EFFECT OF THREE LEVELS OF PHOSPHORUS AND POTASSIUM FERTILIZATION ON INORGANIC LEAF COMPOSITION OF VALENCIA ORANGES

by

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P and K effects on Valencia orange trees

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ABSTRACT

A short-term study of one year was conducted in 1960 in a citrus orchard planted to Valencia oranges on sour orange rootstock, located at Adloun, south of Beirut, to determine the effect of three levels of phosphorus and potassium fertilization on the inorganic leaf composition. 'Puffiness or Creasing' of Valencia oranges was found on the fruit from both six and eleven year old trees. In the fall of 1959, a low, medium, and high treatment was applied, namely 570, 1000, and 1300 grams of P_2O_5 and 625, 1800, and 2250 grams of K_2O, respectively. Nitrogen was applied uniformly throughout the experiment. Thirty trees for each age group were used and each treatment within each age group was replicated ten times. Leaf samples were collected on the 18th of July, 1960, and analyzed for nitrogen, phosphorus, petassium, calcium, magnesium, sodium, manganese, and iron. The effect of the various levels of phosphorus and potassium applied to the soil on these elements was studied.

Statistical analysis of the data by the use of analysis of variance and 't' test revealed that there was no significant effect of phosphorus and potassium fertilization on the elements analyzed in the six year old trees. In the case of eleven year old trees, there was a significant effect of phosphorus and potassium fertilizer treatments on the elements nitrogen, potassium, calcium, and magnesium. Analysis of the data has revealed a significant effect between the two age groups of six and eleven year old trees only in the content of iron. No significant differences were obtained with the other elements studied. The value for each of the elements analysed are presented for each age group.

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Introduction

The citrus tree represents one of the largest tree fruit crops of the world. Many problems are associated with the production of desirable quality of fruit in this crop. Within recent years the problem of 'Puffiness or Creasing' of Valencia oranges has been increasingly observed. This defect is one of the important factors in decreasing the commercial value of the matured fruit and is an alarming problem to commercial citrus growers. Several suggestions have been proposed to explain the cause of puffiness, such as lack of phosphorus or potassium (10, 39), fluctuations in the irrigation practices (2), or prolonged clear weather during fruit development (10).

A considerable amount of research has been conducted to determine the effect of phosphorus and potassium fertilizer on the puffiness of citrus fruits by Chapman and Rayner (10), Ruether et al (38), and Ruether and Smith (39). None of these workers have reported any definite conclusions concerning the role of phosphorus or potassium on this problem. No significant effect of phosphorus and potassium fertilizer have been reported with the problem of puffiness in this study.

In February 1960 the present study was initiated to investigate the effects of three levels of phosphorus and potassium fertilization on the inorganic leaf composition of Valencia orange on sour orange rootstock.

REVIEW OF THE LITERATURE

The composition of plant structure is a combined result of its genetical potentialities and environmental influences (27), and is attributed as the biochemical and physiological response. There are numerous variables such as climate, soil-moisture, nutritional status, availability of nutrients, cultural practices, variety, rootstock, and other factors (6,7,15,25, 26,28) which are directly or indirectly responsible in the production of the fruit crop. Extensive investigations have confirmed that the constitution of the plant is due to the effect of integrated factors which to a certain extent have been analysed individually and interpreted by different workers in their respective specialized fields (2,5,14,19,22,37,44,46)

The idea of the 'Nutritional status of the plant' was actually initiated from the times of Woodward in 1699 as stated by Wallace (50). The study of the inorganic composition of the leaf tissue is a tool in determining the nutritional status of crops. Lundegardh (34), Thomas (45), and Wright and Barton (52) have reported many new findings involving nutritional experiments on citrus fruits. One of the main problems in Citrus production has been improper fertilization, such as excess or deficiency of one or more of the elements. Other problems are low yield, premature dropping, splitting, alternate-bearing, granulation and puffiness. Puffiness or creasing is a citrus fruit problem which

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APPENDIX

Appendix A.

Analysis of variance

Due to	S.S.	D.F.	M.S.	Observed F.	Calculated F.	
					5%	1%
Treatment	.239	2	.120	.833	3.55	6.01
Replication	.219	9	.243	1.688	2.46	3.60
Error	.260	18	.144	-	-	-
Total	.718					

Nitrogen.

Treatment at .05 level n.s.
Replication at .05 level n.s.

is thought to be due to lack of phosphorus and/or potassium, to fluctuation in irrigation water, or to a combination of these factors (10,11).

As far as the problem of the nutritional status in fruit crops is concerned, a large amount of work is being conducted. No definite answer to the exact requirement of nutrients in the fruit or leaf is predictable todate, because the interaction of elements is complicating the solution of this basic problem. (13, 22,23,24,29,30,32,37,39,40,44)

Role of phosphorus in plant nutrition.

Phosphorus occurs in the plant in relatively smaller amounts than nitrogen and potassium (1,3,24). Generally, it is absorbed by the plant as the primary orthophosphate ion, $H_2Po_4^-$ and in lesser amounts as secondary orthophosphate ion, $HP_{o4}^{=}$. There are other forms of phosphorus absorbed by plant roots such as pyrophosphate, metaphosphate, and soluble organic phosphate. Phosphorus is a constituent of nucleic acid, phytin, and phospholipids. It is a very essential element in the cell division of tissues and in the supply of high-energy phosphate bonds for the processes of photosynthesis and metabolism. The high-energy bonds are necessary for the transfer of energy during certain metabolic processes that are fundamental to the life of the plant. In the metabolites, phosphorus plays a direct role as a carrier of energy. For example, the adenosine triphosphate (ATP) is a carrier of high-energy phosphate, which activates energy in transforming glucose to starch (1,3). It plays a role in the reduction of absorbed nitrate-nitrogen (13).

