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THE USE OF LEAF, FRUIT, AND SOIL ANALYSIS IN ESTIMATING POTASSIUM STATUS OF ORANGE TREES

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Several investigations (1, 10, 11) have emphasized the importance of avoiding excessive potash fertilization in the production of oranges containing high soluble solids. Consequently, in recent years the use of potash in fertilization has remained relatively constant in some groves and decreased in others, while the nitrogen application has increased in practically all groves (4, 6). With the decreasing amounts of potash applied, the potassium status of trees should be closely watched to prevent occurrence of any deficiency. Early visible symptoms of potassium deficiency are not clearly defined, and their use for fertilization control is not very dependable. The use of leaf analysis as a guide to potash fertilization has been suggested (7, 9, 13).

This paper presents data from a field study to evaluate the usefulness of leaf, fruit, and soil analyses as guides to determine the potassium status of the trees, and to determine whether a critical level can be established above which the potassium level should be maintained in the tree.

Experimental Procedure

The investigation was conducted on a block of mature Hamlin and Valencia orange trees on rough lemon rootstock on Lakeland fine sand at the Citrus Experiment Station. This block was formerly a potash rate experiment containing seven rates. Treatments and results of that experiment have been previously reported (1, 11). No potash has been applied to any part of the seven-acre block since July 1957. Certain treatments which received 0, 2, 8, and 16 per cent K_2O in the fertilizer between 1942 and 1957 will be reported. These rates were included in mixtures of 4-6-X-4-1-1 prior to 1954 and 8-0-X-6-.6-0 since 1954. These treatments, representing a wide range of potassium levels in the tree, are designated as 0, low (L), medium (M), and high (H) potash treatments in the discussion. The check plots (+K) which received potash regularly were selected from the no-irrigation plots of an irrigation experiment in the adjacent block. Trees in both blocks were planted at the same time and have been under identical cultural practices except for potash.

Leaf and fruit samples were collected annually and analyzed for mineral composition. Soil was sampled in 1957-58 and again in 1960-61 after the fruit was harvested. Fruit samples for measurement of internal quality were collected three times yearly. Sampling procedure, preparation of samples, and analytical methods have been previously reported (4).

Results

Potassium Content of Leaf, Fruit, and Soil.— The potassium content of leaf and fruit over a five-year period is presented in Figure 1. The leaf potassium content of both Hamlin and Valencia decreased after the omission of potash from the fertilizer. The rate of decrease was faster in trees that were high in potassium in 1957 than trees which were low in this element. Table 3 also shows the range in the potassium content of leaves by varieties and years. There was very little change in the potassium content of leaves in either variety between 1957 and 1959. It is possible that some of the potash was returned to the soil from very heavy fruit drop following the 1957-58 freeze. Valencias lost twice as many fruits as Hamlin, which may account for the somewhat higher potassium content in Valencia leaves in 1959. The rapid decrease of leaf potassium content between 1959 and 1961 may be related to leaching caused by the excessive rain-

Florida Agricultural Experiment Stations Journal Series No. 1544.

