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Report Number 120

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SUMMARY AND CONCLUSIONS

A study of the nutrient statud of 20 grapefruit orchards has been conducted of which 7 had been classified as producing poor-quality fruit and 13 good-quality fruit.

One phase of this study involved the chemical analyses of leaf samples taken at monthly intervals for a period of one year. These samples did not show any definitely significant difference in the nutritional status of this group of orchards. It is true that an extreme deficiency or excess of one or more nutrient elements does affect fruit quality in a variety of ways, but no such excess or deficiency was found for the 20 Arizona orchards. Phosphorus and potasium percentages were the only ones that approached the deficinecy range, and this occurred only in the winter months; and was found in both good and poor orchards. Potassium was lowest in February and March; phosphorus in November and December; and magnesium in February and March.

The range in phosphorus percentage for leaves from the 20 orchards was in close agreement with the ranges found for Florida, Texas, and California samples. The lowest minimum values for potassium, which were found during the winter months, are possible within the deficiency range, but here again the low minimum winter values were found in samples from both poor- and good-quality orchards. The decrease in potassium percentage with age of citrus leaves is a natural change found on all trees.

The calcium and magnesium values show that the citrus leaves in all 20 orchards were very well supplied with these two elements throughout the year.

For the micro-nutrient elements (iron, manganese, zinc, and copper), there was no apparent deficiency. However, the activity or the ability of these elements to function in the plant rather than total percentage is extremely important. The higher iron and manganese percentage found in the leaves from trees on rough lemon rootstock is of interest.

The analyses of leaves from fruit-bearing and non-fruit-bearing twigs showed a trend toward lower manganese and phosphorus in the former. This indicates a particular need for these two elements during fruit development.

Orchard cover crops have been quite frequently mentioned in studies on quality grapefruit production. To obtain some data on this, leaf samples were analyzed from an orchard where trees were growing in clean cultivated soil and in Bermuda sod. A higher potassium percentage in the latter was the only difference that appeared to be significant.

Identification of soils in the 20 orchards showed Laveen, Cajon, McClelland, and Mohave series represented, and no significant relation between soil series and fruit quality.

The chemical analyses of the soils showed a low availability of phosphorus as measured by solubility in carbonic acid, in all except one orchard. The major difference between soils from poor- and good- quality fruit orchards was the higher $CaCO_3$ in the latter. Compared with soils from Texas, Florida, and California, a major difference noted is the lower carbonic acid soluble phosphorus in the Arizona soils. This indicates that more phosphate fertilizer is used in other states.

The low availability of phosphorus in the Arizona soils was further confirmed by Neubauer seedling tests, but here again there was no difference between the soils from orchards producing good fruit and those producing poor fruit.

The Neubauer technique was also used to study uptake of iron, manganese, and zinc from the soils. Barley seedlings grown on these soils showed a tendency for a greater accumulation of these elements in the roots of plants grown in soil from poor-fruit-quality groves. This indicates a better utilization and greater activity of the micro-nutrient elements for the seedlings grown in the soil from the good-fruit-quality orchards.

In view of the higher $CaCO_3$ percentages in soils from the good-fruit-quality orchards, a Neubauer test was made on a selected group of soils and subsoils to determine the effect of $CaCO_3$ on the uptake of calcium, phosphorus, and potassium. This experiment showed a tendency toward greater accumulation of all three in the roots of seedlings grown in the more highly calcareous soils.

Comparing orchards 4 and 4A, the higher $CaCO_3$ percentage and higher root to top ratio for iron, manganese, and zinc indicate that trees subjected to some type of stress produce fruit which grades higher than fruit from highly vegetative trees.

This investigation was conducted to determine whether there is any relation between the quality of grapefruit and the nutrient status of the soil and the nutrient status of the tree as measured by chemical analysis of the leaves.

The leaf analyses indicate that variation in fruit quality is not a nutritional problem - at least within the range found for the 20 selected orchards that were studied. There was some evidence that phosphorus percentage in the leaves during the early winter months may be related, but the evidence is not conclusive because the spring leaves are well matured at this time and there is a natural trend toward reduced phosphorus percentage as citrus leaves mature.

In agreement with the leaf analyses, the chemical analyses of the soils from this group of orchards also did not show any relation between fertility tests and fruit quality. The pH tests and the soluble salt in the soil in most part is lower than for soils from Texas and California orchards; but the chloride percentage in the leaves was not related to fruit quality. Most of the soils showed a very low phosphate solubility, particularly when compared with the soils from Texas and California.

There was no evidence that soil type was related to fruit quality, although there was some evidence that the better drained soils might be producing better quality fruit. There was some evidence of a higher calcium carbonate percentage in the soils from the orchards producing good-quality fruit.

NUTRIENT STATUS OF GRAPEFRUIT ORCHARDS

AS RELATED TO FRUIT QUALITY

By W. T. McGeorge[1/]

In 1945 a number of citrus growers raised the question of the relationship between grapefruit quality and soil fertility, soil type, and nutritional status, and requested a study of the problem.

In the commercial grading of grapefruit, the term "quality" is based on a number of fruit characters. Among these are size, color, shape, juice content, peel thickness, and skin texture. In Arizona the peel thickness, size, and shape are of great concern to the gorwers because desert grapefruit frequently develops rough skin, thick peel, and pyriform shape as contrasted with smooth skin, thin peel, and oblate shape which are characters that place the fruit in higher grades. Hilgeman, Van Horn, and Martin (9) reported that fruit with thin peel also has a smooth outside texture and is flat. Pyriform fruit invariably has a thick, rough peel. Flat, well-shaped fruit may have either a thick or thin peel.

The literature on citrus nutrition is quite extensive, but only a small part deals specifically with grapefruit. Among the factors contributing to poor quality the following have been mentioned: excess or deficiency of nitrogen, potassium, or phosphorus; age of tree; cultural care; and the irrigation program.

Martin (10) conducted an extensive survey of Arizona grapefruit orchards in 1939-40 and found that trees in heavy production tend to produce fruit of high quality as compared to trees in low production; and old trees produced better quality fruit than yound trees. Among other contributing factors, the high transpiration rate during the summer and the diurnal shrinkage of fruit during the day and refilling at night have been mentioned.

Any treatment which overstimulates vegetative growth will lower fruit quality. For example, Anderssen (2) found that high nitrogen reduced navel orange quality, but omission of nitrogen seriously reduced yield. He found a reciprocal N-P (nitrogen-phosphorus) relationship and expressed the opinion that thick peel developed by excess nitrogen was in reality due to low phosphorus. This is somewhat in agreement with the observations of Finch and McGeorge (5) for Arizona grapefruit. "Wherever nitrogen was applied and, therefore, was high in the leaves, phosphorus was low regardless of whether it had been applied. Conversely, wherever nitrogen was not applied and was low in the leaves, phosphorus was high." Hardy and Rodriques (7) found higher nitrogen percentage in both rind and juice of poor-quality grapefruit.

SELECTION OF ORCHARDS FOR STUDY

Twenty orchards in the Salt River Valley were slected by four packing house managers as consistent producers of good- or of poor-quality grapefruit on the basis of their methods of grading fruit. The good and poor classification used throughout this report is used in reference to tree condition or care given to the orchard by the farmer.

Leaf samples were taken from these orchards at 30-day intervals from June, 1945, to May, 1946, with a final additional sample taken in October,

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1946. The samples were spring leaves and were taken by the personnel of the University of Arizona Department of Horticulture and always from the same trees. Following is a list of the orchards selected for the study.

1 - Goodyear Farms, Litchfield
2 - LaLoma, Litchfield
3 - R. J. Carr, Lateral 14 and Golden Lane
4 - Dr. Mills, North 7th Avenue
4a- Miller, North 7th Avenue
5 - Ellinwood, North Central Avenue, near Glendale Avenue
6 - Engelder, 7th Street near Northern
7 - Brophy, 7th Street, Conway Lane
8 - Bradley, 10th Street, Ocotillo
9 - Wagonsill, Orchard Lane, Indian School Road
10 - Ensign, Lafayette Blk.
11 - Phoenix Date Company, Lafayette Blk.
12 - Brophy, Arcadia, Lafayette Blk.
13 - Odel, near Jokake Inn
14 - Pierce Farms, Osborn Road near Chicago Avenue
15 - (Dropped from this study)
16 - Darling No. 2, N.E. of Mesa
17 - Holcomb, North of Rambos Sta.
18 - Bond, North of Rambos Sta.
19 - Thayer, Val Vista Drive, (cover crop)
20 - Thayer, Val Vista Drive, (clean cultivation)

ANALYTICAL DATA

Each leaf sample (there were 260 in all) was analyzed for ash, phosphorus, potassium, calcium, magnesium, iron, manganese, and zinc. In order to condense the large amount of analytical date, the values given in tables 1 and 2 represent maximum, minimum, and average analyses for the good- and poor-fruit-quality producing orchards.

Ash. The ash determinations given in table 1 represent the total mineral content of the leaves. It was determined by slow ashing of the samples in an electric muffle furnace at 450°C. for 18 hours. There is no correlation between the percentage of ash and the fruit quality either in the maximum, minimum, or average values. The drop in percentage ash for March, April, and May represents a new spring growth of leaves. The ash is highest in the late summer. For the poor- quality orchards, number 1 was consistently highest in ash percentage throughout the year, and number 5, consistently the lowest. Comparing orchards 4 and 4a, which are poor- and good-quality orchards respectively, and neighboring orchards, the latter is consistently lower in ash percentage.

