

Boron: A close relationship between Mg and B nutrition has been corroborated in field experiments with tung by Shear _et al_. (62) in which it was found that oil content of the fruit was significantly increased by B application, while this beneficial effect of B was nullified by the application of Mg. Reeve and Shive (52, p. 13) found that in tomato plants with the increase of K concentrations in the nutrient sub-strait, there was a progressive increase in the B content of the plant at a high B level and at al low B level deficiency symptoms were accentuated. Wolf (76) in an experiment to find out the availability of B in the soil and its distribution in plants, observed that B content of plants growing on soils receiving moderate applications of calcium sulphate was greater than those of the plants in untreated soils.

Nitrate: Potassium plays an essential role in the absorption of anion such as nitrate. Nightingale (47) observed that pineapple plants were unable to absorb NO_3^- under field conditions when the K supply was low. A balance between Ca and K favourable for K absorption exerts a favourable influence on nitrate absorption (20, pp.169-171).

Soil

The relationship of the plant to soil is of an exceedingly intimate nature. These relationships will be discussed here under.

Soil depth: Tanbara and Kurihara (69) stated that citrus yields were low when the soil was less than 60 cm deep and advocated that to obtain higher yields the soil should be deeper than 80 cm. In Ceylon it was also found out that shallow soils and poor drainage were more responsible for the decline of sweet orange trees than tristeza virus (1). It was proved by Labanauskas et al. (36) that the roots sampled from deeper layer of soil contained higher concentrations of N, Mg, Na, Cl and B than did the roots sampled from the upper 38 cm, the latter containing more P, K, and Zn which were less soluble.

Soil drainage: Excess water in the root zone exerts a much greater effect on the root system than a deficiency of it. Surveys have shown that excessively wet soil conditions lead to tree decline (42). Labanauskas et al. (40) noted that low soil oxygen levels caused by poor drainage decreased the absorption by citrus roots of N, P, Mg, Cl, Na, and Zn while there was an increase of Ca, Cu, and Mn. Stolzy et al. (68) found that the concentrations of most macro and micronutrients in the leaves were directly related to the soil oxygen diffusion rate (O.D.R.). When the O.D.R. in the soil become too low, undesirable minerals such as Na, and Cl were released from the roots to the plant tops. As the O.D.R. increased in the soil there was an increase in the concentration of P, K, Ca, Mg, and B, but Zn and Mn remained unaffected. The amount of rooting was dependent on the depth of water table. Ford (26) showed that by lowering the water table from 30 to 70 inch, quantities of feeder roots were doubled in four year times.

Nematode

Out of soil borne pests parasitic nematodes have become a serious problem in citrus orchards. Nematode effects on the plant, are expressed in many and varied ways; such as nutritional deficiencies, element excesses, changes in the interrelationships among different elements in the tissue, low vigor, yellowing and bronzing of foliage, abnormal root system, and die back of twigs and branches. The rate of plant decline is usually accentuated when plants are weakened by nematode feeding and subjected to adverse environmental stresses (8, p. 218). Reynolds and O'Bannon (60) observed a correlation between tree decline and citrus nematode population. High nematode populations caused rapid deterioration of the root system. Damage to roots was followed by tree decline within 3 - 5 years depending on the over all vigor of the tree. Feldman *et al*. (25) found that leaves from oranges and grape fruit trees showing decline caused by *Radopholous similis* contained less K and N than leaves from healthy trees. There was no difference between levels of Ca or P in the declined and healthy trees.

Labanauskas *et al*. (36) analyzed the leaves and roots of citrus attacked by citrus nematodes (*Tylenchulus semipenetrans*) for 12 nutrients including Na and found that concentrations of several nutrients in the leaves and roots were affected. In one experiment the authors found that leaves obtained from infected plants contained significantly lower Ca, Mg, and higher B concentrations than the leaves from non infected trees. In another set of experiment the same authors observed significantly lower K, Ca, and Fe, and higher P concentrations in nematode infected trees.

pH

Labanauskas *et al.* (39) working on Navel orange found that soil application of various fertilizers affected the concentrations of various elements in the leaves, but they observed that these effects were largely independent of changes in the soil pH brought about by the use of fertilizers. Guest and Chapman (30), and Troug (72) stated that pH values ranging slightly from below pH 4.0 to some what above pH 9.0 exert no appreciable direct ill effect on the growth of sweet orange trees. Pierre and Bowen (48, p. 32) reported that K absorption was more depressed by Ca and NH_4 at high than at low pH.

From the foregoing discussion on the literature surveyed, it is seen that a balanced nutrition in the plant is a very complex problem. The excess or deficiency of one element upsets the whole nutritional complex. Also the antagonistic or synergistic effects of different elements on one another influence the tree growth and behavior. There are many other factors such as depth and drainage of soil, soil borne diseases and pests which also play a major role towards imbalance nutrition and root efficiency and growth.

III. MATERIALS AND METHODS

The studies embodied in this write up were carried out on trees of Valencia orange variety, budded on sour orange root stock in two adjacent orchards, located at sea level at Adloun, in South Lebanon. The orchards will be referred to here after as orchard A and orchard B.

The necessary particulars regarding these orchards such as yield, soil type, pH, and management practices are shown in Tables 1, 2, and 3.

From each orchard, two blocks comprised of 81 trees each, were selected for the present study. In each block 20 trees were marked on the two diagonals for the purpose of leaf collection.

Foliage samples were collected between July 7 and July 22, 1965. One hundred leaves per tree were taken at random from the middle of the non-fruiting spring flush twigs as suggested by a number of workers (7, 16, 24, 31, 64, 65).

Leaves were brought to the laboratory and washed in a detergent, followed by rinsing in running tap water. Then they were immersed in a 0.1% hydrochloric acid solution for about half a minute. Finally the leaves were washed twice in distilled water (7, 12, 35, 49, 63, 70).

Table 1. Age, and yield of fruit per tree in kilogram from the two orchards showing decline and under study at Adloun, South Lebanon.

Year	Orchard A		Orchard B	
	Age	Yield	Age	Yield
1958	4 years	15.60	9 years	73.82
1959	5 years	32.00	10 years	100.45
1960	6 years	63.73	11 years	127.72
1961	7 years	Not available	12 years	Not available
1962	8 years	81.64	13 years	141.64
1963	9 years	Not available	14 years	Not available
1964	10 years	104.27	15 years	124.82
1965	11 years	105.91	16 years	70.64

Table 2. Soil texture, pH and conductivity from the two orchards showing decline and under study at Adloun, South Lebanon.

Orchard	Block	Sand %	Clay %	Silt %	Soil type	pH	Conductivity (mmho/cm)
A	1	32.4	54.0	13.6	Clayey	7.62	1.20
	2	36.2	48.4	15.4	"	7.80	1.20
B	3	33.4	49.6	17.0	"	7.53	1.35
	4	33.5	46.5	20.0	"	7.50	1.30

Table 3. Management and cultural practices followed in the two orchards showing decline and under study at Adloun, South Lebanon.