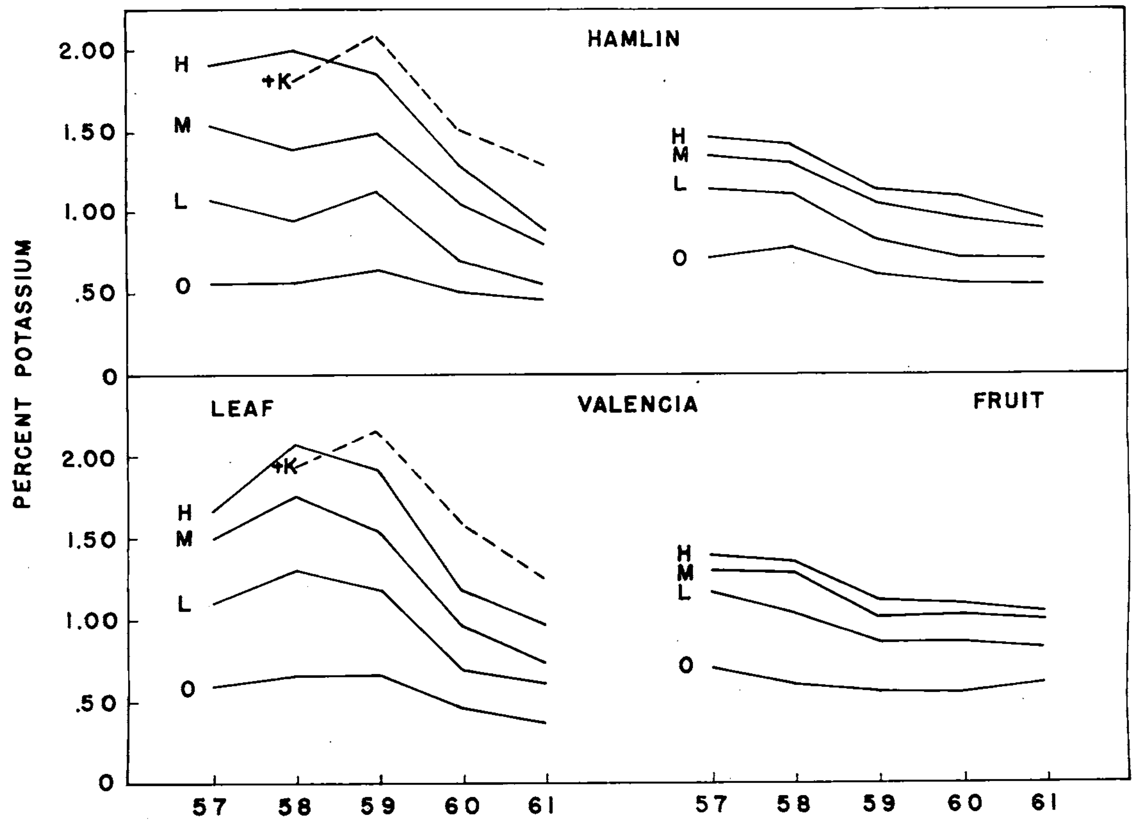

Figure 1.—Effects of omission of potash in fertilization on the posassium content of leaves and whole fruit of Hamlin and Valencia oranges.

fall of 1959 and 1960 and potash removed by fruit crops.

Normal application of potash in the +K check plots was not sufficient to maintain the potassium level of the trees, as shown by the sharp decrease between 1959 and 1961. It is possible that not all the potash applied to the +K check plots in 1961 had been taken up by the trees at the time of sampling, since 1961 was an unusually dry year. In the irrigation experiment, leaves from the irrigated plots showed higher potassium content than leaves from the check plots which were not irrigated.

The potassium content of leaves from the check plots, despite the decrease, remained in the optimum range according to Reuther and Smiths classification (9). Where potash was omitted from the fertilizer, the leaf potassium content of all trees dropped to the low or deficient range in four years regardless of previous treatments.

The potassium content of fruit also decreased after the omission of potash from fertilizer, but it was a more gradual and uniform decrease than that in the leaves. The effects of seasonal variation on the potassium content of fruit is not nearly so pronounced as in leaves. As in leaves, the decrease in the potassium content of whole fruit was greater in Hamlin than in Valencia. This may be explained by the difference in the amount of potassium removed by the fruit crop of the two varieties. The quantities of potassium removed by the fruit as shown in Table 1 are calculated from the yields and the potassium contents of whole fruit each year. Hamlin is a heavier producer than Valencia. Consequently, more potassium was removed.

Soil was sampled in the 1957-58 and 1960-61 seasons. All the plots were sampled to a depth of 48 inches. Certain treatments were sampled to 120 inches, which is in the clay depth. The extractable potassium content in the soil varied

Table 1. Potassium removed by harvest of fruit crop.