Phosphorus. The maximum, minimum, and average phosphorus values are given in table 1 for the poor- and good-quality orchards; and the monthly averages for all orchards in figure 1 as percentage phosphorus in air-dry material. There is no significant difference between good- and poor-quality orchards. For 8 of the 12 months, the average phosphorus is higher in the orchards with good-quality records. While there is no evidence of a critical phosphorus deficiency in any of the orchards, some of the leaf analyses approach the deficiency level in October, November, and December.

For comparison with grapefruit leaf analyses from other states the following phosphorus percentages, on dry basis, are of interest. Texas .106 - .174; Florida .129 - .196; California .099 - .182.*

*These samples were collected by the author. Texas and Florida in January, and California in July.

Table 1. - Analyses of grapefruit leaves, percent air dry basis. Taken over a period of one year. Maximum, minimum, and average for 20 orchards.

	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Oct.	Ave.
Percent Ash														
Poor Orchards*														
Max.	19.07	17.78	20.53	20.44	20.64	21.37	18.50	19.30	17.76	18.00	13.60	12.19	15.60	18.00
Min.	11.65	12.26	15.91	16.00	16.20	15.88	10.45	14.48	13.60	10.40	6.82	10.37	12.93	12.80
Ave.	15.87	14.81	18.22	18.13	18.30	17.95	15.03	16.60	16.00	12.41	10.30	11.48	14.58	15.30
Good Orchards														
Max.	18.34	16.67	19.77	20.10	19.75	19.66	18.80	18.23	18.83	16.42	12.00	15.50	17.80	17.70
Min.	12.90	11.66	13.60	13.99	14.00	14.90	9.58	12.78	9.47	10.85	6.54	9.66	12.15	11.70
Ave.	16.31	14.88	17.77	18.00	18.01	17.99	15.50	16.70	16.00	13.60	10.18	11.90	15.00	15.40
Percent Phosphorus														
Poor Orchards														
Max.	.172	.175	.183	.198	.181	.157	.144	.162	.155	.172	.248	.177	.183	.177
Min.	.125	.125	.111	.127	.110	.110	.086	.113	.107	.116	.170	.153	.153	.123
Ave.	.150	.152	.142	.146	.140	.128	.111	.136	.131	.136	.219	.170	.166	.148
Good Orchards														
Max.	.182	.181	.167	.166	.181	.157	.136	.150	.164	.177	.254	.203	.187	.177
Min.	.132	.139	.115	.127	.103	.099	.103	.123	.113	.128	.166	.152	.140	.126
Ave.	.153	.167	.143	.144	.136	.126	.119	.138	.146	.145	.198	.171	.159	.149
Percent Calcium														
Poor Orchards														
Max.	6.02	6.72	6.94	6.52	7.04	7.37	6.49	6.80	6.63	6.93	4.96	5.74	6.71	6.53
Min.	4.66	4.72	4.92	4.96	5.10	5.01	4.40	4.80	5.49	4.65	2.30	3.43	5.05	4.18
Ave.	5.66	5.68	5.98	6.02	6.07	6.05	5.58	5.85	5.87	5.81	3.54	4.32	5.99	5.57
Good Orchards														
Max.	6.40	6.50	7.04	7.04	6.87	6.95	6.51	6.57	6.55	6.92	4.36	5.09	6.72	6.42
Min.	4.60	4.18	4.36	4.56	4.41	4.58	4.21	4.56	4.14	4.31	2.02	3.03	4.54	4.11
Ave.	5.70	5.72	5.92	6.22	6.05	6.12	5.68	5.85	5.77	5.84	3.67	4.46	6.03	5.62

Table 1 Continued.

	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	Oct.	Ave.
							Percent Potassium							
							Poor Orchards							
Max.	2.18	1.81	.195	1.68	1.53	1.51	1.22	1.64	1.23	1.01	2.41	2.09	1.74	1.69
Min.	1.50	1.37	.93	1.01	.82	.84	.60	1.00	.64	.36	1.99	1.75	1.02	1.06
Ave.	1.78	1.62	1.54	1.37	1.31	1.23	1.01	1.38	.98	.75	2.20	1.94	1.40	1.42
							Good Orchards							
Max.	2.14	1.96	1.88	1.81	1.68	1.67	1.28	1.67	1.47	1.16	2.62	2.40	1.86	1.82
Min.	1.31	1.17	.83	.87	.89	.80	.59	.92	.46	.42	1.78	1.63	.92	.97
Ave.	1.73	1.55	1.37	1.25	1.21	1.18	.95	1.27	.91	.71	2.27	2.10	1.40	1.38
							Percent Magnesium							
							Poor Orchards							
Max.	.568	.520	.460	.423	.413	.478	.374	.359	.343	.356	.530	.461	.440	.440
Min.	.398	.414	.362	.345	.321	.322	.317	.234	.293	.297	.253	.295	.380	.321
Ave.	.458	.457	.416	.389	.380	.397	.347	.328	.320	.324	.370	.370	.406	.381
							Good Orchards							
Max.	.616	.624	.675	.635	.575	.586	.500	.562	.542	.535	.540	.520	.590	.577
Min.	.414	.406	.342	.303	.358	.345	.323	.358	.300	.304	.314	.354	.380	.346
Ave.	.471	.511	.464	.431	.422	.429	.383	.361	.364	.358	.389	.416	.450	.419
Ave. for Arcadia District	.531	.547	.564	.518	.488	.527	.430	.493	.418	.425	.425	.443	.518	.499

* "Good" and "Poor" refer to typical fruit quality produced by these orchards.

Table 2. - Analyses of grapefruit leaves, percent air dry basis. Iron, Manganese, and zinc. Maximum, mininum, and average, 20 orchards.

	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Oct.	Ave.
Percent Iron														
Poor Orchards														
Maximum	.0224	.0138	.0204	.0124	.0177	.0193	.0156	.0141	.0181	.0212	.0125	.0250	.0185	.0178
Minimum	.0070	.0084	.0078	.0088	.0078	.0081	.0085	.0102	.0119	.0131	.0063	.0106	.0095	.0091
Average	.0102	.0107	.0130	.0104	.0126	.0115	.0128	.0136	.0144	.0167	.0083	.0168	.0132	.0126
Good Orchards														
Maximum	.0250	.0208	.0158	.0156	.0119	.0127	.0156	.0124	.0156	.0306	.0100	.0206	.0130	.0168
Minimum	.0090	.0084	.0076	.0078	.0032	.0075	.0081	.0082	.0084	.0113	.0044	.0050	.0055	.0072
Average	.0135	.0102	.0106	.0100	.0076	.0096	.0114	.0105	.0109	.0177	.0069	.0083	.0096	.0105
Percent Manganese														
Poor Orchards														
Maximum	.0026	.0027	.0026	.0027	.0016	.0029	.0026	.0025	.0030	.0024	.0016	.0022	.0026	.0025
Minimum	.0019	.0021	.0020	.0022	.0018	.0021	.0016	.0021	.0017	.0019	.0013	.0016	.0019	.0018
Average	.0023	.0023	.0022	.0023	.0022	.0024	.0021	.0023	.0022	.0022	.0015	.0019	.0024	.0022
Good Orchards														
Maximum	.0030	.0028	.0024	.0025	.0027	.0032	.0024	.0026	.0024	.0026	.0014	.0019	.0042	.0026
Minimum	.0018	.0015	.0016	.0016	.0015	.0017	.0015	.0016	.0015	.0014	.0011	.0013	.0021	.0015
Average	.0022	.0021	.0020	.0021	.0020	.0022	.0019	.0020	.0018	.0019	.0013	.0016	.0027	.0020
Rough Lemon Root Stalk		.0041	.0040	.0038	.0051	.0045	.0042	.0042	.0042	.0038	.0017	.0025	.0034	.0038
Percent Zinc														
Poor Orchards														
Average	.0036		.0038	.0034	.0032	.0023	.0038	.0028	.0022	.0029	.0029	.0025	.0025	.0030
Good Orchards														
Average	.0033		.0035	.0029	.0027	.0027	.0037	.0031	.0031	.0038	.0023	.0026	.0026	.0030

Fertilizer experiments with grapefruit in Jamaica have shown that when the phosphorus percentage is less than .12, the yield of fruit is increased by phosphorus fertilization and above .19 percent response is not expected. On this basis, some of the Arizona orchards may be deficient in phosphorus at several of the periods at which the leaves were sampled. Chapman (4) has tentatively suggested .075 percent phosphorus as a deficiency in navel orange leaves and he found .09 to .18 percent in high-performance orchards. A deficiency of phosphorus has been noted in some lemon orchards in California (1) and the deficiency range of percent phosphorus in leaves was .08 percent and less. A sufficiency level was indicated when the phosphorus percentage in the leaves was increased to .10 percent or more by phosphate fertilization. Valencia orange trees growing in the same soil, where phosphorus deficiency was noted on lemons, did not exhibit phosphorus deficiency symptoms and gave no response in growth or leaf analysis from phosphate fertilization. There is evidence, then, that the phosphorus requirement or feeding power of citrus varieties is variable.

There is an abundance of phosphorus in most of the soils where citrus is grown in Arizona. The availability is often quite low, but there has been little or no evidence of a profitable response to phosphate fertilizers on grapefruit, even though for some other crops on these same soils there is a definite response to phosphate application.

Calcium. There is an abundance of calcium in all Arizona soils on which citrus orchards are located. It is present in most part as $CaCO_3$ (caliche). Calcium is an important element in citrus nutrition and the percentage in leaves increases steadily as the leaves develop, reaching a maximum in mature leaves.

The data given in Table 1 and Figure 2 show little or no difference in the calcium percentages for leaves from "good" or "poor" orchards. Even in April and May when the new spring leaves were sampled, the analyses between these two classifications of orchards are in fair agreement.