I. <u>Fertilizers:</u>

A. Manure

Type	Dose/tree	Time of application
Barn yard manure	60-70 kg	October

B. Inorganic fertilizers

Type	Dose/tree	Time of application
Ammonium nitrate	3 kg	2 kg in February 1 kg in June
Triple phosphate	1 kg	October
Potassium sulfate	2 kg	October

II. <u>Irrigation:</u>

Source	System	Interval
Qasimieh River	Flooding	Every 20 days

III. <u>Cultivation and weeding</u>

Spring cultivation once a year. Weeds removal by hand from time to time.

After the excess water was shaken off the leaves, each sample was placed in a paper bag and put in an oven for drying at $70 \pm 1^{\circ}C$ for not less than 48 hours. The oven dried samples were ground in a Wiley mill with a 40 mesh sieve and stored in air tight jars.

Before weighing out the ground material for analysis the samples were dried in an oven at $70 \pm 1^{\circ}C$ over night and cooled in a desiccator.

Total N was measured by means of the modified Kjeldahl method (32, pp. 183-190). Iron, Mn, P, and Mg were determined colorimetrically with a Beckman B spectrophotometer, while Ca, K, and Na were determined with a Beckman flame attachment to the Beckman Model B spectrophotometer according to methods described by Toth et al. (71). Water soluble nitrate-N was determined in the leaf tissue by the phenol disulphonic acid method in the presence of excess chlorides as described by Johnson and Ulrich (34, pp. 44-45). Boron was also determined by the method suggested by Johnson and Ulrich (34, pp. 62-64).

The results were calculated on a dry weight basis. Iron, Mn, B, and NO_3^- were expressed in parts per million (ppm) while the rest of the elements on a per cent (%) basis.

The tentative set of standards of inorganic leaf composition proposed by Reuther et al. (56, p. 191), were used in this study. The above standards classify plants as to their leaf inorganic composition in five groups starting with low to excess. These standards were used to help in evaluating the nutritional status of the leaves and are reported in Table 4.

Table 4. Tentative standards for classification of the nutrient status of Valencia orange trees based on leaf analysis (56, p. 191).

		Ranges				
Elements	Unit (DW)	Deficient (less than)	Low	Optimum	High	Excess (more than)
N	%	1.9	2.0-2.3	2.4-2.7	2.8-3.2	3.3
P	%	0.08	0.09-0.11	0.12-0.16	0.17-0.29	0.3
K	%	0.6	0.7-1.1	1.2-1.7	1.8-2.3	2.4
Ca	%	1.5	1.6-2.9	3.0-5.5	5.6-6.9	7.0
Mg	%	0.15	0.16-0.29	0.3-0.6	0.7-1.1	1.2
Na	%	-	-	$<$0.16	0.17-0.24	0.25
Fe	ppm	35	36-59	60-120	130-200	250
Mn	ppm	15	16-24	25-200	300-500	1000
B	ppm	20	21-40	50-150	160-260	270

Soil pH was measured by the method described by Jackson (32, p. 47) using soil: water ratio of 1:10. Conductivity of soil solutions for salt content was determined by means of conductivity meter according to the method of Jackson (32, pp. 234-242). Mechanical soil analysis was carried out by hydrometer method as illustrated by Piper (49, pp. 77-79).

Soil samples containing feeder roots were collected in January and May 1966, and sent to Woodstock Agricultural Research Centre of the Shell International Chemical Co., England, U.K., for determining the parasitic nematode populations.

Standard deviation and co-efficient of variability (% age) for determining variation between the trees (41, pp. 32-34); analysis of variance to determine the significance among the blocks (41, pp. 137-141); Duncan range test for comparison among the means of various blocks (41, pp. 141-146), were the statistical methods used in the present study.

IV. RESULTS AND DISCUSSION

This treatise embodies the results of a study designed to investigate the causes of declining yields in two citrus orchards hereafter referred to as orchard A containing blocks 1 and 2 and orchard B containing blocks 3 and 4. The main approach to the problem was through the analysis of inorganic contents of leaves, while some attention was also given to the effects of nematodes, and soil characteristics and conditions.

Leaf Inorganic Chemical Analysis

In order to determine their inorganic composition, the citrus leaves were analyzed for the contents of N, P, K, Ca, Mg, Na, Fe, Mn, B, and NO_3^-. The results are presented in Tables 5 to 14.

Nitrogen: The N content of the leaves in different blocks is given in Table 5. Leaf N of both blocks in orchard A was found to be higher than in orchard B. The difference between the two orchards in mean N content was highly significant. No significant difference was, however, found between the blocks of either orchard. The mean N content in each of blocks 1 and 2 was 2.26% while in blocks 3 and 4 it was 1.97% and 2.03%, respectively. The values for blocks 1, 2, 4 fall in the "low" range, while the value for

Table 5. Nitrogen content of Valencia orange leaves (% D.W.) from two orchards showing decline, and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	2.31	2.54	1.39	1.63
2	2.27	2.17	1.80	2.25
3	2.11	2.30	1.97	1.83
4	2.08	2.24	2.21	2.14
5	2.42	2.21	2.03	2.05
6	2.33	2.06	1.99	2.15
7	2.44	2.28	2.15	2.02
8	1.80	2.24	1.97	2.10
9	2.22	1.99	2.20	1.80
10	2.42	2.44	2.01	2.12
11	2.30	2.41	2.05	2.03
12	2.23	2.03	1.80	2.14
13	2.13	2.29	2.00	1.95
14	2.47	2.20	1.89	2.29
15	2.45	2.39	1.90	1.82
16	2.25	2.41	2.10	2.02
17	2.12	2.16	1.87	2.06
18	2.25	2.41	1.99	2.03
19	2.14	2.28	1.95	2.09
20	2.42	2.21	2.12	2.18

Table 5 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	2.26	2.26	1.97	2.03
S.D.	0.16	0.14	0.17	0.16
Coeff. var.	7.08	6.19	8.63	7.88

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	0.4672	19	0.0246
Blocks	1.3770	3	0.4590[xx]
Error	1.5526	57	0.0272

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.1020	0.1073	0.1108
1%	0.1358	0.1415	0.1455

Block 1	Block 2	Block 4	Block 3
2.26	2.26	2.03	1.97

[xx] Significant at the 1% level.

block 3 falls in the "deficient" range when compared with values worked out by Reuther et al. (Table 4). The standards worked out by Chapman and reported in the text edited by Reuther (55, p. 92) are some what different from those of Reuther et al. (4). The former suggested that leaf N values in the 2.1% to 2.4% range were consistent with good citrus yields. Thus, according to this standard, the leaf N content of orchard A falls within the sufficiency range while those of orchard B fall in the low range. This observation is apparently consistent with the level of yield per tree (Table 1), which is higher in orchard A than in orchard B, indicating that there is some positive association of yields with leaf N content. Low N content of blocks 3 and 4, although receiving the same amount of fertilizers, as blocks 1 and 2 can be partially attributed to the high Ca content of their leaves, as discussed later in detail under the section of Ca. Also the low N could be due to the continuous regeneration of roots because of root rot problems, and as such tree efforts require greater amounts of N.