An adequate supply of phosphorus is usually associated with early maturity of crops and is important in laying down the primordia for the reproductive parts of the plants. It is essential for seed formation in the fruit and in stimulating root growth. It moves readily from the plant parts such as leaves to parts where cell division occurs.

Sufficient quantities of available phosphorus are necessary for normal transformations of carbohydrates in plants, such as the changing of starches to sugar. Phosphorus is also necessary for the assimilation of fats in the plants and apparently it increases the efficiency of the chloroplastic mechanisms. Phosphorus is greatly effective on the root system of plants and it enters into the composition of nuclear compounds in the cells. In general, phosphorus improves the quality of crops by favoring good pollination, stimulating vigorous plant growth and making the plants more disease-resistant (8,13,16).

The mildest deficiency symptoms produce plants that are weaker in flush growth with smaller leaves, that are dull green in color, and usually show a purple coloration. Phosphorus-starved plants tend to have a stunted root system which decreases their feeding zone and thus the plants are less able to withstand adverse conditions. In case of phosphorus deficiency in citrus fruits, a thicker, rougher rind is produced with loose attachment, more open core, especially in orange fruits, a lower percent of juice with lower soluble solids (16), accompanied by a reduced size of plant and a deep green color. As the deficiency advances, the trees tend to bear very small crops of rough fruit where much of the fruit drops in the early stages of development (16,18).

Chapman and Rayner (10) working on the Valencia orange have stated that a phosphorus deficiency may cause a condition known as puffiness or creasing, which is a loosening or softening of the skin of fruit. Many other investigators (15,16,17,32,38,42) support this view. Such affected fruits become unprofitable because of their poor keeping quality (10).

Role of potassium in plant nutrition

Potassium is an essential macronutrient usually present in large quantities. It makes up about 40 percent of the ash of most plants and is not localized in any part of the plant. Potassium is extremely mobile within the plant(13). It is neither a constituent of proteins nor a constituent of any other structural substance in the plant (8). Some evidence suggests that it activates enzymes in the synthesis of proteins, carbohydrates and possibly of fats, oils and albuminoids (8). Hoagland (23) believes that potassium is especially required for the buffer system which is present within the plant. This element is needed considerably in all cell metabolic processes, for instance, in the development of chlorophyll, in regulating the rate of respiration and in affecting the rate of transpiration. This element has a specific role in influencing the uptake of other ions especially phosphate, as mentioned by Wall (49)

Potassium appears to improve the general tone and vigor of the plant, which in turn permits the plant to be more disease-resistant. Potassium encourages the development of the root system of the plants. Research has also shown that potash regulates generally the state of swelling of the plant cells. Wherever active growth processes are taking place in the plant, accumulation of potash is found.

An excess of this element may delay maturity but in general this element has a balancing effect on both nitrogen and phospherus with respect to the maturation processes. Childers (13) believes that the percentage of puffed or creased fruits are sharply reduced if a sufficient amount of potassium is available to the tree.

Potassium deficient plants show a reduced size of leaves in the top and early cessation of growth in that region. At the early stages the symptoms of potassium deficiency are shown by leaf twisting, curling, puckering, and fading of the chlorophyll. The fruits have an abnormally thin rind, low titrable acidity, and a greater amount of total sugar concentration, and carbohydrates, in addition to an accumulation of amino acids (8).

Interaction of phosphorus and potassium in plants.

The leaf inorganic composition of a tree is a complimentary effect of essential elements. The macronutrients like phosphorus and potassium are essential elements needed in large amounts for the composition and growth of the tree. These elements have a multiple function in the vital processes of plant growth, Apparently these elements have an individual function in the plant but there is evidence that one element may be substituted effectively, partially or in total, for another in many complex processes.

There is evidence that some essential mineral elements in the plant not only interact with each other but also interact with certain non-essential elements in influencing plant growth. In general, leaves are high in potassium content which causes an antagonistic effect on the phosphorus content of the plant, keeping the level of phosphorus at a low level and vice versa (38,39). This view has been supported by Ruether and Smith (62) when they experimented with potassium at different levels on citrus trees. This result has been confirmed by Ambleton, Kirkpatrick and Parker (15). Chapman and Rayner (10), also believe that the element phosphorus which aids the plant in absorbing potassium, tends to counteract the effects of excess potassium if it exists in the leaf tissue, whereas, if phosphorus is deficient in the plant tissue then potassium seems to be high in the plant tissue.

