NITROGEN AND PHOSPHORUS CONTENT OF CITRUS LEAVES IN ISRAEL: FREQUENCY DISTRIBUTION, AND INFLUENTIAL FACTORS[1]

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Leaf analyses have been successfully used for evaluating the nutritional status of citrus groves, and standard values which indicate the ranges for deficiency, normal supply, and excess of mineral elements have been determined for many regions in which citrus is grown. In Israel, tentative standards for N,P,K,Ca, and Mg content in Shamouti orange leaves have been reported by Oppenheimer (15). Based on this work, numerous leaf analyses, especially of N and P content, were carried out in local commercial groves over a period of seven years from 1943—1950. Subsequently, in order to obtain general information as to the N- and P-status of Israel groves, the data accumulated during this period were reduced to frequency curves, and the results of the survey are reported in Section I of this paper.

These data were obtained from unselected groves; usually the analyses were made at the request of the owner, or in connection with fertilizer trials being conducted by the Agricultural Research Station. Citrus leaf composition is affected, however, by various factors not directly related to the mineral nutrition of the tree. For example, citrus groves in Israel are planted on soils with widely differing characteristics, and it is conceivable that these differences may not only cause variations in the amounts of nutrients supplied to the trees, but may affect the normal leaf composition — i.e., leaf analysis standards. Such edaphic effects are suggested by the differences in citrus standards reported from various regions. Though these standards are similar for widely differing conditions in California (5), Florida (19), Arizona (7), South Africa (1), Jamaica (11), Trinidad (9), and Israel, there are certain discrepancies. These may be due, at least in part, to fundamental differences in soil characteristics.

The mineral composition of the scion foliage is profoundly affected by the citrus rootstock, as has been shown conclusively by Haas (8), Smith, Reuther, and Specht (20), and Wallace et al. (22). Since sweet lime and sour orange are the main rootstocks used in mature citrus groves in Israel, while Rough lemon is seldom used but may be planted more extensively in the future (14), it is important to determine the effect of rootstock variety on the composition of the scion foliage.

In addition, the scion species and/or variety may also be an important factor. Though Chapman (5) has suggested that standard values for orange leaves may be valid for lemon and grapefruit as well, unpublished preliminary studies made in Israel suggest that leaf composition may differ in different scion species. This possibility is borne out by the work of Camp and Fudge (4) and of Burkhart (3).

In order, therefore, to test the effect of these factors on the N and P content of citrus leaves, leaf analyses were carried out during two seasons, 1948—1950, in experimental plots at the Agricultural Research Station and in 8 commercial groves selected according to the following requirements: (1) that they be truly representative of the kind of soil, species, or rootstock to be tested; (2) that they be in good condition, i.e., with clean cultivation, well-developed trees, dark green

1 Agricultural Research Station, Rehovot 1954 Series, No. 87.

foliage, and high yields; and (3) that they be situated in the same district, to ensure similar climatic conditions. Results are reported in Section II.

METHODS

Leaf Samples: In all cases, 9—10 month old leaves were taken from the fruit-bearing branches on the trees' northern quadrant, according to the sampling method of Bathurst (2) as modified by Oppenheimer (15).

Analytical Procedure: Leaves were gently cleansed in a detergent solution, rinsed several times first in tap, and then in distilled water, and dried immediately at 65°C. Nitrogen was determined by the micro-Kjeldahl method (6) and phosphorus, by King's method (12).

Results were statistically evaluated according to Snedecor (21).

Tree variability: In order to determine variability among trees, leaf samples were taken from 10 trees each, in 10 groves, and were separately analysed. As in previous experiments (10), variability was relatively small: in a total of 100 trees, the average coefficient of variability was 6.81% for leaf-nitrogen and 8.68% for leaf-phosphorus. This indicates that for most practical purposes, a composite sample from 5—8 trees will permit a sufficiently precise estimate of the nutritional status of an orchard — provided, of course, that soil, cultivation, and fertilizing are reasonably uniform throughout.

RESULTS

I. Frequency Distribution of Nitrogen and Phosphorus Content in Shamouti Orange Leaves

As was noted above, leaf analyses were made on a total of 550 Shamouti orange trees in various commercial groves during 1943—1950 inclusive, either at the request of the owner or in conjunction with fertilizer trials. Such factors, therefore, as rootstock, soil type, cultivation, irrigation, and fertilizing, differed considerably and their effects are mingled in the leaf analysis data. Nevertheless, certain trends are clearly evident — probably because the number of trees included in the survey was large.