For comparison with leaf samples from other grapefruit-growing areas, the following calcium percentages are of interest.

Texas 5.16 - 7.74   Florida 3.02 - 6.11   California 4.18 - 6.86

Potassium. The data for potassium given in table 1 and figure 2 do not show any significant difference between good- and poor-quality orchards. However, the maximum potassium content is lower for the samples from the poor-quality orchards; and the minimum and average content ranges are higher. Chapman (4) tentatively suggests that 2.00 percent potassium is a possible indication of potassium excess in orange leaves. He found a range of .38 to 1.18 percent in high-performance orchards. In Jamaica, 1.16 percent potassium is given as the minimum adequate level for grapefruit leaves.

There is no evidence that potassium is in any way related to grapefruit quality in Arizona orchards, although some of the leaves were very low during February and March. For comparison with potassium leaf analyses from other grapefruit areas, the following K percentages are given:

Texas 0.52 - 0.78   Florida .76 - 2.56   California 1.17 - 2.80

Magnesium. The magnesium analyses given in table 1 and figure 1 show that the average and maximum values are higher for the orchards producing good fruit, and the minimum values are higher in 9 of the good orchards. However, these high average values are due to the high magnesium percentages in the leaves from four orchards in the Arcadia district. When comparison is made between the leaves from the poor- and good-quality orchards, after omitting the Arcadia samples, there is little or no difference. In order to illustrate this, the analyses of the leaves from the Arcadia district are given separately in Table 1 and Figure 1.

The well waters used for irrigation in the Arcadia district are high in magnesium salts. The analyses of 11 wells in the Arcadia district varied between 53 and 143 parts per million magnesium. The leaves of the Arcadia district had a high magnesium content.

The importance of magnesium in grapefruit nutrition has been shown in Florida (6) where a magnesium deficiency exists. Research there has shown that less than 0.3 percent magnesium in grapefruit leaves represents a deficiency and that at such a level there a magnesium deficiency pattern appears on the leaves. When this is increased to 0.4 - 0.5 percent by fertilization, the leaves no longer exhibit a magnesium deficiency pattern. The magnesium requirement of Marsh seedless grapefruit is less than that of the seedy varieties.

The following magnesium values for leaves from other grapefruit-growing areas are presented for comparison:

Texas .258 - .392% Florida .194 - .394% California .245 - .520%

Chapman (4) suggest 0.2 to 0.4 percent magnesium as an average range for California oranges and 0.6 as an excess. The Arizona samples are in the average to high range and do not indicate that magnesium is related to fruit quality in these 20 orchards.

Ca:Mg ratio. In some cases, nutritional disturbances have been attributed to an unbalanced calcium to magnesium ratio. Research at the Florida Experiment Station (6) has shown to Ca to Mg ratio of about 29.2 for magnesium-deficient grapefruit leaves and 15.7 for normal leaves (Marsh seedless). The Ca to Mg ratios for the samples from the good- and poor-quality Arizona orchards are given in Table 3. The leaves from the Arcadia district are definitely lower in Ca to Mg ratio: but the leaf samples from the rest of the good orchards are in very close agreement with the samples from the poor orchards.

Table 3. - Ca to Mg ratios for grapefruit leaves from orchards producing good- and poor-quality fruit

Month	Poor orchards	Good orchards	Arcadia orchards
June	12.3	12.6	11.1
July	12.4	11.4	10.4
August	14.4	14.1	10.5
September	15.4	15.9	12.0
October	15.9	15.5	12.4
November	15.2	16.0	11.6
December	16.1	15.7	13.2
January	17.8	14.5	11.9
February	18.3	17.0	13.8
March	17.9	17.7	13.7
April	9.6	9.9	8.6
May	11.6	11.0	10.0
October	14.7	14.3	11.6

IRON, MANGANESE, ZINC, COPPER

In most sections of the world, and particularly in the United States, where citrus is grown, the micro-nutrient elements have been found to be associated with nutritional disturbances even to the extent of tree decline. Each of these, as a deficiency, may be identified as a specific chlorotic leaf pattern.

The chlorotic patterns identified as iron; manganese, and zinc deficiencies have all been observed on grapefruit trees in Arizona. Copper deficiency has not been found. In the analyses of leaf samples from the 20 orchards selected for study, iron, manganese, and zinc were determined in all samples and copper in one set of samples. At the time samples were collected, chlorosis was observed in orchards 2, 4a, 12, 13, 16, and 18. The rest did not show any chlorosis during the sampling period.

Iron. The maximum, minimum, and average iron analyses are given in Table 2, and the average for all orchards in Figure 3. There is no significant difference between the iron values for the orchards producing good- and those producing poor-quality fruit, although the iron percentages vary considerably. The highest iron percentages were found in the March samples, and the lowest in the April samples--new spring leaves. For the February set of samples, both total and active iron, as measured by the Oserkowsky method, were determined. The average active iron in leaf samples from the poor-quality orchards was .0063, and that for the good-quality orchards was .0052 percent. Throughout this one-year period of sampling, the iron percentage for leaves from orchard number 8 was consistently high. It may be significant that this orchard was on rough lemon root stock.

Chapman (4) found a range of .007 to .02 percent iron in leaves from high-performance navel orange orchards in California. He suggests .005 percent or less as a value representing a deficiency. The iron values (content percentages) for the Arizona orchards indicate an ample supply of iron in all leaf samples. The following is for comparison with leaf samples from other areas where grapefruit is grown:

Texas	Florida	California
.0137 - .0232%	.0089 - .0225%	.0082 - .0210%

Manganese. Throughout the one-year sampling period, the manganese percentage for the leaf samples from number 8 orchard was significantly higher than all the others. It was found that this orchard is the only one on rough lemon root stock. In view of this, the values for this orchard are given separetely in Table 2 and Figure 3. For the 12 sampling periods, the minimum and average manganese values are lower in the leaf samples from the orchards producing good-quality fruit, but the difference is not significant.

Chapman (4) found a range of .002 to .008 percent manganese in leaves from high-performance navel orange orchards, and suggests less than .0015 as a deficiency and .003 as an excess. The data in Table 2, compared to these values for navel orange trees, indicate that all 20 orchards are well supplied with manganese. The following manganese percentages of grapefruit leaves from other areas are presented for comparison:

Texas .0026 - .0042% Florida .0023 - .0057% California .0013 - .0027%

Zinc. The average zinc analyses for orchards producing good- and poor-quality grapefruit are given in Table 2 and the average of all in figure 3. These analyses show a good supply of zinc throughout and no evidence of a zinc deficiency despite the presence of zinc deficiency patterns on leaves of some orchards. Chapman (4) found .002 to .008 percent zinc as a range for high-performance orange orchards, and suggests less than .0015 percent as a deficiency and .003 as an excess.

Copper. Copper determinations were made only on the last set of samples taken in October. For the leaves from the orchards producing poor-quality fruit, the values varied between .0004 and .0018 percent with an average of .0011. For the samples from orchards producing good-quality fruit, the values varied between .0010 and .0020 percent with an average of .0013. These values may be compared with a range of .004 to .0010 percent for leaves from high-performance navel orange orchards in California (4).

Chloride. Chloride determinations were made on the set of samples taken in October, 1946. The chloride percentage varied between .071 and .340 with an average of .151 for the leaf samples from the orchards producing poor-quality fruit, and between .066 and .276 percent with an average of .118 for the good-quality orchards. Chlorine is classed as a non-essential element, and in high-performance navel orange orchards in California it varied between .02 and .20 percent with .25 percent suggested as an excess (4). For the 20 Arizona orchards, the chlorine percentage is slightly higher in the orchards producing poor fruit. This is true for the maximum, minimum, and average percentages.

ANALYSES OF LEAVES FROM FRUIT-BEARING AND NON-FRUIT-BEARING TWIGS

In the study of the magnesium deficiency problem in Florida (6), the analysis of leaves from fruit-bearing and non-fruit-bearing twigs was most illuminating and instrumental in identifying the nature of the trouble.

A number of leaf samples were taken from fruit-bearing and non fruit-bearing twigs in 5 Arizona grapefruit orchards and the analyses of these are given in Table 4. In this table, numbers 4, 7, and 19 correspond with the orchards of the same number given previously. These leaf samples were taken in February, 1946, when mature fruit was on the trees. There is a trend toward lower manganese, and phosphorus in the leaves from the fruit-bearing twigs and higher calcium, magnesium, potassium, and iron. The lower phosphorus and manganese are significant. The D. and E. samples are from the Grunow orchard on North 7th in the Salt River Valley and were taken in July, 1946, when the fruit was green. For these samples there is a trend toward lower phosphorus, and manganese and higher calcium in the leaves from the fruit-bearing twigs. The difference is significant for calcium, phosphorus, and manganese. Neither set of samples shows any evidence of a deficiency on the basis of standards given previously.

It is interesting to note that in all orchards, and both the February and July leaf samples, the manganese and phosphorus were lower in the leaves from the fruit-bearing twigs. In studies on citrus chlorosis (12) manganese was found to be quite consistently low in chlorotic leaves. In the analyses of the leaves from the 20 orchards under study, phosphorus approached the deficiency level in some monthly leaf samples. The analyses of leaves from fruit-bearing and non-fruit-bearing twigs certainly suggest further study of phosphorus and manganese nutrition in citrus.

Unpublished phosphorus studies by Fuller and Hilgeman showed an uptake of phosphorus by citrus from phosphate fertilizer using the radio-tracer technique, but did not show any increase in phosphorus percentage in the leaves over the unfertilized trees.

Table 4. Comparative analyses of leaves from fruit-bearing and non-fruit-bearing grapefruit twigs--as percent air dry material.