Phosphorous: The mean P content of the leaves as shown in Table 6, were 0.109%, 0.083%, 0.081%, and 0.080% in blocks 2, 1, 4, and 3 respectively, in their descending order. Block 2 in orchard A contained the highest P which was highly significant above the other blocks. The mean

Table 6. Phosphorous content of Valencia orange leaves (% D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	0.091	0.100	0.076	0.071
2	0.080	0.125	0.067	0.097
3	0.074	0.100	0.083	0.098
4	0.064	0.135	0.082	0.068
5	0.101	0.098	0.085	0.087
6	0.078	0.137	0.088	0.086
7	0.077	0.101	0.065	0.079
8	0.082	0.086	0.083	0.071
9	0.066	0.099	0.095	0.062
10	0.097	0.091	0.080	0.084
11	0.092	0.111	0.075	0.082
12	0.072	0.100	0.068	0.083
13	0.078	0.150	0.078	0.074
14	0.088	0.098	0.087	0.109
15	0.094	0.148	0.091	0.064
16	0.077	0.100	0.095	0.075
17	0.091	0.100	0.065	0.075
18	0.087	0.101	0.068	0.086
19	0.087	0.101	0.092	0.091
20	0.082	0.101	0.074	0.089

Table 6 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	0.083	0.109	0.080	0.081
S.D.	0.009	0.018	0.009	0.011
Coeff. var.	10.84	16.51	11.25	13.58

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	0.00262	19	0.00013
Blocks	0.01157	3	0.00385^{xx}
Error	0.01065	57	0.00018

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.0085	0.0089	0.0092
1%	0.0113	0.0118	0.0121

Block 2	Block 1	Block 4	Block 3
0.109	0.083	0.081	0.080

^{xx} Significant at the 1% level.

P values of blocks 1, 3, and 4 fall in the "deficient" range while that of block 2 in the "low" range when compared with standards set by Reuther _et al_. (Table 4). Chapman and Fullmer (19) stated that leaf P values ranging from 0.07% to 0.1% indicated slight deficiency. It may be seen, therefore, that both orchards are deficient in P content, although the deficiency in blocks 1 and 2 is comparatively less severe. Since low P content is indicated as a factor contributing to low yields (19), an improvement in yield could be attained by increasing leaf P content with P fertilization in both orchards. Reitz and Long (54) have also stressed that special attention should be given to P fertilization in calcareous soils, such as those found in the orchards under study, where P uptake by the trees could have been hindered by physical and chemical factors exerted by the soil.

Potassium: The mean leaf K content (Table 7) ranged from 0.533% to 0.413%. The mean K values of 0.533% and 0.488% for blocks 2 and 1, respectively were higher than the mean K values of 0.426% and 0.413% for blocks 3 and 4, respectively, and the difference between the two orchards was significant at the 1% level. All the four mean K values, however, fall in the "deficient" range when compared with standards set by Reuther _et al_. (Table 4). Chapman and Fullmer (19) reported that low K content has little effect on the yield and that no yield response to K

Table 7. Potassium content of Valencia orange leaves (% D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	0.468	0.650	0.405	0.306
2	0.414	0.526	0.377	0.438
3	0.396	0.500	0.472	0.343
4	0.436	0.639	0.493	0.409
5	0.576	0.516	0.461	0.495
6	0.497	0.473	0.429	0.411
7	0.492	0.506	0.442	0.395
8	0.545	0.542	0.402	0.448
9	0.450	0.395	0.380	0.348
10	0.584	0.473	0.372	0.435
11	0.447	0.545	0.500	0.446
12	0.494	0.400	0.384	0.355
13	0.470	0.702	0.404	0.337
14	0.581	0.540	0.447	0.517
15	0.648	0.566	0.390	0.410
16	0.408	0.574	0.452	0.453
17	0.443	0.497	0.365	0.453
18	0.422	0.605	0.436	0.392
19	0.445	0.505	0.460	0.415
20	0.545	0.504	0.445	0.457

Table 7 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	0.488	0.533	0.426	0.413
S.D.	0.069	0.065	0.040	0.054
Coeff. var.	14.14	12.20	9.39	13.07

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	0.0825	19	0.0043
Blocks	0.1872	3	0.0624^{xx}
Error	0.1774	57	0.0031

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.0340	0.0358	0.0369
1%	0.0453	0.0472	0.0485

Block 2	Block 1	Block 3	Block 4
0.533	0.488	0.426	0.413

xx Significant at the 1% level.

could be expected if K values were between 0.4% to 0.6% as in the present case. Reuther and Smith (58, p. 59) found that heavy application of K fertilizers on calcareous soils would result in relatively small increases in K content of the leaves. From the results of the present study the results of other workers as formerly quoted, it seems that low K is not a factor contributed to declining yields in these orchards.

Calcium: The results of the chemical analysis for the leaf Ca content are presented in Table 8. Maximum Ca content of 8.44% was found in block 3, and a minimum of 7.32% in block 2. Calcium content of leaves in block 3 and 4 was found to be significantly higher at the 1% level than in blocks 1 and 2. The mean Ca values for all the four blocks ranging from 8.44% down to 7.32% were in the "excess" limit when compared with standards set by Reuther *et al*. (Table 4).

High Ca content recorded in this study was found to have a negative relationship with N, P, K. This type of relationship was also reported by various workers (8, pp. 341-343), and (29, 54). High Ca was observed to have a suppressing effect on N. This is seen by comparing the data on Ca in Table 8 with that of N in Table 5. Leaves of block 3 with the highest Ca content, had the lowest N, and conversely, the leaves of blocks 1 and 2 with relatively low Ca content had the highest N. A similar

Table 8. Calcium content of Valencia orange leaves (% D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	6.33	7.05	8.35	6.80
2	8.27	9.06	10.23	7.95
3	9.41	7.08	8.06	9.25
4	8.72	5.94	8.02	7.62
5	6.62	7.16	8.01	6.88
6	7.58	8.70	7.82	9.15
7	6.73	5.66	7.53	7.75
8	6.80	8.95	9.00	8.00
9	7.67	8.70	8.30	7.00
10	6.95	8.46	9.59	8.56
11	7.63	9.00	8.26	7.53
12	7.57	8.00	9.05	9.23
13	8.62	5.72	8.77	7.02
14	7.84	5.39	9.44	6.88
15	7.67	4.53	9.34	9.11
16	7.40	6.69	8.39	7.99
17	6.77	8.08	8.08	7.70
18	7.10	7.53	6.54	7.81
19	8.91	7.36	8.29	8.58
20	5.73	7.32	7.66	8.06