Smith _et_ _al_ (44) have shown by leaf analysis data on Valencia orange trees that the comparative values of phosphorus and potassium are greatly affected by different fertilizer levels applied to the soil. For example, when phosphorus is at a low level, the percentage of potassium in the dry matter of the leaves is at a high level and vice versa. A considerable amount of experimental data has shown a similar trend for citrus trees as interpreted by many different investigators (6,10,11,17,27,33,41, 42,44,51)

The literature on the interaction of phosphorus and potassium conveys the principle that phosphorus has an inverse relationship to potassium in the plant tissue. Moreover, this relationship between phosphorus and potassium is not established in the soil, regardless of the amounts and ratios applied, because phosphrus and potassium are fixed by the soil which affects the availability of these two elements to the plant. A soil balance of phosphorus and potassium must be based on the status of the soil as affected by chemical and biological reactions of soil and fertilizer. As a matter of fact, the significant balance is governed by the interaction of inorganic nutrients with the carbon compounds synthesized and metabolized in the leaf tissue.

Effect of phosphorus and potassium on other ions in the leaf tissue.

Each essential element has an important and specific role in the growth of leaf tissue. In general, the leaf inorganic composition is either based on the individual effect of such elements or it may be due to the combined effects of such elements. Lundegardh (34), believes that the leaf inorganic composition is a result of many physiological and biochemical effects on the tissue. In the first place it depends on the availability (primarily chemical solubility) of such essential and non-essential elements present in the soil. Secondly, it is mainly due to the interaction of such elements present in the leaf tissue. Lundegardh (34) has demonstrated this hypothesis by conducting various experiments using different media like sand-culture, solution-culture and others.

Generally, it has been noticed that each element is either associated with an antagonistic effect on the other element or it may be associated in a direct relationship with the other element. For example, there is an inverse realationship between phosphorus and potassium; phosphorus and nitrogen; phosphorus and iron; potassium and calcium; potassium and magnesium, as well as others (9,13, 15,38).

Chapman and Rayner (10) are of the opinion that citrus leaves if deficient in phosphorus are definitely high in potassium, calcium, manganese, and zinc. As the level of phosphate in the plant is increased, elements such as potassium, calcium, manganese, zinc, and to some extent, sodium, are decreased. However, Truog (48) has shown a direct relationship between the lack of phosphorus in the leaf tissue and mostly all other elements found in the leaves. Leonard and Stewart (31) and Ruether _et al_ (38) working specifically on the effect of an excess rate of phosphorus application to the soil on the availability of iron concluded that iron chlorosis was caused by an excess of phosphorus in the leaf tissue.

It has been generally observed that the absorption of potassium by the plant is related to the absorption of other ions (49), particularly in the absorption of calcium, magnesium and zinc. When the absorption of potassium is promoted, the absorption of calcium,magnesium and zinc are especially depressed on the basis of the amounts of these elements absorbed per unit of plant tissue produced. Conversely the amount of calcium, magnesium and zinc are increased when the potassium is decreased. Brown (4) has reported that excessive amounts of potassium displaces the iron from the active enzyme surface in the growing point of the leaf tissue and consequently disrupts the metabolic processes. Chapman (11) believes that potassium deficiency is one of the factors which affect the iron mobility. Haas (20) has proposed that in the absence of adequate supplies of minor elements potassium is absorbed in excess of its need which he called 'Luxury consumption'. The potassium content in the dry matter of the leaves in partially dependent on the nature of the rootstock variety (19,21,30,43).

Hence, to understand the effect of one element on the other element, a long term investigation with different, combinations of nutrient elements is a correct approach in determining some definite relationships between these elements in the nutritional status of fruit trees.

MATERIALS AND METHODS

The project to be reported on was conducted in a citrus orchard owned by Mr. Abdulkadar Tabbara and located at Adloun about 75 kilometers south of Beirut, near Tyre. The orchard is located at sea level on the narrow coastal plain of Lebanon. The soil type according to the Reconnaissance map of the soils of Lebanon is a clay soil with a pH value of about 8.5. The trees are Valencia orange scion worked on sour orange rootstock. In the orchard puffiness of citrus fruit was observed which, according to the survey of the literature, may be related to either a lack of phosphorus or potassium elements, due to the fluctuations in the irrigation practices, prolonged clear weather during fruit development or a combination of these factors. This problem of puffiness is very critical in citrus since it deteriorates the commercial value and quality of the fruit.

The total number of trees selected for this study was sixty. The reees under this trial were selected from two age groups, six years old and eleven years old. Each age group had thirty very uniform trees, each tree receiving one of the three treatments as shown in Table 1. The terms low, medium, and high will be employed here after to indicate each of the treatments applied, as well as all the pertinent information appearing in (Table 1). The fertilizers, phosphorus and potassium, were applied in the fall of

1959 by spreading them under the crown of each experimental tree. The plots were then irrigated by flooding to carry the elements into the soil. Each treatment was replicated ten times.

From the spring cycle of 1960, forty leaves per tree were selected and on February 7th marked for future identification by punching from the nonbearing terminals. Much care was taken to select normal leaves, free from diseases or any other sort of contamination as stated by Piper (36) and Thomas (45). The punched leaves were collected on July 18th when they were approximately five and half months old, brought to the laboratory and treated according to the procedure mentioned by Piper (36). The leaves were washed with a detergent by rubbing both the surfaces of the leaf with a cheese cloth. Then they were rinsed with tap water before cleaning with dilute hydrochloric acid (20 ml. of concentrated hydrochloric acid per two liters of tap water), and transfered to containers with tap water and from there washed with distilled water twice. The excess water was shaken off and and leaves were put into paper bags and placed in an oven for drying. These leaves were kept in the oven at 70°C for approximately15 hours and then cooled before grinding. The oven dried leaves were ground in a Wiley mill with a 60 mesh sieve and the ground material was collected in screw top bottles. Before weighing the samples, the sample bottles were put in the oven at 70°C for approximately 5 hours to remove the air moisture, cooled in a dessicator, and then weighed on the analytical balance to the nearest tenth of a milligram. Samples were analysed quantitatively for nitrogen, phosphorus, potassium, calcium, magnesium, sodium, manganese, and iron using the procedure described by Toth *et al* (47) and the results were reported an a dry weight basis. Nitrogen was determined by the Kjeldahl method.