Grove No.*	Ash	Phosphorus	Calcium	Magnesium	Potassium	Iron	Manganese	Zinc
	%*	%	%	%	%	%	%	%
			Februray 1946 Mature Leaves					
4-A*	13.37	.119	5.99	.332	1.00	.0179	.0020	.0034
4-B*	13.97	.115	5.87	.304	0.98	.0131	.0021	.0025
7-A	19.38	.154	5.91	.387	1.23	.0153	.0019	.0030
7-B	17.73	.165	5.70	.343	1.21	.0109	.0019	.0025
17-A	16.55	.107	5.84	.293	0.64	.0150	.0017	.0018
17-B	16.05	.129	5.79	.293	0.51	.0081	.0030	.0010
19-A	17.77	.113	6.40	.345	0.78	.0156	.0015	.0016
19-B	18.83	.163	6.55	.321	0.62	.0115	.0024	.0016
			July 1946 No Leaves					
D-A	13.53	.150	6.91	.520	1.47	.0183	.0017	.0060
D-B	14.93	.203	6.24	.470	2.15	.0195	.0020	.0060
E-A	13.24	.133	6.61	.503	1.55	.0187	.0017	.0046
E-B	13.40	.177	6.25	.535	2.05	.0187	.0023	.0054

COVER CROP VERSUS CLEAN CULTIVATION

The question of the influence of cover crops on grapefruit quality; and permanent sod versus clean cultivation have been studied from time to time in Arizona (10). In orchard number 19-20 a part of the area (which was given the number 20) was in Bermuda sod. The rest of the orchard was clean-cultivated. Leaf samples were taken each month from both, and the analyses are given in Table 5.

The data show a trend toward higher phosphorus, calcium, magnesium, and potassium and lower iron and manganese in the leaves from trees where the Bermuda sod covered the ground. Only the higher potassium values appear to be significant. No packing house records were available on the quality of the fruit produced, but observation of the fruit on the trees did not indicate any difference.

*"A" samples are from fruit-bearing twigs; "B" samples are from non-fruit-bearing twigs.

Table 5. Analyses of leaves from grapefruit orchards, clean-cultivated and with cover crop. Percentage air dry basis.

Month	Phosphorus (P)		Calcium (Ca)		Mangesium (Mg)		Potassium (K)		Iron (Fe)		Manganese (Mn)		
	A	B	A	B	A	B	A	B	A	B	A	B	
June	.157	.131	5.36	5.70			1.39	1.65	.0032	.0024	.0023	.0023	
July	.161	.138	5.96	6.12	.406	.497	1.17	1.33	.0116	.0094	.0022	.0019	
Aug.	.115	.135	6.68	6.40	.342	.450	0.83	1.32	.0156	.0110	.0021	.0020	
Sept.	.131	.127	6.96	7.08	.360	.343	0.87	1.10	.0100	.0104	.0024	.0021	
Oct.	.119	.116	6.75	6.79	.372	.368	0.89	1.14	.0087	.0075	.0023	.0020	
Nov.	.119	.119	6.56	6.71	.356	.345	0.80	1.10	.0109	.0075	.0026	.0021	
Dec.	.116	.119	6.49	6.51	.323	.420	0.59	0.93	.0106	.0091	.0022	.0018	
Jan.	.119	.127	6.23	6.34	.303	.328	0.67	1.00	.0078	.0084	.0020	.0019	
Feb.	.137	.163	6.55	6.55	.300	.321	0.46	0.62	.0097	.0115	.0019	.0024	
March	.139	.128	6.54	6.81	.304	.314	0.55	0.42	.0281	.0162	.0024	.0019	
April	.183	.173	4.36	4.25	.384	.367	2.18	2.34	.0066	.0060	.0014	.0014	) new
May	.153	.223	4.83	5.03	.384	.513	1.63	1.96	.0075	.0072	.0018	.0017	) leaves
Ave.	.137	.141	6.09	6.20	.320	.356	1.00	1.24	.0125	.0106	.0021	.0019	)

A - Clean cultivated
B - Cover crop, Bermuda

SOIL TYPES

Soils in all the orchards were examined, with a soil tube, to a depth of 4 feet and the soil series and type identified with the aid of a soil survey map of the Salt River Valley (8). Following are the soil classifications and numbers, which correspond with orchard numbers previously given.

Laveen soil series

1. Laveen sandy loam, Bermuda sod in orchard

16. Laveen loam

Cajon soil series

3. Cajon silty clay loam, shallow phase, may be over Mohave

5, 6. Cajon loam, gravel in 2 - 4 feet depth

8. Mixes Cajon sand and silt loam, gravel below 2 feet depth.

McClelland soil series

4, 4A. McClelland gravelly loam

Mohave soil series

7. Mohave stony loam

9. Mohave fine gravelly loam, highly calcareous phase

10, 11, 12, 13. Mohave fine gravelly sandy loam

14. Mohave sandy loam

17, 18, 19, 20. Mohave loam

There was a bermuda sod in orchards numbers 1 & 19-20 and there was no evidence of quality improvement from this sod cover. Orchards No. 4 and 4A were located on opposite sides of a dividing road and both on McClelland gravelly loam. Number 4 orchard received good cultural care during the 1930's when price of grapefruit was low. Number 4A was somewhat neglected during this period. The fruit in the former was coarse, and in the latter it was small and of good quality. Cultural care was definitely a factor in the difference in quality of fruit from these two orchards. Other cases have been noted where some type of growth stress has produced small size, smooth skin, and better fruit quality.

Most of the orchards with good-quality records were located on Mohave soil, but four of these are in the Arcadia district where boron was a problem for many years. There is evidence that excess boron reduces fruit size and peel thickness of grapefruit.

On the whole, there is little or no evidence that grapefruit quality is related to soil type except that where the soils have better drainage the quality may be of a higher grade.

CHEMICAL ANALYSES OF SOILS

Soil samples were taken from each of the 20 orchards from which leaf samples were analyzed. The first and second foot samples were taken separately and analyzed separately, and are represented in table 6 as A and B respectively. The analyses consisted of the following determinations: pH (paste and 1:10 soil:water ratio), active calcium, calcium carbonate, available phosphorus and available potassium. (CO_2 soluble).

The average salinity is slightly higher in the good-fruit-quality orchards but the difference is not significant. The pH values do not show any relation to fruit quality. The active calcium and total $CaCO_3$ are higher in the good-quality orchards. Available phosphorus is low in all except in two soils, but no critical deficiency was found in the leaf analyses. Available potassium varies over a wide range. All the leaf analyses showed an ample supply of potassium. The soil analyses give little or no information to explain differences in fruit quality.

For comparison with soils from other areas where grapefruit is grown in the United States, soil samples were collected by the author from orchards in Florida, the Rio Grande Valley in Texas, and in the Coachella and Imperial Valleys in California. These soil samples were taken in orchards from which leaf samples were taken, analyzed and reported as maximum and minimum values, in comparison with analyses of leaf samples from Arizona orchards in this report. The soil analyses are given in Table 7.

In Florida, grapefruit is grown on both acid and calcareous soils. The Indian River soil is the only calcareous soil from which a sample was obtained. At the time the author visited Florida, he was informed that 70 percent of the grapefruit was being canned either in sections or as juice. This left only the fruit with better shape and skin texture for the fresh-fruit market.

The soils in the Rio Grande, Coachella, and Imperial valleys are all calcareous. The average salinity in the three valleys is higher than for the Arizona orchards. An examination of the fruit in the Rio Grande Valley at the time the soils were taken (Ripe fruit was on the trees at this time.) showed a better shape and smoother skin texture in the Bayview district where soil salinity was highest. The pH values for the Texas and California soils are about the same as for the Arizona soils. The available phosphate in the soil is, in most cases, higher in all three states than in Arizona. Some of these high values may be a result of phosphate fertilization.

NEUBAUER VALUES

In order to further study the nutritional status of the soils from the 20 grapefruit orchards, Neubauer tests were conducted. In this test 100 barley seedlings are grown in 100 grams of soil for a period of three weeks. At the end of this period the plants are analyzed and the analysis compared with that of 100 barley seedlings grown in sand. The difference between the nutrients in the plants grown in soil and in sand represents the uptake from the soil Neubauer values and an indication of the availability in the soil. The Neubauer values for phosphorus and potassium are given in Table 8 as milligrams P_2O_5 and K per 100 grams of soil. These values tend to confirm the soil analyses: namely, low available phosphorus and high available potassium show no relation to fruit quality. Particular attention is called to the high availability of potassium in the subsoils.

Table 6. Analyses of soils (A, 0-1 ft.) and subsoils (B, 1-2 ft.) taken from orchards in which quality study was conducted. Basis air dry soil.