Table 8 (continued)

	Block 1	Block 2	Block 3	Block 4
Mean	7.52	7.32	8.44	7.96
S.D.	0.93	1.33	0.82	0.81
Coeff. var.	12.37	18.17	9.71	10.17

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	23.4448	19	1.2339
Blocks	15.2872	3	5.0957[xx]
Error	52.4443	57	0.9201

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.5949	0.6260	0.6462
1%	0.7921	0.8257	0.8488

Block 3	Block 4	Block 1	Block 2
8.44	7.96	7.52	7.32

[xx] Significant at the 1% level.

antagonistic effect was observed between Ca and P as seen from comparing Tables 8 and 6, and Ca and K as reported in Tables 8 and 7. It was found that leaves in blocks 3 and 4 which were high in Ca were low in P and K, while the leaves from blocks 1 and 2 which were low in Ca were high in their P and K content. These results are in agreement with those of Reitz and Long (54), and Reuther and Smith (58).

The exceedingly high Ca content of leaves which is due to the calcareous nature of the soil (70% of the cation exchange complex of the soil, according to the soil analysis conducted by Agricultural Research Institute, Soil Laboratory at Tel Amara), observed in the two orchards, has upset the nutritional balance between different elements and could be one of the factors contributing to decline by lowering the leaf N, P, and K values.

Magnesium: Data regarding Mg content in the leaf tissue as reported in Table 9 reveal that the leaf Mg content of all the blocks was far below the "optimum" standard worked out by Reuther *et al*. (Table 4). The mean Mg values of 0.175%, 0.171%, and 0.168% of blocks 4, 3, and 1. respectively, fall in the "low" range and were not statistically significant. Leaf Mg content of 0.109% in block 2 falls in the "deficient" range, and was highly significantly low from the rest. Magnesium in block 2 was exceptionally low and in this block typical Mg deficiency

Table 9. Magnesium content of Valencia orange leaves (% D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	0.195	0.070	0.164	0.188
2	0.161	0.138	0.134	0.207
3	0.173	0.126	0.222	0.171
4	0.154	0.123	0.154	0.191
5	0.121	0.074	0.182	0.173
6	0.131	0.099	0.177	0.173
7	0.120	0.088	0.195	0.198
8	0.191	0.074	0.166	0.165
9	0.172	0.099	0.190	0.186
10	0.153	0.100	0.186	0.133
11	0.131	0.099	0.150	0.164
12	0.175	0.137	0.192	0.189
13	0.150	0.138	0.157	0.158
14	0.177	0.098	0.100	0.204
15	0.189	0.172	0.182	0.179
16	0.191	0.087	0.179	0.176
17	0.208	0.137	0.182	0.151
18	0.200	0.126	0.191	0.171
19	0.198	0.114	0.184	0.143
20	0.163	0.088	0.136	0.178

Table 9 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	0.168	0.109	0.171	0.175
S.D.	0.027	0.027	0.027	0.019
Coeff. var.	16.07	24.77	15.79	10.86

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	0.0127	19	0.0007
Blocks	0.0579	3	0.0193[xx]
Error	0.0362	57	0.0006

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.0142	0.0149	0.0154
1%	0.0189	0.0197	0.0202

Block 4	Block 3	Block 1	Block 2
0.175	0.171	0.168	0.109

[xx] Significant at the 1% level.

symptoms appeared. These symptoms were interveinal and marginal chlorosis leaving an inverted V green area at the base of the leaf. A comparison of the data in Tables 7 and 9 indicates that K is antagonistic to Mg. Leaves of blocks 2 and 1 were found high in K, and low in Mg, while those of blocks 3 and 4 with low K were high in Mg. The findings were similar to those of Pratt and Harding (50), Bingham et al. (5), and Chapman and Brown (18) who reported that Mg deficiency symptoms were more pronounced at high levels of K. However, K was not high in any of the blocks, Table 7, and an increase in K to get the level up to the optimum range as suggested by Reuther et al. (Table 4), may further decrease Mg in the leaves. The low Mg found in this study could also be caused by factors other than leaf K. The positive relationship between Mg and N as reported by many workers (9, 10, 53) was not observed in the present study, persumably because the N content was low. Smith et al. (66) had found positive relationship between N and Mg only at high N and not at low or intermediate N level of the leaves.

Magnesium levels in the leaves of all the four blocks was found to be below the desired standard and this may be one of the major contributing causes for declining yields, as suggested by Camp (14). The former worker stated that severe Mg deficiency has a very deleterious effect on a citrus tree. It causes severe chlorosis, premature defoliation, extreme susceptibility to cold damage, die back of branches, poor root growth, reduced yields and poor quality fruit. Most of the conditions mentioned above were also seen prevailing in the two orchards like, premature defoliation, die back of branches, poor root growth, and reduced yields.

Sodium: The mean values for the leaf Na content in the descending order were 0.028%, 0.024%, 0.021%, and 0.020% in blocks 2, 3, 4, and 1, respectively as shown in Table 10. All these values were highly significantly different from each other except those of blocks 4 and 1.

The Na content of the leaves in all cases was below 0.1%, a range which is highly desireable in citrus leaves, (55, p. 93). Sodium, therefore, could not have caused a toxic effect and as such Na nutrition of both the orchards was not found to be a problem.

Iron: The data for leaf Fe content are tabulated in Table 11. Mean Fe values of 135 ppm in block 4 and 125 ppm in block 3, were found to be significantly higher than the mean values of 105 ppm and 95 ppm obtained in blocks 1 and 2 respectively. Iron leaf values of blocks 3 and 4 fall in the "high" range while those of blocks 1 and 2 in the "optimum" range when compared with standards suggested by Reuther *et al*. (Table 4). A comparative study of the data in Tables 11 and 5, 11 and 6, and 11 and 13 indicates a relationship between leaf Fe and leaf N, P,

Table 10. Sodium content of Valencia orange leaves (% D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	0.026	0.025	0.023	0.031
2	0.025	0.032	0.027	0.019
3	0.011	0.037	0.022	0.022
4	0.015	0.024	0.018	0.019
5	0.014	0.027	0.024	0.020
6	0.018	0.027	0.028	0.025
7	0.018	0.030	0.026	0.024
8	0.022	0.025	0.021	0.021
9	0.034	0.034	0.031	0.032
10	0.019	0.025	0.024	0.024
11	0.018	0.025	0.025	0.026
12	0.017	0.035	0.027	0.019
13	0.016	0.025	0.022	0.021
14	0.013	0.024	0.025	0.024
15	0.016	0.034	0.023	0.020
16	0.023	0.025	0.021	0.012
17	0.021	0.025	0.026	0.017
18	0.025	0.023	0.027	0.019
19	0.025	0.028	0.021	0.020
20	0.024	0.030	0.027	0.015

Table 10 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	0.020	0.028	0.024	0.021
S.D.	0.007	0.004	0.003	0.004
Coeff. var.	35.00	14.28	12.50	19.05

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	0.0006	19	0.00003
Blocks	0.0007	3	0.00023[xx]
Error	0.0010	57	0.00001

Duncan Range Test

Shortest significance range:

	2	3	4
5%	0.0020	0.0021	0.0021
1%	0.0026	0.0027	0.0028

Block 2	Block 3	Block 4	Block 1
0.028	0.024	0.021	0.020

[xx] Significant at the 1% level.