The methods of statistical analysis used in this experiment were the analysis of variance and the 't' test (35) which gave the critical difference between the two means for each two of the treatments as well as between the treatments and the two age groups for their average values. The results obtained by analysis of variance were compared with the 'F' value in the distribution table at .05 and .01 levels. When the observed values were higher than the calculated values from the distribution table at .05 and .01 levels, the results were statistically sigificant, otherwise they were insignificant. The same method was followed in the 't' test. When the observed values were higher than the cabulated value of the 't' distribution table at .05 and .01 levels, the results were statistically significant otherwise they were considered insignificant if less or equal to the calculated 't' values.

The 't' test was made by using this formula:

$$t = \frac{c}{s\sqrt{\frac{2}{r}}}$$

where,

't' = Calculated value at the .05 and .01 levels in the distribution table with the degree of freedom of the error.

s = The value from the analysis of variance as the under-root of the mean square of error.

r = Replication.

c = Critical difference between the two means.

Table 1. The fertilizer application rates for each level of phosphorus and potassium applied to the experimental Valencia orange trees*

Level of Treatment	Grams per tree	
	P_2O_5	K_2O
Low	570	625
Medium	1000	1800
High	1300	2250

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* The source of commercial fertilizer was as follows; P_2O_5 — super phosphate and K_2O — potassium chloride. For nitrogen each tree received 5 kg of ammonium nitrate. Also, each tree received an application of 70 kg of goat manure.

Results and Discussion

A study was made to evaluate the effect of three different levels of phosphorus and potassium fertilizers on the inorganic leaf composition of Valencia orange trees of two different age groups, six years and eleven years old. The analytical results for nitrogen, phosphorus, potassium, calcium, magnesium, sodium, manganese, and iron are presented for each group with three fertilizer treatments; namely, low, medium, and high. Tables 2 and 11 show the mean figures for the leaf analysis of the above-mentioned elements. Tables 3 to 10 and 12 to 19 show the data for each element of the six and eleven year old trees separately. These tables show the differences between the three treatments and the ten replications which were computed to see if any significant differences occurred. Tables 20 to 27 show the means of each treatment for each of the age groups for each of the elements and their significant differences, if any. The elements phosphorus and potassium will be discussed in detail to show the effect of these two elements on the content of the other elements present in the leaf tissue. Values in the tables were reported as percent dry weight or parts per million dry weight.

Effect of three different levels of phosphorus and potassium fertilization on the inorganic leaf composition of six year old Valencia orange scion on sour orange rootstock.

The results on the inorganic leaf composition are presented as mean values in Table 2 for the six year old trees. Data in Tables 3 to 10 report the concentration of each element separately as influenced by the different levels of phosphorus and potassium. To assist in the evaluation of the data, analysis of variance and 't' test were used in this study. An example of the analysis of variance is appended at the conclusion of the dissertation as Appendix A. The material used in this example is taken from table 3.

Nitrogen

The trends in the nitrogen concentration in the foliage in relation to the different leavels of fertilizer treatments is summarized in Table 3. There was no significant difference between these treatments at the .05 level. Therefore, it can be concluded that the leaf nitrogen content was not altered by the addition of varying amounts of phosphorus and potassium.

Phosphorus

The data in Table 2 shows that the average values of phosphorus are .136o/o, .117o/o, and .119o/o for the low, medium, and high treatments, respectively. There was no significant difference between these treatments at the .05 level, as shown in Table 4. However, the general level of phosphorus seemed to be in very close agreement with the values reported by Chapman (12) and Reuther and Smith (39). Consequently, it may be concluded that the phosphorus content in the leaves of the six year old trees was adequate for proper tree growth and development.

Potassium

As shown in Table 5 there is no statistically significant difference between the treatments at the .05 level for potassium. However, a significant difference was obtained between the replications for potassium at the .05 level which might be due to soil differences, physiological factors of the tree, or a combination of these variables. The data in Table 2 indicate that there was a tendency toward a direct relationship between phosphorus and potassium. For example the high content of phosphorus, .136o/o, was associated with high content of potassium, namely, .578o/o, at the low level treatment. The addition of increasing amounts of phosphorus and potassium seem to depress the amount of the two elements in the leaf tissue.

Calcium

The data in Table 6 show that there is no statistically significant difference between the treatments at the .05 level for calcium due to the varying amounts of fertilizer applied to the soil. However, there was an indication of a slight antagonistic effect between phosphorus and calcium, as shown in Table 2, in that the low average percent of phosphorus, .117o/o, was associated with high average percent of calcium, namely 7.034, at the medium level treatment.

Magnesium

The data presented in Table 7 show that there is no statistically significant difference between the treatments at the .05 level due to the varying amounts of fertilizer applied to the soil. However, it has been shown in Table 2 that there was an indication of an inverse realtionship between both phosphorus and magnesium and potassium and magnesium with regard to the amounts of these elements present in the leaf tissue.