Grove No.	Soluble salts		pH 1:10		pH paste		Active calcium		$CaCO_3$		Available phosphate		Available potassium	
	p.p.m.						percent Ca		percent		p.p.m. PO_4		p.p.m. K	
Poor Orchards	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	400	440	8.9	9.0	8.3	8.1	.28	.23	0.85	0.45	7	2	41	39
4	485	700	9.2	9.4	8.1	8.4	.22	.69	0.84	4.78	8	3	161	75
5	370	595	9.3	9.4	8.2	8.1	.54	.48	2.88	2.71	9	3	121	224
6	400	410	8.6	9.1	8.5	8.6	.38	.24	2.67	3.38	4	4	102	29
7	385	320	9.0	9.0	8.6	8.7	.32	.18	4.32	4.81	5	5	84	9
8	420	525	9.1	9.1	8.6	8.5	.38	.30	2.56	2.48	6	2	76	32
17	795	1020	9.5	9.7	8.2	8.0	.29	.28	0.86	0.82	1	1	92	39
Max.	795	1020	9.5	9.7	8.6	8.7	.38	.69	4.32	4.81	9	5	161	224
Min.	370	320	8.6	9.0	8.1	8.0	.22	.18	0.84	0.45	1	1	41	9
Good Orchards														
2	395	490	9.2	9.3	8.5	8.5	.50	1.10	2.41	8.12	19	3	146	109
3	940	1275	9.1	9.4	8.1	8.3	.62	.60	2.58	2.93	4	1	99	35
4A	1252	445	9.5	9.3	8.1	8.4	.55	.33	3.38	1.65	6	13	98	122
9	330	458	9.1	9.2	8.4	8.5	.33	.16	1.53	0.75	1	1	43	16
10	435	415	9.0	9.1	8.4	8.6	.35	.85	1.38	5.88	4	3	22	
11	350	555	8.9	9.1	8.2	8.4	.24	1.24	0.67	9.40	4	1	45	4
12	428	730	9.2	9.5	8.3	8.4	.26	.72	0.97	4.80	9	1	174	80
13	485	690	9.5	9.5	8.5	8.3	.41	2.05	1.98	18.11	2	1	75	28
14	472	575	9.3	9.4	8.2	8.2	.38	1.00	1.60	7.90	8	1	151	35
16	508	2362	9.5	9.2	8.5	8.0	1.62	2.84	12.66	27.87	1	1	90	35
18	750	835	9.3	9.4	8.0	8.1	.26	.68	0.32	2.85	1	1	98	36
19	635	1428	8.0	9.0	8.0	8.1	.20	.62	0.41	4.68	4	1	174	22
Max.	1252	2362	9.5	9.5	8.5	8.6	1.62	2.84	12.66	27.87	19	13	174	122
Min.	330	415	8.0	9.0	8.0	8.0	.20	.16	.32	0.75	1	1	22	4

Table 7. Partial analyses of soils from Florida, Texas, and California grapefruit orchards, air dry soil.

Orchard	Sample depth/ft.	pH paste	pH 1:10	Soluble salts p.p.m.	Phosphate p.p.m. PO_4
		Florida			
Oak Hill	0-1	4.90	5.00	345	14
Sugar Loaf Mt.	0-1	5.50	5.50	110	trace
Indian River	0-1	7.90	7.50	255	4
Smith Island	0-1	6.80	6.25	480	9
		Texas, Rio Grande Valley			
Engleman	0-1	8.35	8.50	750	8
Engleman	0-1	8.20	8.00	510	8
Engleman	0-1	8.20	8.50	840	1
Bayview	0-1	8.00	8.00	1378	42
Bayview	1-2	8.10	8.40	3595	trace
Bayview	0-1	8.20	8.60	900	12
Bayview	1-2	8.50	9.10	1435	2
Goodwin	0-1	7.90	7.85	1260	22
Goodwin	1-2	8.10	8.30	1335	--
		California, Imperial and Coachella Valleys			
Whittier	0-1	7.80	8.80	595	8
Whittier	1-2	8.20	9.15	395	
Mitchel	0-1	7.85	8.86	745	52
Mitchel	1-2	7.55	8.95	1545	
Forbes	0-1	8.40	9.20	795	22
Forbes	1-2	9.20	9.50	295	
Forbes	0-1	8.15	9.15	1010	14
Palm Springs	0-1	8.90	9.30	350	
Meuler	0-1	8.25	9.05	330	10
Steiner	0-1	7.75	9.20	820	1
Du Bois	0-1	7.85	8.85	4075	1

NEUBAUER TESTS--MICRO-NUTRIENT ELEMENTS

Micro-nutrient elements, particularly iron, manganese, zinc, and copper, are definitely associated with citrus fruit quality. This has been shown by citrus nutrition research in Florida and California.

In Arizona citrus orchards, the chlorotic leaf patterns identified with iron, manganese, and zinc occur quite frequently. In the analyses of leaf samples from the 20 orchards, there was no definite evidence of a deficiency of iron, manganese, zinc, or copper. Despite this, it appeared advisable to explore this phase of the problem further.

In our study of citrus chlorosis (11) the Neubauer technique was employed to examine micro-nutrient element availability in Arizona soils. By analyzing the roots and tops separately, information on their movement within the plant was gained. There is a great deal of evidence that the micro-nutrient problem in Arizona is one of physiological availability or poor movement within the plant, after these elements have been taken up by the root, rather than restricted uptake from the soil.

For this test, 200 barley seedlings are grown in 200 grams of soil; and the controls are represented by 200 seedlings grown in 200 grams of sand. This type of test appears to show the presence of an inherent soil character which contributes to an accummulation of micro-nutrient elements in the roots and a restricted movement to the leaves where they are most needed.

The data obtained from this experiment are given in Table 9 and Figures 4 & 5 as milligrams in roots and tops. For comparison with data for Arizona soils a test was also made on 6 Rio Grande Valley soils, 8 soils from Coachella and Imperial Valleys, and 5 Florida soils, all of which were from grapefruit orchards.

The ratio between the micro-nutrient elements in the roots and tops is shown in Table 10. These data show the degree of fixation in the roots or the tendency toward restricted movement within the plant because of the character of the soil.

The average data in Tables 9 and 10 show some interesting trends, but the range over which the soils from the 20 orchards vary, limits the significance of the analyses. This is particularly true for iron in the roots. The average zinc, manganese, and iron percentages are lower in the roots and higher in the tops for seedlings grown on soils from the good-quality orchards as compared to the low quality orchards. This is true for both soils and subsoils. (See Figure 4.) This shows that the barley seedlings were better able to utilize these three micro-nutrient elements when grown on soils from the good-quality orchards - this is sometimes referred to as better physiological availability. It is further illustrated by the root to top ratios given in Figure 5. The lower the root to top ratio, the more efficient is the utilization of the elements within the plant.

The Texas and California soils gave values and root-to-top ratios which are similar to the values obtained for the Arizona soils. For the Florida soils, the roots are much the lowest in iron. This is probably due to the fact that there is a definite deficiency of iron in many Florida soils, while in Arizona, Texas, and California the deficiency arises within the plants, because of the calcareous nature of the soil and fixation in the roots.

Table 8. Neubauer values for soils from 20 Arizona grapefruit orchards.

Orchard number	P_2O_5 values soil	P_2O_5 values subsoil	K values soil	K values subsoil
		Poor quality orchards		
1	2.9	2.3	41.3	26.1
4	2.5	2.9	37.0	32.4
5	6.4	3.2	41.6	36.0
6	2.7	1.9	36.9	24.0
7	2.8	2.4	28.8	19.7
8	2.3		30.6	15.2
17	1.4	1.5	47.4	22.9
Ave.	3.0	2.4	37.7	25.2
		Poor quality orchards		
2	3.6	1.0	36.5	27.7
3	3.4	3.1	38.7	30.1
4A	5.7	3.3	44.2	39.5
9	0.5	1.7	29.2	15.7
10	0.8	1.5	25.3	21.1
11	0.2	0.1	32.1	16.1
12	2.1	0.7	32.0	20.2
13	1.1	0.8	33.5	10.9
14	3.4	1.0	39.7	24.4
16	1.2	0.7	34.4	12.4
18	0.9	1.1	41.6	31.2
19	3.3	0.8	55.5	30.8
20	3.3	0.8	55.5	30.8
Ave.	2.3	1.3	38.3	23.9

Table 9. Zinc, iron, manganese in roots and tops of barley seedlings grown in soils and subsoils from good and poor Arizona grapefruit orchards and in soils from Texas, California, and Florida grapefruit orchards. Expressed in mgms. per 200 plants

	In roots grown in surface soil			In roots grown in subsoil			In tops grown in surface soil			In tops grown in subsoil		
	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn
	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.
	Arizona Poor Quality Orchards											
Max.	.240	42.0	.62	.230	40.0	.78	.185	.72	.30	.180	.75	.37
Min.	.155	5.6	.21	.55	7.0	.29	.145	.25	.15	.145	.40	.18
Ave.	.194	20.3	.53	.200	17.8	.49	.172	.55	.23	.167	.58	.29
	Arizona Good Quality Orchards											
Max.	.225	15.0	.40	.230	16.0	.41	.240	1.12	.51	.185	.77	.64
Min	.140	3.9	.17	.150	4.0	.18	.160	.45	.19	.150	.48	.21
Ave.	.168	8.1	.27	.178	8.4	.29	.180	.60	.25	.172	.61	.31
	Texas Orchards											
Max.	.150	6.7	.23				.195	.69	.23			
Min.	.100	5.2	.17				.170	.48	.22			
Ave.	.129	5.6	.19				.183	.59	.22			
	California Orchards											
Max.	.195	15.4	.28				.210	.78	.31			
Min.	.145	3.8	.15				.115	.27	.11			
Ave.	.168	6.6	.26				.181	.52	.18			
	Florida Orchards											
Max.	.275	2.6	.63				.175	.53	.26			
Min.	.155	2.4	.16				.170	.25	.13			
Ave.	.202	2.5	.32				.172	.35	.18			

Table 10. Root to top ratios for iron, manganese, and zinc in barley seedlings grown in Arizona, Texas, California, and Florida soils. Mgms per 200 seedlings.

	Surface soil Poor	Subsoil Poor	Surface soil Good	Subsoil Good	Texas	Calif.	Florida
Zinc	1.13	1.2	.93	1.03	.71	.93	1.18
Iron	36.8	30.8	13.2	13.8	9.5	12.70	7.20
Manganese	2.3	1.7	1.1	.94	.86	1.44	1.77

RELATION BETWEEN CALCIUM CARBONATE IN SOIL AND ROOT TO TOP RATIO OF POTASSIUM, CALCIUM, AND PHOSPHORIC ACID IN BARLEY SEEDLINGS.