Table 11. Iron content of Valencia orange leaves (ppm D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	88	80	76	146
2	138	115	118	112
3	79	105	211	201
4	82	113	62	114
5	110	84	34	109
6	75	80	76	148
7	119	81	171	200
8	120	94	90	118
9	169	109	110	155
10	139	82	48	150
11	121	109	165	118
12	110	95	192	104
13	110	95	139	180
14	86	108	204	114
15	65	84	88	113
16	70	85	110	86
17	90	94	224	134
18	105	88	120	122
19	109	86	115	140
20	125	106	148	137

Table 11 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	105	95	125	135
S.D.	26.4	24.9	57.2	30.9
Coeff. var.	25.14	26.21	45.76	22.89

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	30432	19	1601.68
Blocks	35147	3	11715.67^{xx}
Error	51268	57	809.44

Duncan Range Test

Shortest significance range:

	2	3	4
5%	18.02	18.96	19.38
1%	23.99	25.01	25.71

Block 4	Block 3	Block 1	Block 2
135	125	105	95

^{xx} Significant at the 1% level.

and B contents. Leaves of block 1 and 2 were high in N and low in Fe. This observation is in agreement with that of the established rule that deficiencies of heavy metals like Fe, Mn, Zn, and Cu are associated with high N and K, and low Ca in leaves (58, p. 59). Similarly low Fe appears to be associated with high P as also quoted by Nasrallah (45, p. 53). A positive relationship between Fe and B was also observed (Tables 11 and 13). Leaves of blocks 4 and 3 which were high in Fe were also high in B. These results are in harmony with those of Bolkan (6, p.19).

From the foregoing discussion it is seen that, Fe content in the leaves of all the four blocks are in the satisfactory range and Fe could not be considered a factor in the declining yields.

Manganese: The data in Table 12 show that the mean leaf Mn values were 42 ppm, 37 ppm, 35 ppm, and 33 ppm in blocks 4, 3, 1, and 2 respectively. There was no significant difference between Mn content of leaves from blocks 3, 1, and 2, but in the case of block 4, Mn contents were significantly higher than the remaining blocks. Manganese concentration in all blocks was in the "optimum" range (Table 4). Manganese depicted the same relationship with N, P, K, and B as did Fe.

As no deficiency of Mn in the leaves was observed, it can be concluded, that Mn does not play a part in lowering the yields of the two orchards.

Table 12. Manganese content of Valencia orange leaves (ppm D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	26	25	25	47
2	34	38	27	49
3	37	38	42	49
4	38	37	51	41
5	29	25	25	37
6	39	37	25	49
7	26	25	39	26
8	41	37	36	47
9	53	49	36	50
10	56	50	27	48
11	39	37	25	47
12	26	25	41	47
13	26	25	34	42
14	25	25	50	41
15	54	49	52	51
16	26	25	36	38
17	39	37	52	33
18	26	25	41	37
19	37	38	46	26
20	27	25	37	38

Table 12 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	35	34	37	42
S.D.	10.0	8.7	9.5	7.5
Coeff. var.	13.33	25.59	25.67	17.86

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	2914	19	153.37
Blocks	819	3	273.00[xx]
Error	3291	57	57.74

Duncan Range Test

Shortest significance range:

	2	3	4
5%	4.79	5.04	5.20
1%	6.37	6.64	6.83

Block 4	Block 3	Block 1	Block 2
42	37	35	33

[xx] Significant at the 1% level.

Boron: The data presented in Table 13 show that there is highly statistically significant difference in the leaf B content between the two orchards, with blocks 3 and 4 having higher B mean values, each of 106 ppm, and blocks 1 and 2 having a mean B content of 80 ppm and 86 ppm, respectively. All the mean values for B were in the "optimum" range as set out by Reuther et al. (Table 4). A comparative study of the data in Tables 13, 5, 6, 7, 8, 9, and 11 show that B is negatively associated with N, P, and K and positively associated with Mg, Ca and Fe content of the leaves.

Low N increases B content in the leaves (Muhr, 44, p. 65). Although N content in the leaves of the four blocks were low, but not sufficiently to cause B to exceed the "optimum" range and result in B toxicity of the plants. Hence, it can be presumed that B content in the leaves of all the four blocks are satisfactory and not contributing to the declining yields of both orchards.

Nitrate: The results obtained for leaf NO_3^- content are given in Table 14. The mean NO_3^- values ranged from 189 ppm to 85 ppm. However, it is not possible to categorise these values as no standard figures for leaf NO_3^- are available in the literature. Nightingale (47), stated that K played an important role in the absorption of NO_3^-. Except for data from block 2, the present results show that leaves high in K were also high in NO_3^-.

Table 13. Boron content of Valencia orange leaves (ppm D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	86	95	110	98
2	87	73	139	137
3	91	51	138	83
4	76	102	96	104
5	99	102	101	106
6	63	65	105	119
7	69	89	107	115
8	94	69	111	79
9	112	81	88	132
10	61	74	95	120
11	55	67	140	90
12	66	84	138	100
13	63	64	102	135
14	73	64	107	85
15	79	77	75	104
16	91	117	77	65
17	87	140	112	130
18	80	136	94	122
19	83	92	93	88
20	90	77	92	117

Table 13 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	80	86	106	106
S.D.	14.5	31.4	19.6	20.4
Coeff. var.	18.12	36.51	18.49	19.22

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	6402	19	336.95
Blocks	11022	3	3674.00[xx]
Error	23624	57	414.56

Duncan Range Test

Shortest significance range:

	2	3	4
5%	12.89	13.56	13.83
1%	17.16	17.89	18.39

Block 3	Block 4	Block 2	Block 1
106	106	86	80

[xx] Significant at the 1% level.

Table 14. Nitrate content of Valencia orange leaves (ppm D.W.) from two orchards showing decline and under study at Adloun, South Lebanon.