Sodium

The data in Table 8 show that there is no statistically significant difference between the treatments at the .05 level for sodium, due to the varying amounts of fertilizer applied to the soil. However, there is an indication of a direct relationship between both phosphorus and sodium and potassium and sodium as shown in Table 2.

Manganese

As shown in Table 9 there is no significant difference between the treatments at the .05 level for manganese due to the varying amounts of fertilizer applied to the soil. However, the data in Table 2 indicate that there is a trend toward a direct relationship between both the phosphorus and manganese and potassium and manganese content in the leaf tissue.

Iron

The data shows in Table 10 that the various levels of fertilizer caused no significant differences between these treatments at the .05 level for iron.

The data in Table 2 suggest that the phosphorus and potassium content of the leaf was associated with different effects on the elements present in the plant tissue. For example, in a few cases the phosphorus and potassium were associated with an antagonistic effect such as with calcium and magnesium; while for the other elements it indicated a direct relationship, such as with sodium and manganese. However, it should be emphasized that none of these differences were statistically significant, and that these associations between phosphorus and/or potassium and the other elements are by no means conclusive.

Table 2. Mineral content (dry weight basis) of five month old Valencia orange leaves from the Spring cycle of six year trees expressed as the mean value of the level of each fertilizer treatment.

Fertilizer Treatment	Percent dry weight						Parts per million dry weight	
	N	P	K	Ca	Mg	Na	Mn	Fe
Low	3.119	.136	.578	6.338	.307	.102	167.8	61.0
Medium	2.930	.117	.569	7.034	.339	.093	155.1	61.1
High	3.119	.119	.563	6.170	.367	.086	122.9	58.4

Table 3. Nitrogen content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

Replication	Fertilizer Treatment		
	Low	Medium	High
1	2.952	2.922	3.284
2	3.075	2.965	3.011
3	3.225	2.996	3.411
4	3.130	2.899	3.018
5	2.965	3.039	3.007
6	3.200	2.930	3.098
7	3.200	2.661	2.920
8	2.926	2.810	3.143
9	3.310	2.998	3.144
10	3.206	3.076	3.150
Total	31.189	29.296	31.186
Mean	3.119	2.930	3.119

Treatment .

Calculated F.2/18 0.833

at .05 level n.s.

Replication .

Calculated F.9/18 1.688

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 4. Phosphorus content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

Replication	Fertilizer Treatment Low	 Medium	 High
1	.153	.102	.130
2	.130	.107	.099
3	.142	.118	.111
4	.148	.129	.121
5	.139	.107	.112
6	.154	.107	.095
7	.151	.123	.184
8	.115	.057	.097
9	.115	.142	.118
10	.109	.177	.122
Total	1.356	1.169	1.189
Mean	.136	.117	.119

Treatment.

Calculated F.2/18 .038

at .05 level n.s.

Replication.

Calculated F.9/18 .031

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 5. Potassium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

	Fertilizer Treatment				
Replication	**Low**	**Medium**	**High**	**Total**	**Mean**
1	.570	.408	.481	1.459	.486
2	.577	.450	.402	1.429	.476
3	.568	.591	.620	1.779	.593
4	.545	.683	.638	1.866	.622
5	.477	.693	.687	1.857	.619
6	.470	.598	.519	1.587	.529
7	.871	.705	.727	2.303	.734
8	.591	.491	.461	1.543	.514
9	.486	.517	.553	1.556	.519
10	.624	.600	.541	1.765	.588
Total	5.779	5.686	5.629	17.144	5.714
Mean	.578	.569	.563		

Treatment.

Calculated F.2/18		.062
	at .05 level	n.s.

Replication.

Calculated F.9/18		2.500
	at .05 level	significant
	at .01 level	n.s.

Critical difference for the treatment means
at .05 level n.s.

Table 6. Calcium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

Replication	Fertilizer Treatment Low	 Medium	 High
1	6.849	5.409	5.490
2	6.550	6.463	6.380
3	6.154	6.893	5.012
4	5.955	6.835	6.780
5	5.855	6.729	6.417
6	5.321	7.180	5.689
7	6.154	8.008	6.643
8	7.663	8.053	7.026
9	6.087	6.360	7.242
10	6.291	8.411	5.012
Total	63.379	70.341	61.691
Mean	6.338	7.034	6.170

<u>Treatment.</u>

Calculated F.2/18 3.480

at .05 level n.s.

<u>Replication.</u>

Calculated F.9/18 1.124

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 7. Magnesium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

Replication	Fertilizer Treatment Low	Medium	High
1	.322	.331	.313
2	.270	.325	.289
3	.266	.347	.303
4	.279	.297	.481
5	.306	.308	.438
6	.406	.305	.269
7	.269	.409	.545
8	.372	.357	.282
9	.310	.310	.270
10	.274	.398	.478
Total	3.074	3.387	3.668
Mean	.307	.339	.367

<u>Treatment.</u>

Calculated F.2/18 1.800

at .05 level n.s.