Year	0	Low	Medium	High
		Pounds per Tree		
		Hamlin		
1958-59	.68	.98	1.12	1.30
1959-60	.42	.99	1.46	1.75
1960-61	.13	.30	.83	1.12
1961-62	.23	.72	1.23	1.18
Total	1.46	2.99	4.64	5.35
		Valencia		
1958-59	.34	.57	.71	1.00
1959-60	.23	.66	1.13	1.11
1960-61	.37	.54	.92	1.12
1961-62	.06	.43	.85	.89
Total	1.00	2.20	3.61	4.12

Table 2. Changes in the extractable potassium content of soil following omission of potassium fertilization.

Depth	Year	Potassium Treatments			
		0	Low	Medium	High
			Pounds per Acre		
0-6"	1957	17	32	42	49
	1960	14	18	25	36
	Removed	3	14	17	13
0-48"	1957	63	86	117	168
	1960	38	50	58	85
	Removed	25	36	59	83
0-120"	1957	112	--	207	352
	1960	72	--	98	140
	Removed	40	--	109	212
K removed by fruit crop		45	110	179	203

directly with previous treatments (Table 2). The very high mobility of this element is indicated by the relatively low accumulation of extractable potassium in the surface 6 inches, in view of very wide ranges of potash applied (0-420 pounds per acre per year) through 1957.

Removal of potassium in the fruit accounts for most of the changes in the extractable potassium content of the soil when sampled to the clay depth. The soil showed a loss of 40 pounds per acre in the 0 treatment, 109 in the medium, and 212 pounds per acre in the high treatments