Nitrogen Content: Results of all N assays, as summed up in Fig. 1 show that the N-content of Shamouti orange leaves ranged from 1.3—3.1% of dry matter, with the peak at 2.03%. Since an N-content of 2.2% in leaves is considered to be indicative of a sufficient supply of N in the soil, Fig. 1 shows that only 25% of the groves were adequately supplied with N, while 75% required increased N-fertilizing.

This was doubtless due to the fact that in the years during which these analyses were made, the local citrus industry suffered serious economic difficulties with the consequence that fertilizing was often kept to the minimum and cultivation was much neglected. This resulted in the gradual decrease of N-reserves in the trees which was reflected in a general deterioration in grove conditions and a marked decline in yields.

The relationship between N-fertilizing and N-content of leaves is clearly shown in Fig. 2: where less than 12 kg of N per dunam[1] per year was supplied, leaf analyses indicated a severe N-deficiency according to previously-established standard values (10).

Phosphorus Content: A P-content of less than 0.10% of dry matter in leaves is considered to indicate that P-fertilizing is inadequate. As may be seen from Fig. 3, no P-values indicating severe P-deficiency were found, and only 10% of the samples

1 Equivalent to 107 lbs. per acre.

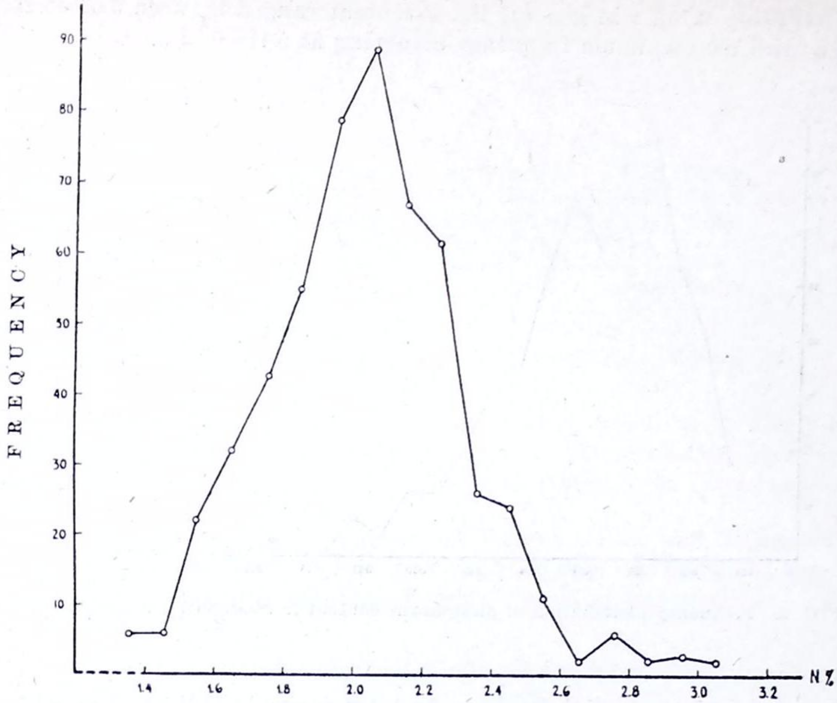

FIG. 1. Frequency distribution of nitrogen content in Shamouti orange leaves.

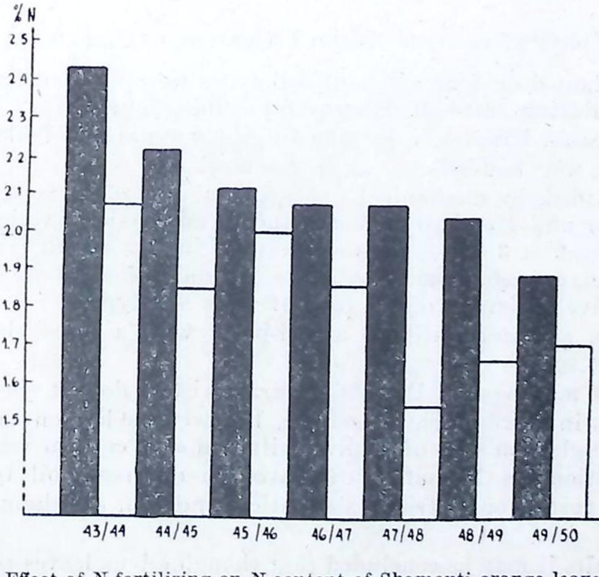

FIG. 2. Effect of N-fertilizing on N-content of Shamouti orange leaves (1943—50).
Black columns: Groves fertilized with 12 kg. of N per dunam or more.
White columns: Groves fertilized with less than 12 kg. of N per dunam.

analysed fell below 0.10% ; in general the P-content ranged between 0.08—0.28% of dry matter, with the maximum frequency occurring at 0.11—0.12%.