Tree No.	Orchard A		Orchard B	
	Block 1	Block 2	Block 3	Block 4
1	102	51	168	153
2	152	84	168	119
3	119	67	151	187
4	187	51	188	135
5	51	67	167	151
6	273	68	134	156
7	154	67	169	136
8	219	68	151	185
9	117	119	152	205
10	170	136	170	117
11	202	105	151	153
12	167	117	136	137
13	152	111	188	135
14	219	119	151	119
15	187	105	169	136
16	267	101	102	117
17	270	51	134	185
18	273	85	102	154
19	219	53	151	134
20	273	67	168	203

Table 14 (continued).

	Block 1	Block 2	Block 3	Block 4
Mean	189	85	153	151
S.D.	64.1	28.1	23.3	28.1
Coeff. var.	33.9	33.06	15.23	18.61

Analysis of Variance

Due to	S.S.	D.F.	M.S.
Trees	17995	19	947.10
Blocks	113314	3	37771.33^{xx}
Error	99659	57	1748.40

Duncan Range Test

<u>Shortest significance range:</u>

	2	3	4
5%	26.35	27.72	28.62
1%	35.08	36.57	37.59

Block 1	Block 3	Block 4	Block 2
189	153	151	85

^{xx} Significant at the 1% level.

It is quite evident from the data that blocks 3 and 4 which were significantly low in leaf NO_3^- content as compared to block 1 of orchard A, were also low in leaf N content (Table 5) and also low in yield (Table 1). It can be assumed from the above that NO_3^- is related to some extent with low yields and decline of the trees.

Soil Depth and Drainage

Depth of the soil from both the orchards was found to range between 50 and 60 cm. In some cases a hard pan was observed above the 50 cm depth. Soil drainage of both the orchards was defective. It was observed that pits remained filled with water for many days after rainfall or irrigation. Fibrous roots were found drying and new roots regenerating, thus weakening the trees. Soil depth and good aeration are both important for high yields and general health of the trees (69, 36). Stolzy *et al.* (68) found that the concentrations of most macro and micro-nutrients in the leaves were directly related to soil oxygen diffusion rate. Labanauskas *et al.* (40) noted that low soil oxygen levels caused by poor drainage decreased absorption by citrus roots of N, P, Mg, Cl, Na, and Zn which there was an increase of Ca, Cu, and Mn. A comparative study of the data in Tables 5, 6, 8, and 9 confirm the above reported findings. Nitrogen, P, and Mg contents in the leaf tissue were found to be low, while that of Ca was very high. Not only has the poor drainage an influence on the uptake of some of the macro and micro elements required by the plant, but it also effects the plant in other ways. Poor drainage was found to retard the roots from growing down deep into the soil, it was also found that it contributed to the rotting of feeder roots. This latter condition forced the tree to continuously regenerate its feeder roots which resulted in weakening of tree and reduced above ground growth.

Nematode

Results obtained on nematode count and identification from the soil samples sent to the Shell Co., England, in January 1966, are presented in Table 15. For the samples sent in May 1966, the company due to unavoidable reasons was unable to carry out the analysis. The data show that parasitic nematode population is not very high in both the orchards during winter. Orchard A contained an average of 312 parasitic nematode per 200 cc of soil while in orchard B the population was 160.

The probable reason for the low population of nematode obtained may be due to the season at which time the samples were collected or due to the clayey soil and wet conditions prevailing at the time of sampling. According to VanGundy et al. (73) reproduction rate of citrus nematodes was significantly lower in soils of 50%

clay such as the soils of the experimental orchards. They also observed that nematode reproduction was favoured by dry conditions in fine textured soils. Nematodes are a serious problem in citrus orchards and considerable reduction in yield is experienced if the population is high. In the present study a great reliance can not be placed on nematodes as a cause of declining yields, due to the incomplete data.

Table 15. Parasitic nematode population from two orchards showing decline and under study at Adloun, South Lebanon.

Block No.	Parasitic nematodes per 200 cc of soil	
1.	Tylenchulus	143
2.	Tylenchulus	481
3.	Tylenchulus	297
4.	Tylenchulus	24

V. SUMMARY AND CONCLUSIONS

The study reported in this write up was undertaken to investigate the causes of declining yields in two citrus orchards located at Adloun, South Lebanon. Orchard A comprising of blocks 1 and 2, and orchard B comprising of blocks 3 and 4 were planted with Valencia orange trees, budded on sour orange root stock.

Besides, soil conditions prevailing in the groves and nematode population, main emphasis of the study was placed on the contents of various nutrients present in the leaves and their antagonistic and synergestic effect upon each other.

Leaves from the experimental trees were sampled and analyzed for N, P, K, Ca, Mg, Na, Fe, Mn, B, and NO_3^-. The following results were obtained.

By comparing the leaf in organic constituents of the two orchards with that of standards set out by Reuther _et al_. (56, p.191) it was observed that leaves from all the four blocks were "low" or "deficient" in their N, P, K, and Mg contents, while Ca was found in the "excess" range. The micro-elements Fe, Mn, and B were found to be in the "optimum" range worked out by Reuther _et al_. (56, p. 191). Sodium was also found to be much below the toxic range.

A comparative study of the leaf inorganic analysis data of the two orchards show, that orchard A was significantly higher in N, P, (only block 2) and K contents as compared to orchard B. However, leaf Ca, Fe, Mn (only block 4), and B contents of orchard B were significantly higher than orchard A.

It was found that soil depth of both the orchards was shallow and soil drainage was affected by water logged conditions prevailing therein. Nematode population, however, could not be assessed correctly.

From the results obtained in this study, it is apparent that high Ca content in the leaves, due to the calcareous nature of the soil, and poor drainage has upset the nutrient balance and made the availability of other elements insufficient. Shallowness of the soil has further deteriorated the health and vigor of the trees due to less absorption of N, Mg, Na and B from the upper surface of the soil.

From the findings of this study it is recommended, that the owner of the orchard should take particular precautions against water logging. Attention should also be given to the use of fertilizers. Fertilizers which increase Ca content of the leaves, and decrease K and Mg such as superphosphate or ammonium sulphate, should either be used restrictly and supplimented to an economic extent by barnyard manure. Magnesium content of the leaves is particularly low and foliar sprays containing Mg could improve the tree condition, or Mg salts like $MgSO_4$, should be regularly included in the fertilizer program.

SELECTED BIBLIOGRAPHY

1. Anonymous. Sweet orange decline problem. Trop. Agriculturist. 18, 2, 1962.

2. Bahrt, G.M., and R.R. Wallace. Progress report of the effects of no potassium and various sources and amounts of potassium on citrus. Proc. Fla. State Hort. Soc. 53, 26, 1940.

3. Bailey, L.H. <u>The Standard Cyclopedia of Horticulture. Vol. II. The McMillan Co., New York. 1950.</u>

4. Bingham, F.T., and J.P. Martin. Minor nutrients of citrus. Calif. Agric. 9, No. 9, 4, 1955.

5. Bingham, F.T., R.C. McColloch, and D.G. Aldrich. Interrelation of soil potassium and magnesium. The Calif. Citrogr. 41, 122, 1956.