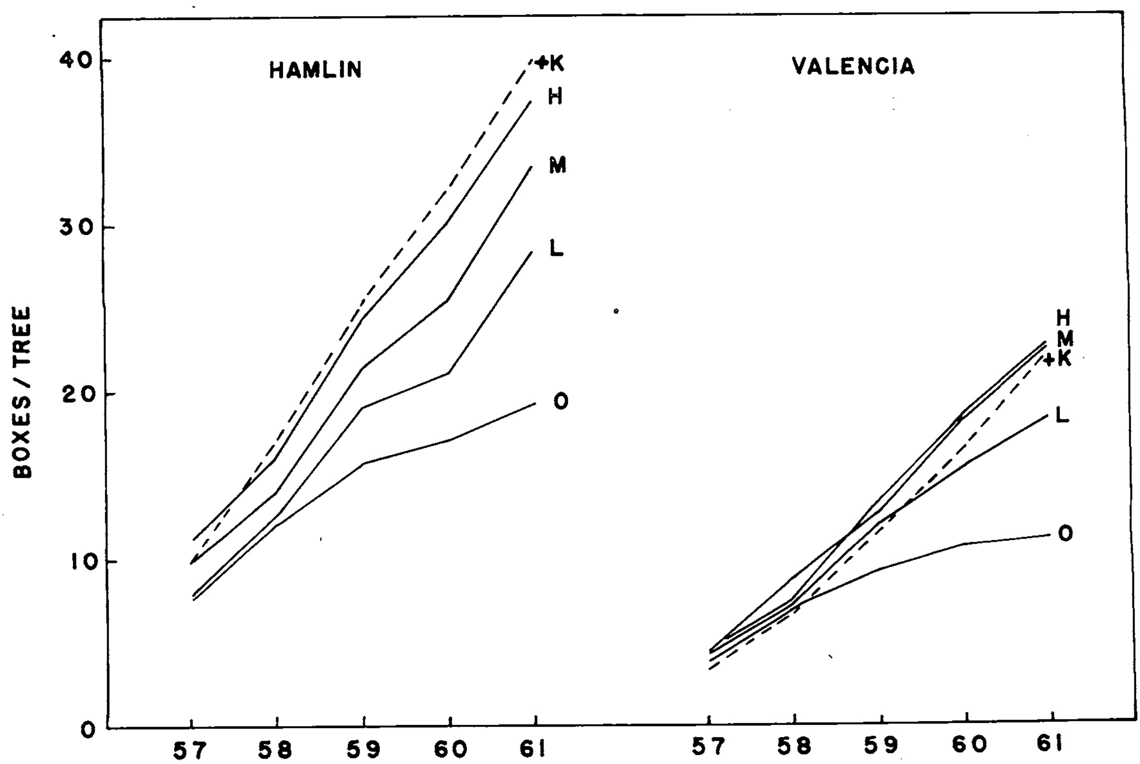

Figure 2.—Effects of omission of potash in fertilization on cumulative yield of Hamlin and Valencia oranges.

between 1957-58 and 1960-61. Calculation of potassium removed by the fruit crop for the same period showed 45, 179, and 203 pounds per acre respectively for these treatments.

Yield.—Omission of potash from the fertilizer did not affect fruit production in 1957 and 1958 (Figure 2). In Hamlin, the differences in yield among treatments became apparent in 1959 and were much more evident in 1960 and 1961, indicating the potassium level in the trees had become a limiting factor in fruit production. Plots which formerly received high potash produced as much fruit as the check plots until 1960 and 1961, when they began to decrease in yield. In Valencia orange very little difference in fruit production was observed between the medium and high treatments throughout the period. Both treatments had yields similar to the +K check plots until 1961, when the latter produced more fruit than all other treatments. Decrease in fruit production in the 0 treatment was first observed in 1959.

The fact that differences in fruit production resulting from omission of potash became apparent in 1959 for both varieties may be related to the sharp decrease in the potassium content of whole fruit for that year, although leaf potassium content remained about the same as in 1957. Year to year variation in the potassium content of whole fruit is not nearly as great as in leaves.

Relation of Potassium Content of Leaf, Fruit, and Soil to Yield.—The relation between potassium content of tree and soil and fruit production is shown in Table 3. All the individual plots were used in the calculation of correlations. Correlations between the potassium content of leaf and fruit and yield of Hamlin in 1957 were the only significant relations found in either 1957 or 1958. No significant correlation was found in 1957 between the extractable soil potassium and yield. Highly significant correlations between potassium content of leaf and fruit and yield were observed for both varieties from 1959 to 1961, indicating the potassium content in the tree had reached a level where fruit production may be affected. This is in agreement with results reported by other workers (1, 2, 7).

The low correlation coefficient (r) values between the extractable potassium of soil and fruit production in 1960-61 indicate the data are quite variable both in the 0-6 and 0-48 inch depths, even though a significant correlation was obtained.

Effects of Potassium Content of Leaf and Fruit on Yield of Soluble Solids.—The inverse relation between the potassium content of the tree and soluble solids in the juice has been reported (1, 10, 11). Such a relation is much more apparent in Valencia than in Hamlin (1, 11). It would be desirable to lower the potassium content of the tree in order to produce fruit of high

Table 3. The relationship between potassium content of leaf, fruit, soil and production of Hamlin and Valencia oranges.