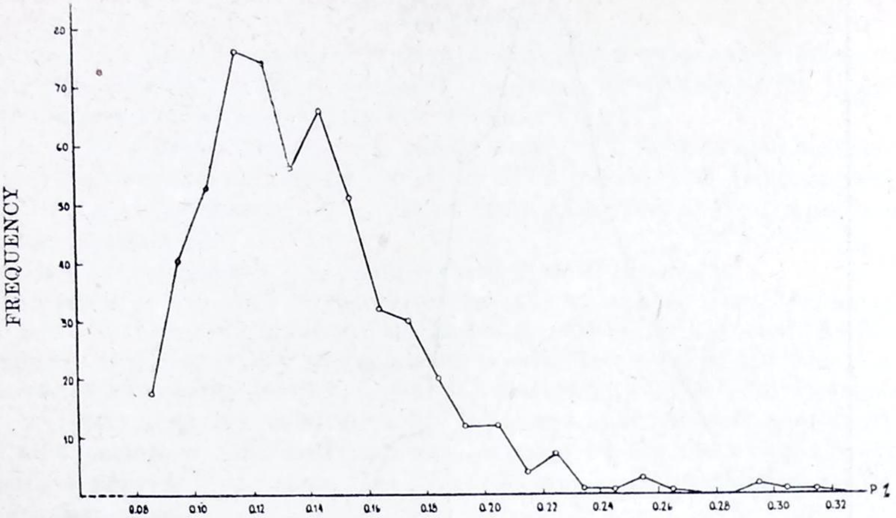

FIG. 3. Frequency distribution of phosphorus content in Shamouti orange leaves.

However, these relatively high P-values do not necessarily indicate that the supply of P was abundant, since it has been shown (10) that in N-deficient leaves, there is an inverse relationship between N- and P-content. The true P-status can be detected, therefore, only after any N-deficiency has been corrected. Thus it is quite likely that the P percentages in these groves may have increased due to their low N-status.

II. Factors Affecting N- and P-Content in Citrus Leaves

1. *Soil*: Groves planted on four different soil types were selected for the leaf analyses carried out during 1948—50. Wherever possible, four citrus species were included; in three cases, however, a specific species was not available on one of the soil types. All trees were budded on sour orange stock.

Soils were identified, by mechanical analysis and according to the classification of Prescott, Taylor and Marshall (17), as sand, sandy loam, clay loam, and heavy clay. Groves on the first 3 soil-types were located in the vicinity of Rehovot; the fourth, on heavy clay, was located in the eastern part of the Valley of Esdraelon. Groves are extensively planted on all four of these soil-types.

pH of the soils, as determined on a soil-paste with a glass electrode, ranged between 7.22 and 7.92.

From Table 1 it may be seen that soil characteristics do not significantly affect the P percentages in leaves. The N content, however, is low on sandy and heavy clay soils and is higher on soils of medium silt and clay content (sandy loam, clay loam). The variations in N content of leaves on different soil types reflect the effects of soil properties on nutrient absorption and root development, as will be discussed below.

From these results it may be concluded that though citrus leaves reflect the differing nutritional conditions of trees on various soil types, the standard values are applicable regardless of soil properties.

TABLE 1. — EFFECT OF SOIL TYPE ON N AND P CONTENT OF CITRUS LEAVES
(% of dry matter)

Variety	*Sand*		*Sandy loam*		*Clay loam*		*Heavy clay*	
	N	P	N	P	N	P	N	P
Eureka lemon	1.30	0.107	1.51	0.084	1.45	0.093	1.52	0.083
Marsh Seedless grapefruit	—	—	1.63	0.078	1.73	0.078	1.55	0.088
Valencia orange	1.75	0.096	1.81	0.095	1.78	0.099	1.61	0.099
Clementine mandarin	—	—	1.92	0.108	—	—	1.87	0.101
Average	1.53	0.101	1.72	0.091	1.65	0.090	1.62	0.093

Standard error of the difference between two means for N percentages: 0.0392%.
Standard error of the difference between two means for P percentages: 0.00399%.

2. *Rootstock*: For the determination of the effect of rootstock on N- and P-content, leaf samples were taken from a field-trial of the 3 main rootstocks used in Israel groves, carried out at the Agricultural Research Station (13). Trees were planted on sandy soil.