6. Bolkan, H. The influence of boron nutrition on the "Peteca" disease in lemons. M.S. Thesis. American University of Beirut, Beirut, Lebanon. 1965.

7. Bould, C., E.G. Bradfield, and G.M. Clarke. Leaf analysis as a guide to nutrition of fruit crop. I. General principles, sampling techniques and analytical methods. Jour. Sci. Food and Agri. 11, 229, 1960.

8. Bould, C., P. Prevot, and J.R. Magness. (Editors). <u>Plant Analysis and Fertilizer Problems</u>. IV. Amer. Soc. Hort. Sci. 1964.

9. Boynton, D., and O.C. Compton. The influence of differential fertilization with ammonium sulphate on the chemical composition of McIntosh apple leaves. Proc. Amer. Soc. Hort. Sci. 45, 9, 1944.

10. Boynton, D., and O.C. Compton. Leaf analysis in estimating the potassium, magnesium, and nitrogen needs of fruit trees. Soil Sci. 59, 339, 1945.

11. Bradford, G.R., and R.B. Harding. A survey of micro-elements in leaves of 43 high producing orange orchards in Southern California. Proc. Amer. Soc. Hort. Sci. 70, 252, 1957.

12. Brown, J.C. Iron chlorosis. Ann. Rev. Plant Physiol. 7, 171, 1956.

13. Bukhari, M.A. Phosphorous and potassium effect on Valencia orange trees. M.S. Thesis. American University of Beirut. Beirut, Lebanon, 1960.

14. Camp, A.F. Magnesium in citrus fertilization in Florida. Soil Sci. 63, 43, 1947.

15. Chapman, H.D. Citrus leaf analysis. Calif. Agric. 3, No. 11, 10, 1949.

16. Chapman, H.D. Leaf and soil analysis in citrus orchards. Calif. Agric. Expt. Sta. Manual No. 25, 1960.

17. Chapman, H.D. Potash in relation to California citrus. The Calif. Citrogr. 49, 455, 1964.

18. Chapman, H.D., and S.M. Brown. Potash in relation to citrus nutrition. Soil Sci. 55, 87, 1943.

19. Chapman, H.D., and F. Fullmer. Leaf analysis of citrus. Calif. Agric. 5, No. 9, 6, 1951.

20. Chapman, H.D., and G.F. Liebig, Jr. Nitrate concentration and ion balance in relation to citrus nutrition. Hilgordia. 13, 141, 1940.

21. Chapman, H.D., and A.P. Vanselow. Phosphorous deficiency and excess. The Calif. Citrogr. 42, 50, 1956.

22. Ducharme, E.P., and R.F. Suit. Citrus tree decline. The Punjab Fr. Jour. 27, 138, 1964.

23. Embleton, T.W., J.D. Kirkpatric , and E.R. Parker. Visible response of phosphorous deficient orange trees to phosphatic fertilizers and seasonal changes in mineral constituents of leaves. Proc. Amer. Soc. Hort. Sci. 60, 55, 1952.

24. Embleton, T.W., C.K. Labanauskas, W.W. Jones, and C.B. Cree. Interrelations of leaf sampling methods and nutritional status of orange trees and their influence on the macro and micronutrient concentrations in orange leaves. Proc. Amer. Soc. Hort. Sci. 82, 131, 1963.

25. Feldman, A.W., E.P. Ducharme, and R.F. Suit. Nitrogen, phosphorous, and potassium in leaves of citrus with Radopholous similis. Plant Dis. Reptr. 45, 564, 1961.

26. Ford, H.W. Root distribution in relation to the water table. Proc. Fla. State Hort. Soc. 67, 30, 1955.

27. Fudge, B.R. The effect of applications of calcium and magnesium upon absorption of potassium by citrus. Proc. Fla. State Hort. Soc. 59, 41, 1948.

28. Fuleihan, J.S., G.H. Ward, R.M. Khalidy, O.L. Brough, and M. Taki. Economic analysis of the production of oranges and bananas in Damour and South Lebanon. Faculty of Agricultural Sciences, Publication No. 26. American University of Beirut. Beirut, Lebanon. 1965.

29. Gauch, H.G., and C.H. Wadligh. Effect of high concentration of sodium, calcium, chloride, and sulfate on ionic absorption by bean plants. Soil Sci. 59, 139, 1945.

30. Guest, P.L., and H.D. Chapman. Some effect of pH on the growth of citrus in sand and solution cultures. Soil Sci. 58, 455, 1944.

31. Harding, R.B., T.M. Ryan, and G.R. Bradford. A comparison of the macro-elements composition of orange leaves from non-fruiting terminals and fruiting terminals. Proc. Amer. Soc. Hort. Sci. 80, 255, 1962.

32. Jackson, M.L. Soil Chemical Analysis. Prentice Hall, Inc., Englewood Cliffs, N.J. 1962.

33. Jacoby, B. Calcium-magnesium ratios in the root medium as related to magnesium uptake by citrus seedlings. Plant and Soil. 15, 74, 1961.

34. Johnson, C.M., and A. Ulrich. Analytical methods for use in plant analysis. Calif. Agric. Exp. Sta. Bull. No. 766, 1959.

35. Koo, R.C.J., H.J. Reitz, and J.W. Sites. A survey of the mineral nutrition status of Valencia orange in Florida. Univ. of Fla. Agric. Exp. Sta. Bull. No. 604, 1958.

36. Labanauskas, C.K., R.C. Baines, and L.H. Stolzy. Effects of citrus nematodes (Tylenchulus semipenetrans) and two levels of water suction on nutrient concentrations in Navel orange leaves and roots. Soil Sci. 99, 367, 1965.

37. Labanauskas, C.K., T.W. Embleton, W.W. Jones, and M.J. Garber. Nitrogen effects on micronutrients in Valencia leaves. The Calif. Citrogr. 44, 66, 1958.

38. Labanauskas, C.K., T.W. Embleton, W.W. Jones, and M.J. Garber. Effects of soil applications of nitrogen, phosphorous, potassium, dolomite, and manure on the micronutrient concentration in Valencia orange leaves. Proc. Amer. Soc. Hort. Sci. 73, 257, 1959.

39. Labanauskas, C.K., W.W. Jones, and T.W. Embleton. Effects of nitrogen, potassium, limestone, gypsum, and manure soil applications on soil pH, and on macro- and micronutrient concentrations in Washington Navel orange leaves. Proc. Amer. Soc. Hort. Sci. 80, 259, 1962.