Year		Hamlin Yield	Hamlin Potassium Content Leaf	Hamlin Potassium Content Fruit	Hamlin Soil 0-6"	Hamlin Soil 0-48"	Valencia Yield	Valencia Potassium Content Leaf	Valencia Potassium Content Fruit	Valencia Soil 0-6"	Valencia Soil 0-48"
		Box/Tree	%	%	lb./A		Box/Tree	%	%	lb./A	
1957	Average	9.2	1.51	1.26	38	122	4.0	1.31	1.15	32	61
	Range	6.3-11.3	.56-1.94	.71-1.49	17-49	59-177	1.7-4.7	.59-1.75	.60-1.41	13-61	55-213
Correlation Coefficient (r)			.595*	.622*	.346ns	.456ns		.188ns	.024ns	.397ns	.440ns
1958	Average	4.7	1.41	1.18	--	--	3.2	1.55	1.44	--	--
	Range	3.4-5.9	.56-2.00	.77-1.37	--	--	2.1-4.4	.49-2.49	.54-1.52	--	--
Correlation Coefficient (r)			.151ns	.156ns	--	--		.014ns	.085ns	--	--
1959	Average	7.0	1.49	.97	--	--	4.6	1.40	.92	--	--
	Range	3.8-9.2	.63-1.88	.60-1.13	--	--	1.8-6.7	.63-1.85	.45-1.21	--	--
Correlation Coefficient (r)			.594*	.675**	--	--		.705**	.705**	--	--
1960	Average	4.3	1.00	.90	25	66	4.3	.88	.90	24	43
	Range	1.3-7.7	.45-1.35	.55-1.11	15-41	46-93	.7-6.3	.43-1.35	.52-1.12	11-45	30-97
Correlation Coefficient (r)			.981**	.894**	.589*	.158ns		.848**	.852**	.561*	.552*
1961	Average	5.5	.74	.86	--	--	2.9	.70	.91	--	--
	Range	1.7-7.5	.41-.98	.54-1.06	--	--	.7-5.8	.35-1.09	.56-1.19	--	--
Correlation Coefficient (r)			.804**	.721**	--	--		.829**	.846**	--	--

Statistical symbols: ns - no significance; * - significant at 5% level; ** - significant at 1% level.
Correlation coefficient was calculated from 14 pairs of values for Hamlin and 18 pairs for Valencia.

soluble solids. The question is how much can the potassium be lowered before it becomes a limiting factor in fruit production. The soluble solids produced in each treatment between 1957 and 1961 are compiled in Table 4. The potassium content of leaf and fruit is also included to observe any relation which may exist.

In Hamlin the maximum yield of soluble solids was produced from treatments having a leaf potassium content of about 1.50 per cent. Leaf potassium content higher than that did not appreciably increase the soluble solids production. Lower potassium content resulted in lower yield. Soluble solids production in the check plots of 1958 and 1961 are the two exceptions. In 1958, the highest soluble solids were produced in the check plots at 1.81 per cent potassium. Little difference was observed in other treatments. In 1957 fruit in the check plots was harvested just prior to the freeze, whereas fruit in the other treatments was not harvested until after the freeze. Also, the production of soluble solids in the check plots in 1957 was relatively low. It is not known to what extent these factors influenced the production of soluble solids in 1958. In 1961 the highest production was in the check plots at 1.28 per cent potassium. One can only guess whether more soluble solids can be produced at a higher potassium content.

For Valencia a different level should be maintained because of suppressing effects of potassium on soluble solids. Highest solids were produced when the leaf potassium content ranged between 1.10 to 1.20 per cent. Higher or lower leaf potassium content resulted in lower soluble solids; 1958 was the only exception.

Discussion

The present study shows leaf analysis can be helpful as a guide to estimating the potassium status of orange trees. The residual effects of previous potash treatments were apparent in the leaf analyses for the first two years. After that, Hamlin fruit production dropped below the check plots in 1960 and 1961, but in Valencias this did not occur until 1961. This would suggest that a higher potassium level should be maintained in Hamlin than in Valencia. Willson (13) has suggested that the potassium level for Valencia and Pineapple oranges should not be permitted to drop below 1.0 per cent for fertilizer control purposes. That figure seems to be low, according to results of the present study.

Climatological factors influence the potassium status in the groves. Although potash was applied to the check plots at 200 pounds per acre annually, which should be more than adequate to maintain the potassium level in the trees under normal conditions, the excessive rainfall of 1959 and 1960 lowered the potassium level considerably in the trees. This may explain why a number of groves in the State showed symptoms

Table 4. Effects of potassium content of leaf and fruit on yield of soluble solids of Hamlin and Valencia oranges.