<u>Replication.</u>

Calculated F.9/18 .800

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 8. Sodium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	.111	.082	.129
2	.113	.077	.102
3	.111	.089	.049
4	.109	.092	.063
5	.064	.104	.084
6	.111	.109	.009
7	.161	.049	.071
8	.101	.088	.143
9	.075	.125	.106
10	.059	.113	.105
Total	1.015	0.928	0.861
Mean	.102	.093	.086

Treatment.

Calculated F.2/18 .455

at .05 level n.s.

Replication.

Calculated F.9/18 .364

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 9. Manganese content (parts per million dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	210	221	155
2	144	223	95
3	146	139	114
4	148	117	104
5	191	111	86
6	179	98	240
7	107	120	127
8	137	279	102
9	260	130	93
10	156	113	113
Total	1678	1551	1229
Mean	167.8	155.1	122.9

Treatment.
Calculated F.2/18 1.884
at .05 level n.s.

Replication.
Calculated F.9/18 0.708
at .05 level n.s.

Critical difference for the treatment means
at .05 level n.s.

Table 10. Iron content (parts per million dry weight) of five month old Valencia orange leaves from the spring cycle of six year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	69	51	74
2	60	64	59
3	59	62	65
4	57	58	41
5	60	63	44
6	55	57	66
7	48	53	66
8	68	75	61
9	72	65	64
10	62	63	44
Total	610	611	584
Mean	61.0	61.1	58.4

Treatment.

Calculated F.2/18 .331

at .05 level n.s.

Replication.

Calculated F.9/18 1.200

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Effect of three different levels of phosphorus and potassium fertilization on the inorganic leaf composition of eleven year old Valencia orange scion on sour orange rootstock.

The data presented in Table 11 show the average content of each element in the inorganic leaf composition for the eleven year old trees. The data in Tables 12 to 19 report the concentration of each element separately as influenced by the different levels of phosphorus and potassium. Analysis of variance and 't' test were used in the computations.

Nitrogen

The data show in Table 12 that there is a statistically significant difference between the treatment means of the low and high level treatment at the .05 level for nitrogen which might be due to the varying amounts of fertilizer applied to the soil. As the amount of fertilizer applied to the soil was increased, the amount of nitrogen in the leaf tissue was increased. No significant difference was found between the treatments for nitrogen.

Phosphorus

The phosphorus content of the leaves is presented in Table 13. No significant difference between the treatment are revealed at the .05 level, although varying amounts of fertilizer were applied to the soil. However, the figures obtained in this experiment are in the adequate range according to Chapman (12) and Reuther and Smith (39)

Potassium

The data in Table 14 show that there is a significant difference between the treatment means of the medium and high level treatment at the .05 level for potassium which might be due to the varying amounts of fertilizer applied to the soil. No satisfactory explanation can be presented by the writer to account for this relatively low potassium leaf content at the high level treatment. The data in Table 11 suggest that there is a direct relationship between phospherus and potassium, which is not in agreement with the findings of Reuther and Smith (39).

Calcium

As shown in Table 15 there is no statistically significant difference between the treatments at the .05 level for calcium, when the varying amounts of fertilizer were applied to the soil. However, there is a statistically significant difference between the treatment means of the low and high treatments. It is evident that the higher fertilizer treatments caused the calcium content of the leaf tissue to be reduced.

Magnesium

The data show in table 16 that there is a statistically significant difference between both the treatments and the replications at the .05 level, and between the replications at the .01 level for magnesium. It is evident that replications 4 and 7 are abnormally low and replications 8 and 10 are unusually high. This wide range of variation indicates that soil heterogeneity is a big factor with respect to magnesium. The significant difference obtained between treatments is harder to explain because of the huge differences within the treatments as well as between the treatments. These differences within treatment are two-fold in some cases. These extreme differences are also evident between the treatment means which showed a statistically significant difference at both the .05 and .01 level between the medium and high level fertilizer treatments. The writer can not explain why the amount of magnesium in the leaf tissue should drop at the medium fertilizer level and then increase so much at the high level treatment. Certainly more critical data will have to be collected before the answers to this behavior will become apparent.

Sodium

The data presented in Table 17 show that there is no significant difference between the treatments and the .05 level for sodium due to the varying amounts of fertilizer applied to the soil.

Manganese

The data reported in Table 18 show that there is no significant difference between the treatments at the .05 level for manganese when the varying amount of fertilizer were applied to the soil.

Iron

The data show in Table 19 that no significant difference was obtained between the treatments at the .05 level for iron due to the varying amounts of fertilizer applied to the soil. However, the data suggest in Table 11 that there is a slight antagonistic effect between phospherus and iron in that the low level phosphorus was associated with the high level iron.

Table 11. **Mineral content (dry weight basis) of five month old Valencia orange leaves from the Spring cycle of eleven year trees expressed as the mean value of the level of each fertilizer treatment.**

Fertilizer Treatment	Percent dry basis						Parts per million dry basis	
	N	P	K	Ca	Mg	Na	Mn	Fe
Low	2.631	.121	.643	7.152	.405	.097	89.3	49.3
Medium	2.778	.134	.711	7.000	.355	.085	92.5	45.3
High	2.834	.125	.592	6.743	.449	.107	99.1	45.1

Table 12. Nitrogen content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	2.728	2.706	3.093
2	2.170	2.935	2.785
3	2.691	2.777	2.453
4	2.659	2.637	2.916
5	2.593	2.770	2.653
6	2.657	2.881	2.805
7	2.665	2.663	3.125
8	2.701	2.823	2.866
9	2.806	2.688	2.819
10	2.638	2.896	2.825
Total	26.308	27.776	28.340
Mean	2.631	2.778	2.834

<u>Treatment.</u>

Calculated F. 2/18 3.484

at .05 level n.s.