Table 2 indicates that the N content of Eureka lemon and Shamouti orange foliage is significantly lower on sour orange stock than on Rough lemon or sweet lime. There is no significant difference between the latter two stocks.

TABLE 2. — EFFECT OF ROOTSTOCK ON N CONTENT OF CITRUS LEAVES
(% of dry matter)

Scion variety	*Rootstock Variety*			*Average*
	Rough lemon	*Sweet lime*	*Sour orange*	
Eureka lemon	1.59	1.64	1.51	1.58
Shamouti orange	1.97	1.97	1.88	1.94
Average	1.78	1.80	1.69	

Significance of F tests: Varieties — significant at 0.01 level.
Sour orange vs. other stocks— significant at 0.01 level.
Rough lemon vs. sweet lime — not significant.

The P content of the leaves shows that there is a pronounced interaction between scion and rootstock effects (Table 3). The P content in Shamouti orange leaves is

TABLE 3. — EFFECT OF ROOTSTOCK ON P CONTENT OF CITRUS LEAVES
(% of dry matter)

Scion variety	*Rootstock variety*			*Average*
	Rough lemon	*Sweet lime*	*Sour orange*	
Eureka lemon	0.102	0.094	0.084	0.093
Shamouti orange	0.100	0.111	0.145	0.119
Average	0.101	0.103	0.115	

Significance of F tests: Varieties — significant at 0.01 level.
Stocks — significant at 0.01 level.
Var. × stocks — significant at 0.01 level.

lowest on Rough lemon, higher on sweet lime, and highest on sour orange. In lemon leaves P content increases in the inverse order: sour orange, sweet lime, Rough lemon. A possible explanation for these relationships will be offered in the Discussion.

The effect of rootstock on N content of scion leaves is relatively small, and may be immaterial in leaf analysis interpretation. On the other hand, the amount of P in scion foliage is significantly influenced by rootstock variety, and this factor should be considered in evaluating and interpreting leaf analysis data.

3. *Scion Species*: For analysis of leaf content of N and P in different citrus species, four of the commercially important varieties grown in Israel were selected, i.e., Eureka lemon, Marsh Seedless grapefruit, Valencia orange, and Clementine mandarin. All were in groves planted on sandy loam soil in the vicinity of Rehovot, and all were budded on sour orange rootstock.

Results are presented in Figure 4. Data obtained in both years agree well, though in the 1949/50 season slightly higher values were found in leaves of all four varieties. The N content of the leaves increases in the following order: Eureka lemon, Marsh

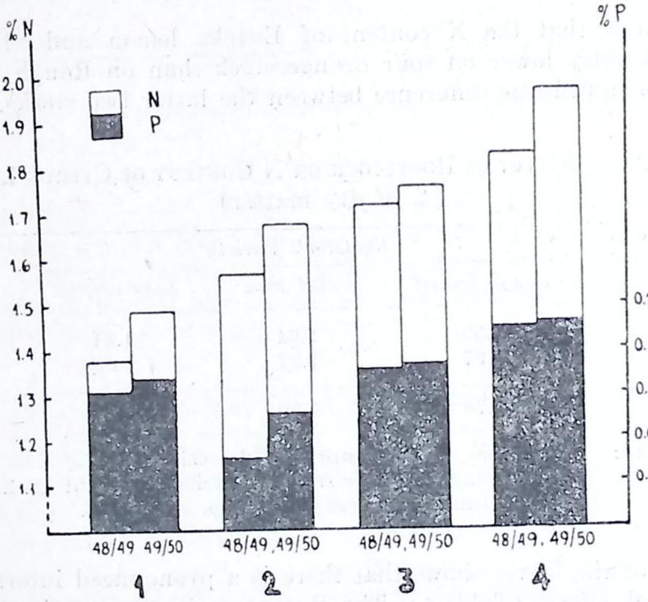

FIG. 4. Leaf contents of N and P in different citrus species during 1948—50.
(1) Eureka lemon; (2) Marsh Seedless grapefruit; (3) Valencia orange; (4) Clementine mandarin.

Seedless grapefruit, Valencia orange, Clementine mandarin. P content in different varieties increases in the same order, except that P is somewhat lower in grapefruit than in lemon leaves. The analysis of variance indicates a highly significant variance ratio, F, for both N and P percentages in different varieties.