		Hamlin					Valencia				
		Potassium Treatments					Potassium Treatments				
Year		0	Low	Medium	High	+K	0	Low	Medium	High	+K
1957	Sol. Solids (lb./tree)	32.3	44.0	62.5	66.6	45.6	20.4	24.4	22.9	20.7	16.8
	Leaf K (%)	.56	1.07	1.53	1.91	--	.59	1.10	1.50	1.60	--
	Fruit K (%)	.71	1.13	1.33	1.45	--	.71	1.17	1.29	1.38	--
1958	Sol. Solids (lb./tree)	26.8	23.0	27.6	26.4	41.5	13.7	14.0	15.2	18.4	17.1
	Leaf K (%)	.56	.94	1.38	1.99	1.81	.66	1.37	1.75	1.99	1.93
	Fruit K (%)	.77	1.11	1.29	1.41	--	.59	1.03	1.28	1.52	--
1959	Sol. Solids (lb./tree)	14.5	28.6	39.2	36.4	40.1	10.4	24.9	28.0	25.0	23.5
	Leaf K (%)	.63	1.12	1.48	1.85	2.09	.66	1.18	1.54	1.63	2.15
	Fruit K (%)	.60	.83	1.05	1.13	--	.55	.86	1.02	1.11	--
1960	Sol. Solids (lb./tree)	5.0	8.0	17.4	21.4	27.1	7.9	18.9	29.6	29.7	26.9
	Leaf K (%)	.45	.70	1.04	1.27	1.50	.46	.69	.97	1.06	1.58
	Fruit K (%)	.55	.72	.95	1.04	--	.54	.86	1.03	1.09	--
1961	Sol. Solids (lb./tree)	10.0	25.2	35.9	35.7	42.0	2.7	16.5	26.6	23.9	42.2
	Leaf K (%)	.41	.54	.79	.91	1.28	.37	.61	.74	.83	1.17
	Fruit K (%)	.54	.75	.89	.96	--	.60	.82	1.00	1.05	--

usually associated with low potassium in the past few years even though recommended fertilizer programs were followed (3, 8).

The potassium content of leaves may be influenced by a number of factors. Some of the variables are age of leaves (9, 12), growth cycle (5), season (13), rootstocks (9), soil types (7), and other fertilizer materials used, notably the rates and sources of nitrogen (12). These variables should be considered in analyzing the results of leaf potassium content. In spite of these variables, leaf potassium content can be used to diagnose the potassium status of the tree. It will be more difficult to use the leaf potassium content of any one year for fertilization control, especially if the trees are under no stress for potassium. The value of leaf analysis lies in establishing trends resulting from a specific fertilizer program over the years. The fertilizer program can be adjusted if the trend indicates certain elements have been supplied over abundantly or not enough.

Fruit analysis can also be used to determine potassium status of orange trees. Both leaf and fruit potassium contents correlate well with fruit production at the lower range of the scale. Data from fruit analysis are usually more uniform than that of the leaves. Seasonal variations seemed to have little influence on the potassium content of whole fruit. Variability in the potassium content of fruit is half as great as in leaves (5), which will result in smaller sampling error. Quantity of potassium removed by fruit crop can be one of the useful aids in formulating the fertilizer program.

The value of analyzing extractable potassium on acid, sandy soil is questionable. Because of the high mobility of this element, only a small portion of the added potash is retained in the surface soil. Most of the changes in the soil potassium can be accounted for as removal in fruit if the soil is sampled to the depth of clay, but this would be impractical in commercial groves.

SUMMARY

Potash was omitted from a block of Hamlin and Valencia orange trees having a wide potassium range resulting from a previous experiment. The residual effects of previous treatments were measured by leaf, fruit, and soil analysis for five years. Little change in leaf potassium content and fruit production was noted in the first two years. Fruit production was affected as the potassium content from different treatments approached the critical level beginning the third year. At the end of the experiment, all plots were producing less fruit than the check plots, which received potash regularly.

A potassium content of 1.5 per cent for Hamlin and 1.2 per cent for Valencia is suggested as the critical level in leaves, above which level the potassium content should be maintained.

The relative application and limitations of leaf, fruit and soil analyses for potash fertilization are discussed.

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