<u>Replication.</u>

Calculated F. 9/18 .017

at .05 level n.s.

Critical difference for the treatment means between low and high level,

at .05 level Significant
at .01 level n.s.

Table 13. Phosphorus content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	.115	.145	.129
2	.083	.169	.110
3	.132	.111	.099
4	.155	.136	.142
5	.142	.133	.132
6	.094	.147	.126
7	.135	.128	.145
8	.112	.114	.116
9	.137	.135	.125
10	.106	.128	.129
Total	1.211	1.346	1.253
Mean	.121	.135	.125

Treatment.

Calculated F. 2/18 1.667

at .05 level n.s.

Replication.

Calculated F. 9/18 1.000

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 14. Potassium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	.729	.801	.537
2	.331	.694	.492
3	.709	.784	.494
4	.535	.506	.698
5	.798	.565	.724
6	.626	.797	.600
7	.586	.554	.502
8	.617	.740	.668
9	.742	.597	.624
10	.756	1.074	.586
Total	6.429	7.112	5.925
Mean	.643	.711	.593

Treatment.

Calculated F. 2/18 2.250

at .05 level n.s.

Replication.

Calculated F. 9/18 1.375

at .05 level n.s.

Critical difference for the treatment means between medium and high level,

at .05 level Significant
at .01 level n.s.

Table 15. Calcium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year oldtrees.

	Fertiliser Treatment		
Replication	Low	Medium	High
1	6.979	6.864	6.227
2	9.122	6.738	7.298
3	6.811	6.918	8.265
4	6.184	6.632	6.670
5	6.141	7.294	5.666
6	8.195	6.732	6.511
7	6.787	7.001	5.582
8	7.243	6.720	7.491
9	7.371	8.884	6.736
10	6.691	6.219	6.983
Total	71.524	70.002	67.429
Mean	7.152	7.000	6.743

Treatment.

Calculated F. 2/18 .682

at .05 level n.s.

Replication.

Calculated F. 9/18 1.210

at .05 level n.s.

Critical difference for the treatment means between low and high level,

at .05 level Significant
at .01 level n.s.

Table 16. Magnesium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

Replication	Fertilizer Treatment Low	Medium	High	Total	Mean
1	.438	.281	.440	1.159	.386
2	.437	.250	.480	1.167	.389
3	.348	.488	.494	1.330	.443
4	.371	.297	.316	.984	.328
5	.324	.321	.550	1.195	.398
6	.449	.299	.480	1.228	.409
7	.287	.308	.339	.944	.314
8	.456	.484	.488	1.428	.476
9	.480	.305	.467	1.252	.417
10	.459	.514	.431	1.404	.468
Total	4.049	3.547	4.485	12.091	4.030
Mean	.405	.355	.449		

Treatment.

Calculated F.2/18 4.50

at .05 level Significant
at .01 level n.s.

Replication.

Calculated F.9/18 17.40

at .05 & .01 level Significant

Critical difference for the treatment means between medium and high level,

at .05 & .01 level Significant

Table 17. Sodium content (percent dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	.096	.072	.104
2	.096	.058	.095
3	.065	.063	.139
4	.075	.098	.095
5	.094	.061	.113
6	.096	.082	.099
7	.084	.085	.170
8	.112	.099	.090
9	.119	.114	.100
10	.134	.122	.063
Total	.971	.854	1.068
Mean	.097	.085	.107

Treatment.

Calculated F. 2/18 1.429

at .05 level n.s.

Replication.

Calculated F. 9/18 .429

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 18. Manganese content (parts per million dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	67	85	107
2	55	72	92
3	146	98	69
4	102	126	180
5	89	123	62
6	46	119	102
7	148	100	145
8	85	45	52
9	91	88	97
10	64	69	85
Total	893	925	991
Mean	89.3	92.5	99.1

Treatment.

Calculated F. 2/18 .0003

at .05 level n.s.

Replication.

Calculated F. 9/18 .002

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Table 19. Iron content (parts per million dry weight) of five month old Valencia orange leaves from the spring cycle of eleven year old trees.

	Fertilizer Treatment		
Replication	Low	Medium	High
1	43	50	48
2	39	74	47
3	61	50	48
4	65	37	43
5	62	38	47
6	36	37	47
7	61	37	47
8	40	41	40
9	45	44	42
10	41	45	42
Total	493	453	451
Mean	49.3	45.3	45.1

<u>Treatment.</u>

Calculated F. 2/18 .564

at .05 level n.s.

<u>Replication.</u>

Calculated F. 9/18 .687

at .05 level n.s.

Critical difference for the treatment means

at .05 level n.s.

Effect of the average content of inorganic constituents from the low, medium, and high level treatments on the two age groups, six year and eleven year old trees of Valencia orange scion on sour orange rootstock.

The data presented in Tables 20 to 27 give the average value of each element for each of the three treatments for the two age groups, namely, six and eleven year old Valencia orange trees. The 't' test was used to compare the effect of each element on each group. The values reported in the tables are as per cent dry weight or parts per million dry weight.