The soil analyses given in Table 6 shows a trend toward higher active calcium and calcium carbonate in the soils from the good-quality orchards. The leaf analyses did not show any relation between calcium percentage in leaves and in orchard performance. Since K and P are frequently mentioned in literture on grapefruit quality, the effect of $CaCO_3$ on uptake of potassium and phosphorus was studied, using the Neubauer technique. Six soils and five subsoils from the 20 orchards were selected for this experiment.

The data obtained from this experiment are given in Table 11. The relation between percent $CaCO_3$ and root to top ratio for calcium, potassuim, and phosphorus pentoxide (P_2O_5) are given in figure 6 and the relation between the root to top ratio for calcium and root-to-top ratio for potassium and phosphorus pentoxide are given in figure 7.

This experiment shows that with increasing $CaCO_3$ percentage in the soil, there is an increase in root-to-top ratio for Ca, K and P_2O_5. This shows that $CaCO_3$ in the soil tends to increase the amount of these three nutrients held in the roots. It is also of interest that as the root-to-top ratio for Ca increases, there is an increase in the root-to-top ratio for K and P_2O_5.

Table 11. The effect of $CaCO_3$ on uptake of Ca, K, and P_2O_5, expressed in mgms. per 200 seedlings. Determined by Neubauer tests 1/

Soil No.	$CaCO_3$ in soil	Active Ca in soil	P_2O_5 Roots	P_2O_5 Tops	Ca Roots	Ca Tops	K Roots	K Tops	R:T P_2O_5	R:T Ca	R:T K
	%	%	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.	mgms.
					Surface soils, 0-1'						
8	2.56	0.38	11.08	27.20	7.48	5.44	21.25	41.12	.37	1.37	.52
13	1.98	0.41	12.28	28.58	7.16	4.44	27.00	44.25	.43	1.61	.61
9	1.53	0.33	10.88	27.50	5.24	5.68	22.38	39.50	.40	0.92	.57
10	1.38	0.35	11.35	27.75	7.73	5.22	22.00	37.50	.41	1.48	.59
12	0.97	0.26	13.80	27.58	5.06	4.44	21.00	37.12	.50	1.13	.57
11	0.67	0.24	11.35	27.65	4.72	4.60	22.62	37.50	.41	1.02	.60
					Subsoils						
11	9.40	1.24	13.28	28.18	11.48	4.78	17.72	24.62	.47	2.40	.72
10	5.88	0.85	12.15	27.05	9.84	5.04	18.80	29.00	.45	1.95	.65
12	4.80	0.72	12.08	26.78	6.50	3.90	16.75	25.75	.45	1.66	.65
8	2.48	0.30	11.83	26.70	7.26	5.80	17.72	30.50	.44	1.25	.58
9	0.75	0.16	11.35	26.48	4.40	5.50	20.00	26.25	.43	.080	.76

1/ Figures represent total uptake as they are not corrected by subtracting the sand controls.

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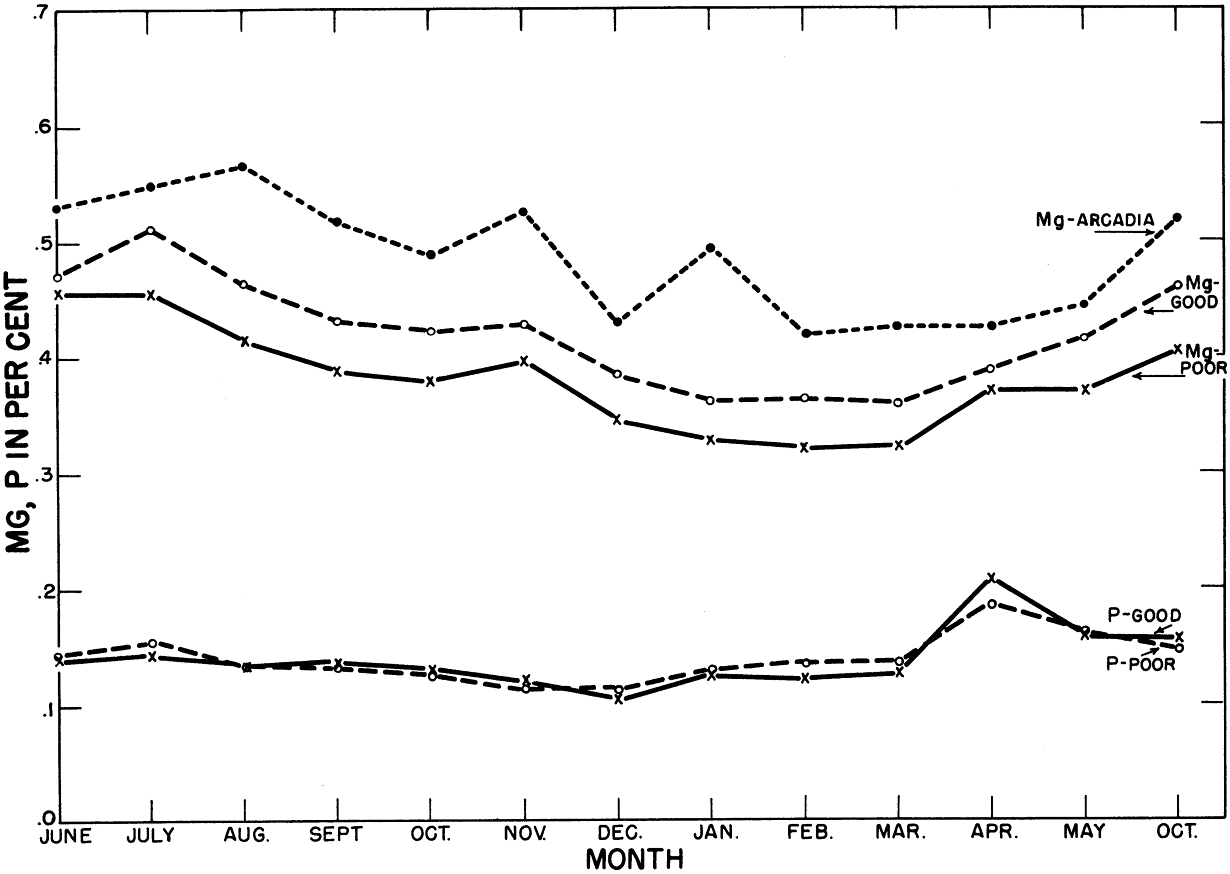

Figure 1. Phosphorus percentage in leaves from good and poor quality grapefruit orchards and percentage magnesium in leaves from good, poor, and Arcadia orchards. Air dry basis. Samples taken at monthly intervals.

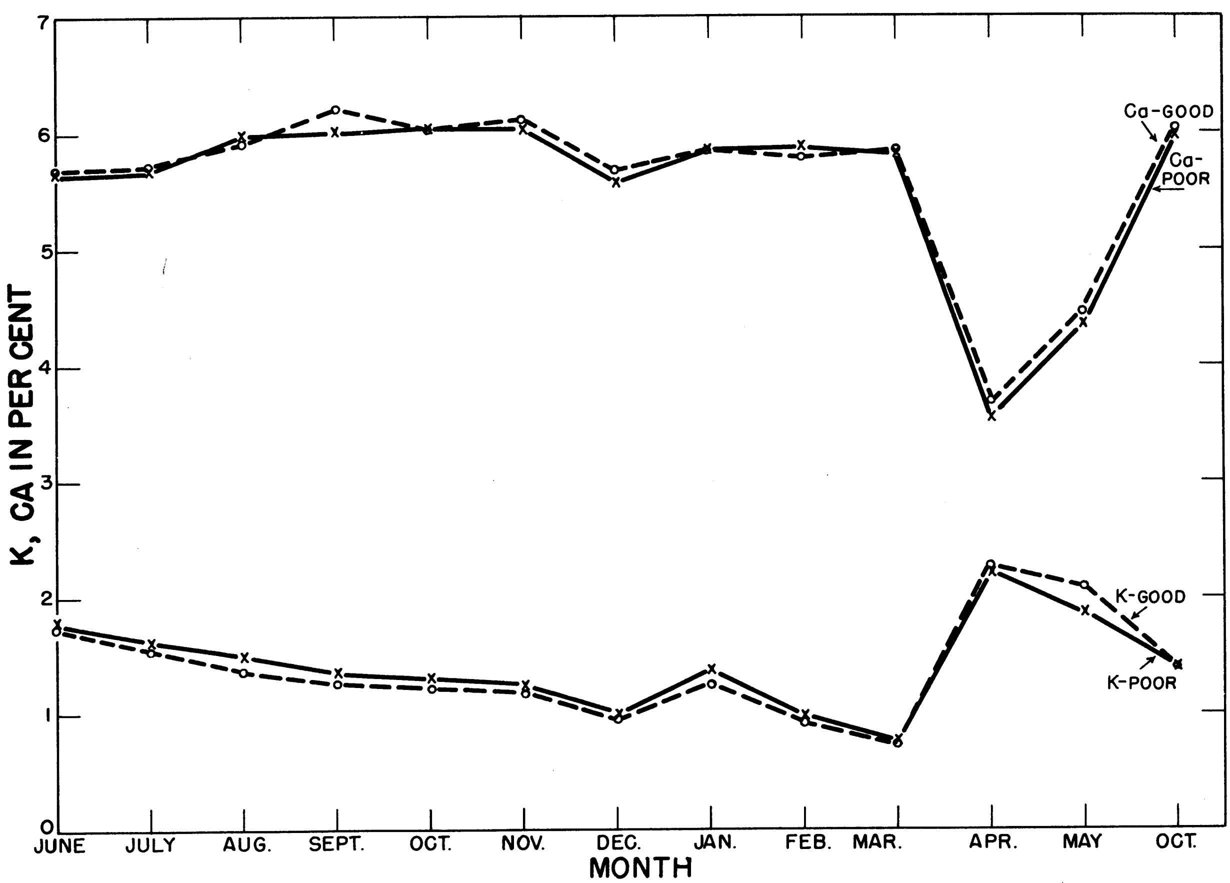

Figure 2. Percentage calcium and potassium in leaves from good and poor quality grapefruit orchards. Air dry basis. Samples taken at monthly intervals.