DISCUSSION

Statistical analyses of leaf-content data accumulated during seven years showed that inadequate N-fertilizing seriously reduces N-content in citrus leaves, which in turn affects the P-status. However, leaf analyses carried out during 2 seasons in selected groves indicate that other factors are involved as well: soil properties affect nutrient absorption and hence should determine fertilizing practices; while rootstock and scion species influence P-, and N- and P-content, respectively.

Trees on the loamy soils, which are considered most suitable for citrus-growing from the standpoint of ease in cultivating and irrigating, showed higher percentages of N in the leaves. This is due to the fact that these soils provide desirable nutritional conditions, for N-deficiencies were found more frequently on sandy and clay soils than on loamy types. Heavy clays probably restrict root development and nutrient absorption, while sandy soils contain only small quantities of available plant nutrients, and retention of added nutrients is less effective than in soils containing more colloids. Furthermore, such soils must be frequently irrigated, thus increasing the danger of loss by leaching. Organic matter, which on heavier soils ensures a slow and steady N supply, is rapidly oxidized from sandy soils; N losses by ammonia volatilization may be considerable (18); and non-symbiotic N fixation has been shown, in Israel, to be less in sandy soils than in all other soils of the coastal belt (6). Particular care, therefore, must be taken to ensure an adequate N supply to citrus trees planted on sandy soil. Nitrogenous fertilizers should be applied in a form which is not readily leached and, possibly, in small but frequent applications. In irrigating, care should be taken to avoid leaching of soluble nitrogen compounds below the root zone. Leaf analysis is an efficient means of checking on the effectiveness of fertilizing practices and the adequacy of fertilizer quantities.

Various hypotheses have been put forward to explain the effects of rootstock on scion foliage-composition, among them, that the scion foliage reflects the varying absorption capacities of different rootstocks. This hypothesis fails to explain why the same stock has different effects on various scions. Smith, Reuther and Specht (20) found a correlation, in Valencia oranges, between the total amount of N per leaf, and the size of the unbudded rootstock trees. However, there were many exceptions. Our results, on the other hand, suggest a relation between nutrient levels in leaves and stock-scion compatibility. The highest N and P percentages are found in leaves of lemon trees budded on Rough lemon stock, but are lower in trees on sweet lime, and lowest on sour orange stock. In rootstock trials, the compatibility of lemon trees with these three rootstocks, as judged by smoothness of the bud-union and tree vigour, decreases in the same order (23, p. 174). Similarly fluctuations of P content in leaves of orange trees are parallel with the compatibility of the scions to the three examined rootstocks.

Leaf analyses of grapefruit on various rootstocks tend to support this hypothesis. We found (unpublished data) an average N content of 1.67% in grapefruit leaves on sour orange stock, as against 1.56%, on sweet lime. Grapefruit forms a stronger and smoother bud union with sour orange than with sweet lime.

That scion species, also, affects both N and P content was clearly evident from our results; percentages of both were lower in lemon and grapefruit than in orange and mandarin. The differences were sufficiently significant to suggest that at least two different standards of citrus-leaf composition may have to be distinguished: one for lemon and grapefruit varieties, and a second for orange and mandarin.

It is possible that the lower nutrients content of grapefruit and lemon leaves indicates that they have higher nutritional requirements than do orange and Clementine. Both Burkhart (3) and Camp and Fudge (4), comparing the composition of grapefruit and orange leaves in Florida, found similar differences. Further experiments are required to elucidate the cause.

SUMMARY

Results of analyses of nitrogen and phosphorus content in citrus leaves made in unselected groves during the seven years between 1943—1950 are summed in frequency curves: data obtained from 550 Shamouti orange trees indicate that in 75% of the examined groves N-supply was low or deficient, with maximum frequency occurring at 2.03% of N in leaves, while P-content was relatively high, with maximum frequency occurring at 0.11—0.12%.

Leaf analyses undertaken in carefully selected groves during two seasons, 1948—1950, to determine effects of soil, rootstock, and scion variety on N- and P-content of leaves show that:

1. Leaves from trees on soils with medium silt and clay content have higher N-percentages than those on sandy or heavy clay soils.
2. Leaves of Eureka lemon and Shamouti orange trees budded on sour orange had significantly lower N content than did those budded on Rough lemon or sweet lime; P percentages in Shamouti orange leaves were highest in sour orange, while those in Eureka lemon were lowest on this stock. Variations may tentatively be ascribed to differences in scion-stock compatibility.
3. Marsh Seedless grapefruit and Eureka lemon leaves contained less N and P than did Valencia orange and Clementine mandarin leaves.

It was concluded that while both N and P content in citrus leaves are greatly affected by N-fertilizing, they are also dependent on soil-type, rootstock, and species.

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