The results reported in Tables 20 to 27 clearly show that there is no significant difference between the treatments and the two age groups on any of the studied elements except iron which showed a significant difference between the six and eleven year old trees at the .01 level. The data show in Table 27 that the content of iron in the six year old trees was consistently higher than that of the eleven year old trees. The reason the younger trees contain more iron in the leaves might be attributed to a period of more active growth in these trees. The effect of the increasing amounts of fertilizer applied to the soil was to decrease the amounts of iron contained in the leaf tissues of both age groups.

Table 20. Average nitrogen content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.

Age	Fertilizer Treatment		
	Low	Medium	High
6 year	3.119	2.930	3.119
11 year	2.631	2.778	2.834
Total	5.750	5.708	5.953
Mean	2.875	2.854	2.977

Treatment.

Calculated F. 2/2 .586

at .05 level n.s.

Age.

Calculated F. 1/2 9.793

at .05 level n.s.

Table 21. Average phosphorus content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	.136	.117	.119
11 year	.121	.134	.125
Total	.257	.251	.244
Mean	.129	.126	.122

Treatment.

Calculated F. 2/2 .000

at .05 level n.s.

Age.

Calculated F. 1/2 .000

at .05 level n.s.

Table 22. Average potassium content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	.578	.569	.563
11 year	.642	.711	.592
Total	1.220	1.280	1.155
Mean	.610	.640	.578

Treatment.

Calculated F. 2/2 .75

at .05 level n.s.

Age.

Calculated F. 1/2 4.5

at .05 level n.s.

Table 23. Average calcium content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	6.338	7.034	6.170
11 year	7.152	7.000	6.743
Total	13.490	14.034	12.913
Mean	6.745	7.017	6.457

Treatment.

Calculated F. 2/2 1.658

at .05 level n.s.

Age.

Calculated F. 1/2 3.211

at .05 level n.s.

Table 24. Average magnesium content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	.307	.339	.367
11 year	.405	.355	.449
Total	.712	.694	.816
Mean	.356	.347	.408

Treatment.

Calculated F. 2/2	6.000
at .05 level	n.s.

Age.

Calculated F. 1/2	12.000
at .05 level	n.s.

Table 25. **Average sodium content of the Valencia orange leaves (percent dry weight) of the treatment and the two age groups.**

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	.102	.093	.086
11 year	.097	.085	.107
Total	.199	.178	.193
Mean	.100	.089	.097

Treatment.

Calculated F. 2/2 .0001

at .05 level n.s.

Age.

Calculated F. 1/2 .00015

at .05 level n.s.

Table 26. Average manganese content of the Valencia orange leaves (parts per million dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	167.8	155.1	122.9
11 year	89.3	92.5	99.1
Total	257.1	247.6	222.0
Mean	128.6	123.8	111.0

Treatment.

Calculated F. 2/2 .416

at .05 level n.s.

Age.

Calculated F. 1/2 11.448

at .05 level n.s.

Table 27. Average iron content of the Valencia orange leaves (parts per million dry weight) of the treatment and the two age groups.

	Fertilizer Treatment		
Age	Low	Medium	High
6 year	61.0	61.1	58.4
11 year	49.3	45.3	45.1
Total	110.3	106.4	103.5
Mean	55.15	53.20	51.75

Treatment.

Calculated F. 2/2 2.744

at .05 level n.s.

Age.

Calculated F. 1/2 129.95

at .05 & .01 level Significant

Summary and Conclusions

This study deals with the evaluation of the effect of three levels of phosphorus and potassium fertilization on the inorganic leaf composition of Valencia orange leaves on sour orange rootstock. Trees of two age groups, six and eleven years old, were selected for this experiment. Each age group contained thirty experimental trees with three levels of treatment. A low, medium and high treatment was applied, namely 570, 1000, and 1300 grams of P_2O_5, and 625, 1800, and 2250 grams of K_2O respectively. Each treatment was replicated ten times in each group. The total number of trees used in this project was sixty. Chemical determinations were made on five months old leaves collected from the spring cycle of the 1960 growing season. The elements analysed were nitrogen, phosphorus, potassium, calcium, magnesium, sodium, manganese and iron.

The results presented in Tables 2 to 10 reveal that there is no statistically significant effect of phosphorus and potassium fertilizers on any of the elements for the six year old trees. A statistically significant difference was obtained for potassium between replications. This difference is probably due to soil heterogeneity.

The results presented for the eleven year old trees reveal several statistically significant differences. The amount of nitrogen in the leaf tissue was increased as the amount of fertilizer applied to the soil was increased. A statistically significant difference between the treatment means of potassium could not be explained. It was evident that the increases in fertilizer applications caused the amount of calcium in the leaf tissue to be reduced.

The results for magnesium show that there was considerable soil heterogeneity involved. The tremendous variations between the individual plots resulted in significant differences which the writer can not explain. More critical data will have to be collected before the answers to this behavior will become apparent.

No significant differences were obtained for the elements, phosphorus, sodium, manganese, and iron. The data for iron show a statistical significant effect between the two age groups. The high content of iron in the six year trees might be due to the more active growth in these trees.

The statistical results reported in this study have pointed out that the experimental trees were growing satisfactorily and that the amounts of phosphorus and potassium available were adequate for all the treatments. Phosphorus and potassium could not be listed as a cause of 'Creasing or Puffiness' of Valencia oranges in this study.

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