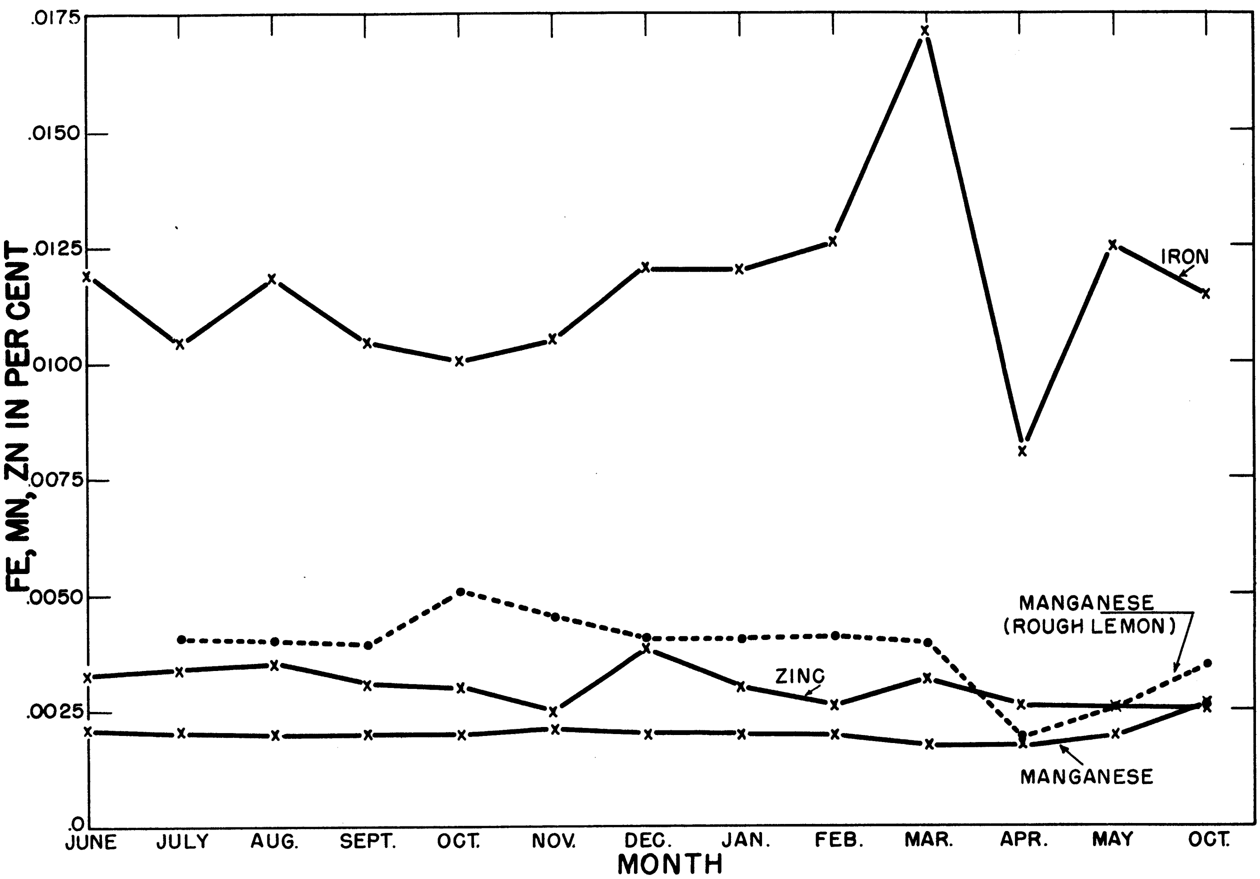

Figure 3. Percentage iron, manganese, and zinc in leaves from good and poor quality grapefruit orchards and manganese percentage in leaves from trees on rough lemon root stock. Samples taken at monthly intervals.

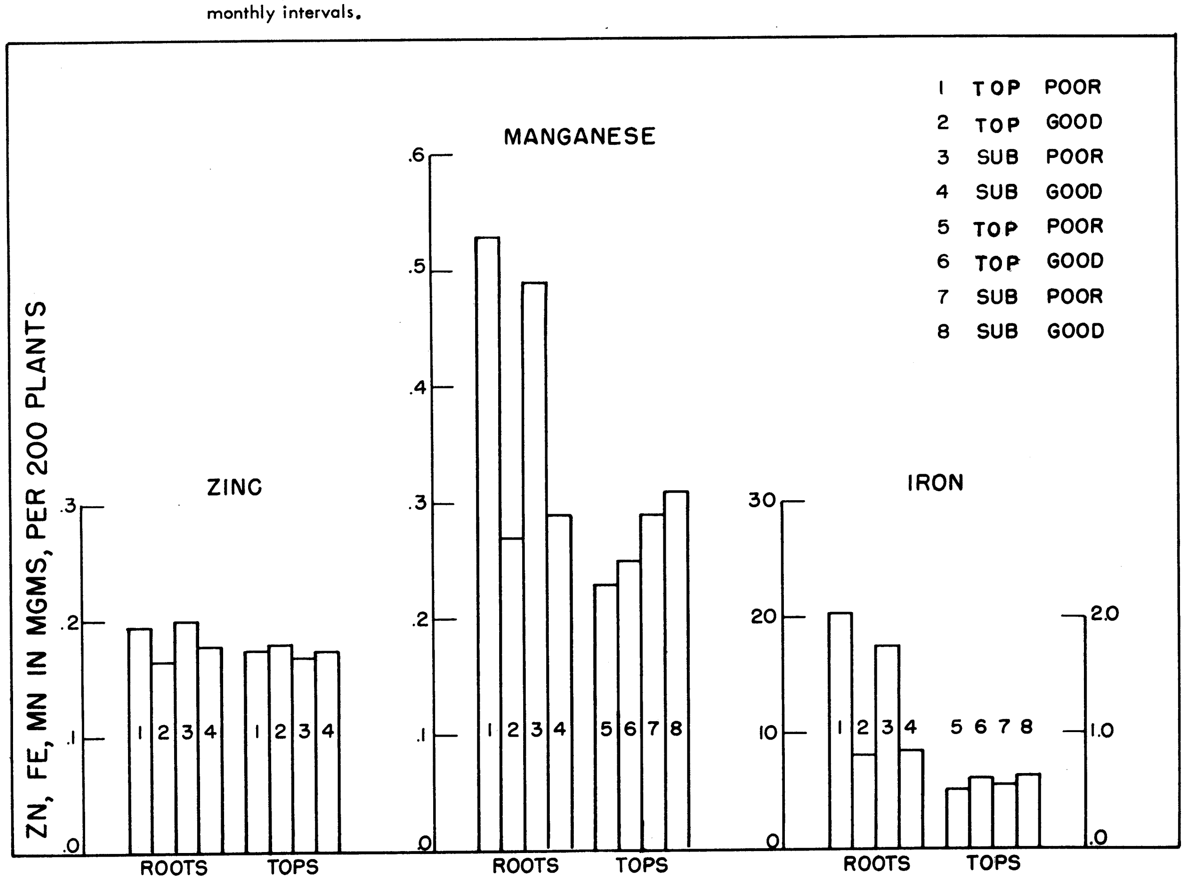

Figure 4. Iron, manganese, and zinc in roots and tops of barley seedlings grown in soils from good and poor quality grapefruit orchards. Mgms. per 200 seedlings.