40. Labanauskas, C.K., L.H. Stolzy, L.J. Klotz, and T.A. Wolfe. Effect of soil temperature and oxygen on the amounts of macro- and micronutrients in citrus seedlings (Citrus sinensis Var. Bessie). Proc. Soil Sci. Soc. Amer. 29, 60, 1965.

41. LeClerg, E.L., W.L. Leonard, and A.G. Clark. Field Plot Technique. Burgess Publishing Co., Minnesota, 2nd ed., 1962.

42. Marsh, A.W. Effect of irrigation on citrus root environment. The Calif. Citrogr. 50, 163, 1965.

43. McPhee, J. Oranges. I. The New Yorker. New York, U. S. A., May 14, 1966.

44. Muhr, G.R. Plant symptoms of boron deficiency and the effects of borax on the yield and chemical composition of several crops. Soil Sci. 54, 55, 1942.

45. Nasrallah, S. Iron chlorosis in citrus. M.S. Thesis. American University of Beirut. Beirut, Lebanon. 1959.

46. Nicholas, D.J.D. Minor mineral nutrients. Ann. Rev. Plant Physiol. 12, 63, 1961.

47. Nightingale, G.T. Physiological chemical functions of potassium in crop growth. Soil Sci. 55, 73, 1943.

48. Pierre, W.H., and C.A. Bower. Potassium absorption by plants as affected by cationic relationships. Soil Sci. 55, 23, 1943.

49. Piper, C.S. Soil and Plant Analysis. Interscience Publishers, Inc., New York, 1950.

50. Pratt, P.F., and R.B. Harding. Fertilizer effect on loss of magnesium from soil. The Calif. Citrogr. 42, 76, 1957.

51. Preece, W.E. (Editor). Encyclopedia Britanica. The Univ. Chicago, U.S.A., 1965.

52. Reeve, E., and J.W. Shive. Potassium-boron and calcium-boron relationships in plant nutrition. Soil Sci. 57, 1, 1947.

53. Reitz, H.J., and R.C.J. Koo. Effect of nitrogen and potassium fertilization on yield and fruit quality of Valencia orange on calcareous soils. Proc. Flo. State Hort. Soc. 72, 12, 1959.

54. Reitz, H.J., and W.T. Long. Mineral composition of citrus leaves from the Indian River area of Florida. Proc. Flo. State Hort. Soc. 65, 32, 1953.

55. Reuther, W. (Editor). Plant Analysis and Fertilizer Problems. Publication No. 8. Amer. Inst. Biol. Sci. Washington 6, D.C., 1961.

56. Reuther, W., T.W. Embleton, and W.W. Jones. Mineral nutrition of tree crops. Ann. Rev. Plant Physiol. 9, 175, 1958.

57. Reuther, W., F.E. Gardner, and P.F. Smith. Phosphate fertilizer trials with oranges in Florida. I. Effects on yield growth, and leaf and soil composition. Proc. Amer. Soc. Hort. Sci. 53, 71, 1949.

58. Reuther, W., and P.F. Smith. A preliminary report on the relation of nitrogen, potassium, and magnesium fertilization to yield, leaf composition and incidence of zinc deficiency in oranges. Proc. Amer. Soc. Hort. Sci. 56, 27, 1950.

59. Reuther, W., and P.F. Smith. Leaf analysis of citrus. Chap. VII. Fruit Nutrition. Somerset Press, Somerville, New Jersey, 1954. (Editor N.F. Childers).

60. Reynolds, H.W., and J.H. O'Bannon. Decline of grape fruit trees in relation to citrus nematode populations and tree recovery after chemical treatment. Phytopathology. 53, 1011, 1963.

61. Shear, C.B., H.L. Crane, and A.T. Myers. Nutrient element balance: A fundamental concept in plant nutrition. Proc. Amer. Soc. Hort. Sci. 47, 239, 1946.

62. Shear, C.B., H.L. Crane, and A.T. Myers. Nutrient element balance: Application of the concept to the interpretation of foliar analysis. Proc. Amer. Soc. Hort. Sci. 51, 319, 1948.

63. Smith, P.F. Mineral analysis of plant tissues. Ann. Rev. Plant Physiol. 13, 81, 1962.

64. Smith, P.F., and W. Reuther. Seasonal changes in Valencia orange trees. I. Changes in leaf dry weight, ash, and macronutrient elements. Proc. Amer. Soc. Hort. Sci. 55, 61, 1950.

65. Smith, P.F., W. Reuther, and A.W. Specht. Seasonal changes in Valencia orange trees. II. Changes in micro elements, sodium, and carbohydrates in leaves. Proc. Amer. Soc. Hort. Sci. 59, 31, 1952.

66. Smith, P.F., W. Reuther, A.W. Specht, and G. Hrnciar. Effect of differential nitrogen, potassium, and magnesium supply to young Valencia orange trees in sand culture on mineral composition especially of leaves and fibrous roots. Plant Physiol. 29, 349, 1954.

67. Smith, P.F., G.K. Scudder, Jr., and G. Hrnciar. Twenty years of differential phosphate application on pineapple orange. Proc. Fla. State Hort. Soc. 76, 7, 1963.

68. Stolzy, L.H., S.D. VanGundy, C.K. Labanauskas, and T.E. Szuszkiewiez. Influence of soil aeration on nematodes, plant growth, and nutrients. The Calif. Citrogr. 49, 134, 1964.

69. Tanbara, K., and H. Kurihara. On the relationship between productivity and the physical properties of citrus orchard. Soils. Jour. Sci. Soil Manure. 34, 327, 1963. (Abstracted in Horticultural Abstracts (1832). Vol. 35, No. 1, March 1965.

70. Taylor, G.A. The effectiveness of five cleaning procedures in the preparation of apple samples for analysis. Proc. Amer. Soc. Hort. Sci. 67, 5, 1956.

71. Toth, S.J., A.L. Prince, A. Wallace, and D.S. Mikkelsen. Rapid quantitative determination of eight mineral elements in plant tissue by a systematic procedure involving a flame photometer. Soil Sci. 66, 459, 1948.

72. Troug, E. Lime in relation to availability of plant nutrients. Soil Sci. 65, 1, 1948.

73. VanGundy, S.D., J.P. Martin, and P.H. Tsao. Some soil factors influencing reproduction of citrus nematode and growth reduction of sweet orange seedlings. Phytopathology. 54, 294, 1964.

74. Webber, H.J., and L.D. Batchelor. The Citrus Industry. Vol. I. Univ. of Calif. Press. Berkeley, 1946.

75. Weeks, W.D., F.W. Southwick, M. Drake, and J.E. Steckel. The effect of rates and sources of nitrogen, phosphorous, and potassium on the mineral composition of McIntosh foliage and fruit color. Proc. Amer. Soc. Hort. Sci. 60, 11, 1952.

76. Wolf, B. Factors influencing availability of boron in soil and its distribution in plants. Soil Sci. 50, 209, 1940.