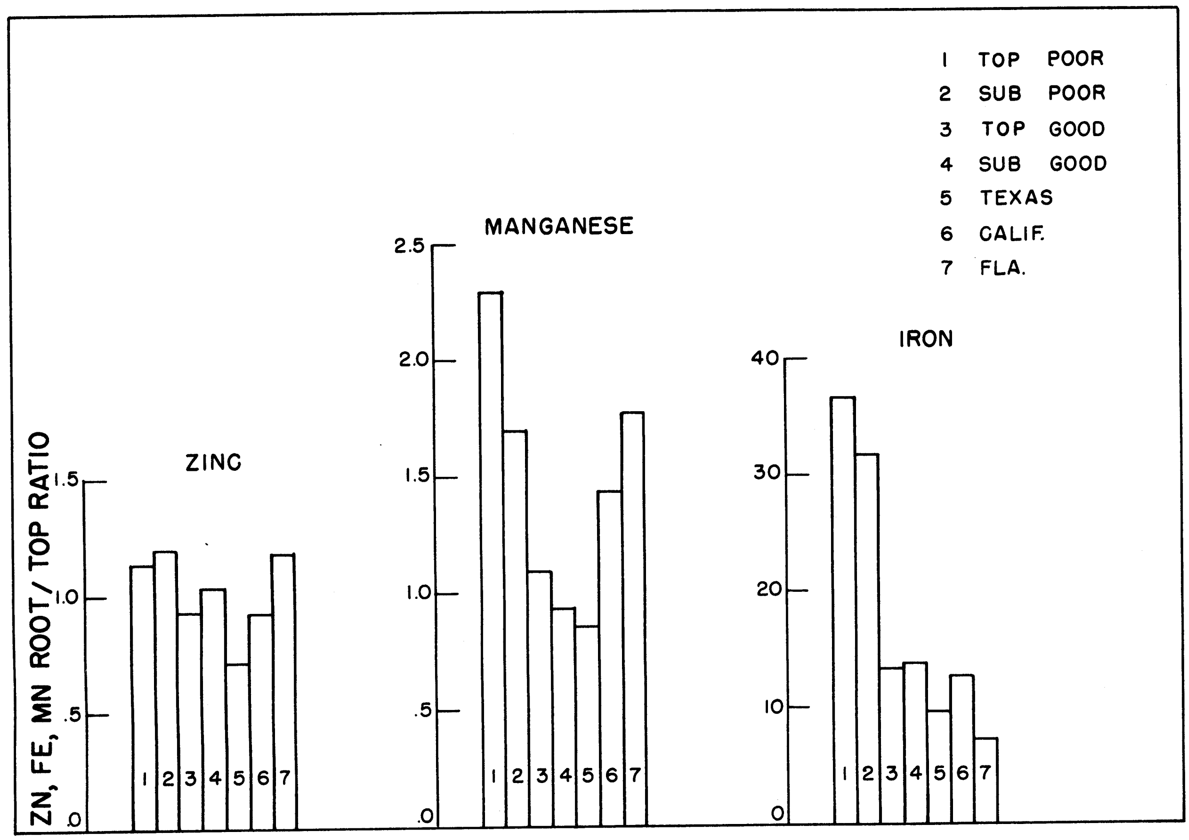

Figure 5. Root to top ratio for iron, manganese, and zinc in barley seedlings grown in soils from good and poor quality grapefruit orchards.

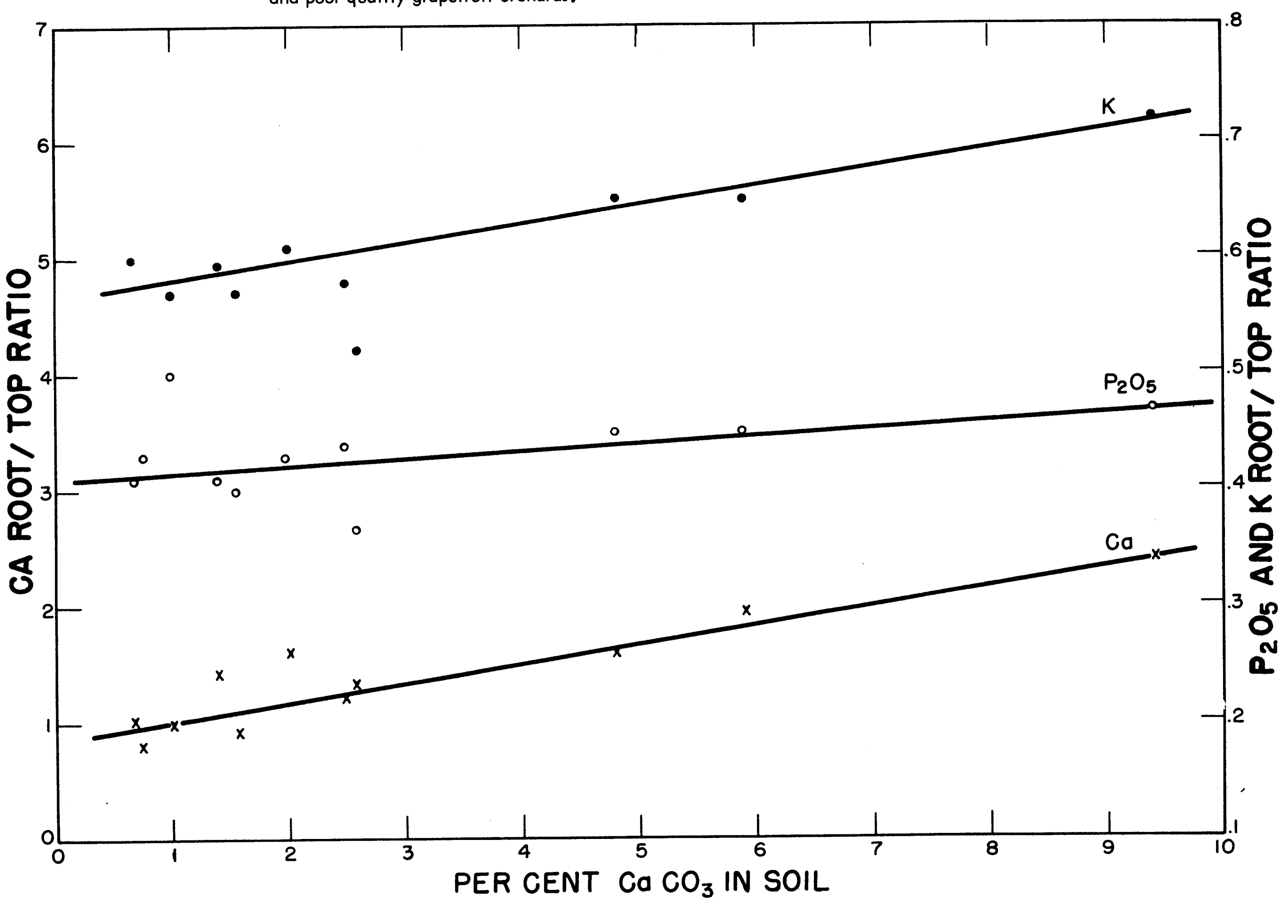

Figure 6. Relation between percent $CaCO_3$ in soil and root to top ratios for calcium, potassium, and phosphate (P_2O_5) in barley seedlings grown in soils from good and poor quality grapefruit orchards.

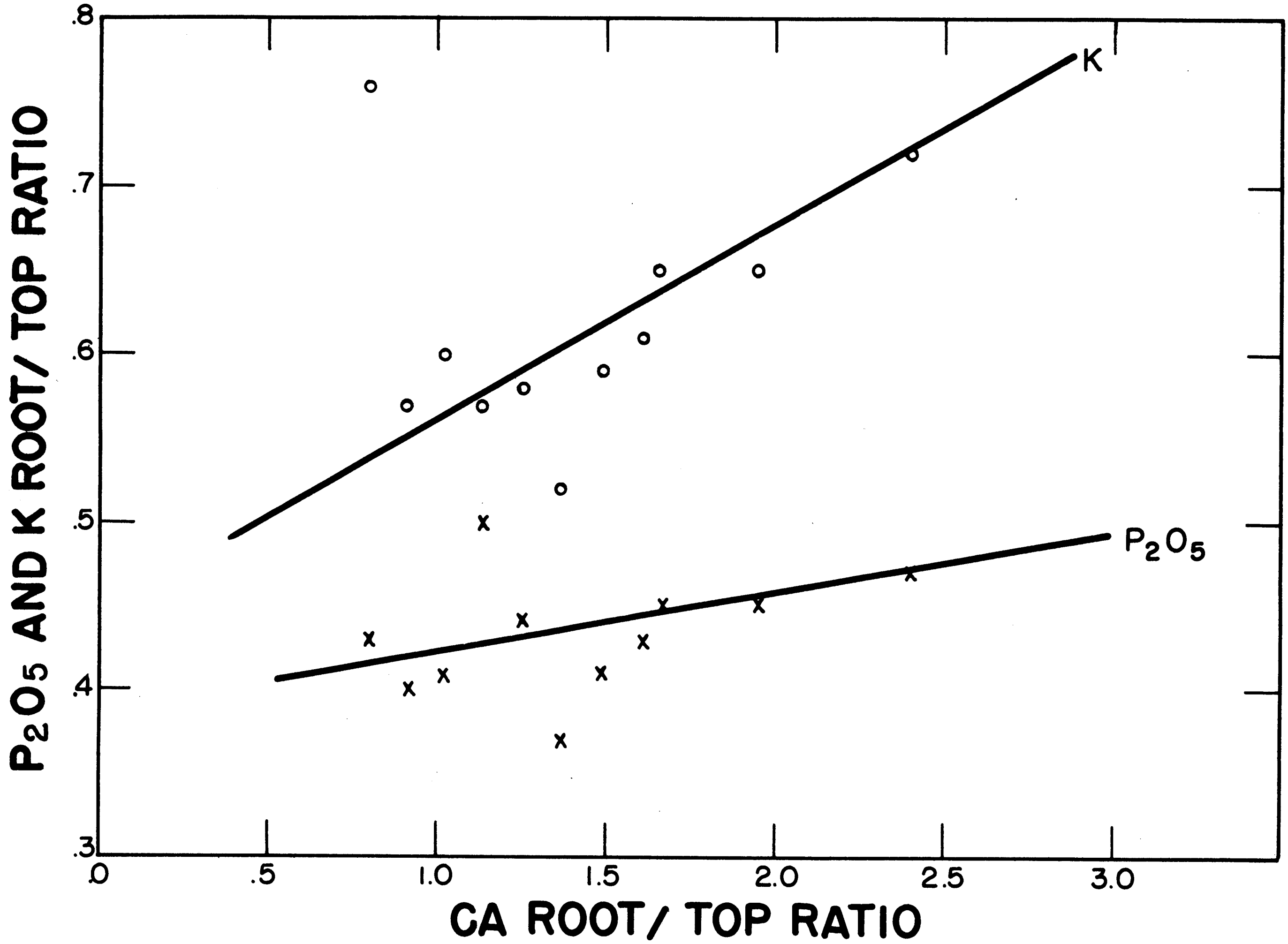

Figure 7. Distribution of phosphate (P_2O_5) and potassium (K) between roots and tops of barley seedlings grown in soils from good and poor quality grapefruit orchards.