SOME CHEMICAL STUDIES OF SOILS IN RELATION TO SATISFACTORY AND UNSATISFACTORY GROWTH OF PEACH TREES

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Tsu-Siang Chu

1946

THESIS

This is to certify that the

thesis entitled

Some Chemical Studies of Soils in Relation to Satisfactory and Unsatisfactory Growth of Peach Trees.

presented by

Tsu Siang Chu

has been accepted towards fulfillment of the requirements for

M. S. degree in Soil Science

C. E. Millar
Major professor

Date Aug 20, 1946

M-795

SOME CHEMICAL STUDIES OF SOILS
IN RELATION TO
SATISFACTORY AND UNSATISFACTORY GROWTH
OF
PEACH TREES

BY

TSU-SIANG CHU

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Soil Science

1946

THESIS

Acknowledgement

The writer is grateful to Dr. C. E. Millar for guidance in the work reported in this paper. He wishes also to express appreciation to the other members of the Department of Soil Science, particularly Dr. N. S. Hall and Dr. K. Lawton, for their help during the course of investigation. Sincere gratitude is extend to Mr. T. C. Stebbins of the County Agriculturist's Office and to Mr. A. W. Irvine of Soil Conservation Service, Benton Harbor, for the collection of soil samples.

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	REVIEW OF LITERATURE	2
III.	EXPERIMENTAL	6
	Methods of Soil Sampling	6
	Methods of Chemical Analysis	7
	Measurement of pH	
	Determination of Total Adsorbed and Acid-Soluble Phosphorus	
	Determination of Base Exchange Capacity	
	Determination of Exchangeable Potassium	
	Determination of Exchangeable Calcium and Magnesium	
IV.	RESULTS AND DISCUSSION	10
	pH Values	11
	General Consideration	
	In Relation to the Growth Conditions of the Peach Trees	
	Available Phosphorus Contents	14
	Vertical Distribution in the Soil	
	In Relation to the Growth Conditions of the Peach Trees	
	Relative Availability of the Adsorbed and Acid-soluble Phosphorus	

	Page
Zone of Active Root Absorption	
Amount of Exchangeable Bases	16
Base Exchange Capacity and Degree of Base Saturation	17
General Consideration	
In relation to the Growth Conditions of the Peach Trees	
Relationship Between Percent Base Saturation and Soil pH	22
Relationship Between Total Exchangeable Bases and Hygroscopic Moisture	23
V. SUMMARY AND CONCLUSIONS	25
VI. LITERATURE CITED	28

SOME CHEMICAL STUDIES OF SOILS IN RELATION TO SATISFACTORY AND UNSATISFACTORY GROWTH OF PEACH TREES

TSU-SIANG CHU

I. Introduction

In Michigan, the safest areas for growing peaches, according to Johnston(19), are those which experienced a minimum temperature of -12^{O}F. not more than seven times during the thirty years(1910-1940). On the western side of the state this area begins in southern Berrien County and extends in a belt of varying width north to the proximity of Ludington in Mason County. On the eastern side of the state a narrow belt having the most favorable winter temperatures for peach growing extends from the southeastern part of Monroe County to a point approximately half way between port Huron and Harbor Beach.

For best results, the peach tree requires a resonably fertile soil that is well drained. Generally sandy loam soils produce the finest fruits, although clay soils are suitable, provided they are well drained. Some of the peach trees in orchards within the peach region along the shore of Lake Michigan, have not been growing satisfactorily. Sometimes the injury is apparent the first year, again the trees will grow well until three or four years of age. Very often in one part of the orchard the trees may grow very well, while in another they will grow so weakly that they cannot produce profitable crops. It was suspected that the poor growth resulted from unfavorable soil conditions or properties.

Although it is true that chemical analysis of orchard soil sometimes fails to evaluate many factors which might contribute to the abnormal growth of the fruit tree, yet as far as physiological and nutritional factors of plants are concerned, it is still an important diagnostic aid.

The present paper presents a labotatory chemical study of soils which has arisen from an investigation of satisfactory and unsatisfactory growth conditions in peach trees along the lake shore of the lower Michigan Pennisula.

II. Review of Literature

Peaches differ from apples and pears in respect to several features which bear upon plant-food supply(34). Compared on the acre basis, peach crops are larger consumers of plant-food. They use about one-third more N,P and K than do apples and twice as much calcium and considerably more magnesium. Also they use two to three times as much of each of these constituents as pears do.

Several years ago, a definite case of calcium deficiency in a young peach orchard planted on a light sandy soil in New Jersey was reported by Davidson(13). An examination of the soil revealed a very low but normally adequate amount of available calcium together with an abnormally high concentration of available potassium. A detailed sand culture experiment was later made by the same author to study the importance of nutrient balance to the growth of peach trees. According to this study(13) ,high calcium with low potassium induced potassium deficiency symptoms in the leaf. The pH value of the soil under trees showing the most acute potassium deficiency symptoms ranged from 5.8 in the first foot to 4.8 in the third foot.

Waugh et al found in their sand culture experiments(36) that increasing the potassium level from low(3.33 p.p.m.) to intermediate (10 p.p.m.)significantly increased growth at the higher levels of nitrogen and phosphorus. It was also shown with peach trees in sand culture by Cullinan et al(10) that when nitrate was high and potassium low in the nutrient solution,leaf deficiency symptoms of potassium were more acute on the rapidly growing high nitrogen peach trees, Since light,sandy soils low in organic matter have much in common with sand cultures the significance of nutrient balance as reported by Davidson and Cullinan et al is worthy of consideration when dealing with such soils.

Van Slyke(33) found the ash of a single peach tree to contain nearly half as much potash as in the ash of a single apple tree,although the total ash of the apple trees averaged nearly eight times as much as the total ash of the peach trees. More recently Thompson(32) reported that,with nine-year old trees ,peach contained four times as much potash as apples. This heavier use of potassium by peach trees would lead us to expect greater responses by peaches to potash fertilization.

Marked response of peach trees to potassium fertilizer under field conditions was observed in light loamy soils by Cullinan and Waugh(11)(37),Boynton(3),Rawl(30) and many others. Two particular cases of potassium deficiency in peach orchards in South Central Pennsylvania were reported by Dunbar and Anthony (15). In one seven-year-old orchard consisting of a mixed planting of Elberta peaches and several varieties of apples,approximately a third of the peach trees were clearly abnormal and had no crop; in the rest of the orchard,growth and yield seemed to be normal. The peach trees in the affecbed area did not show marginal leaf scorch or the bluish-green leaf color so commonly described as potassium deficiency symptoms in the apple. Analysis of leaves showed potassium very low and nitrogen also low. The differences in tree growth did not appear until two years after the orchard was planted. A treatment of three pounds of potassium sulfate broadcast in a circle under the outer-branches and worked into the ground to a depth of about 2 inches resulted in quick recovery of the trees. Nitrate fertilizer,however,had an inhibitive effect to potassium response by the trees.

Symptoms of some mineral deficiencies of young peach trees were described according to the observations made in sand culture experiment by Davidson and Blake (12),and Weinberger and Cullinan (38). The symptoms,however,will vary to a marked degree under varying environmental conditions and according to their hereditary factors.

A review of literatures shows that in the United States very little work has been done regarding the chemical properties of the orchard soils,particularly those of peach orchards. Analysis of soils of peach orchards at Vineland,Canada, by Lilleland and Brown(21) found that symptoms of scorch or unsatisfactory growth and early death of peach trees occurred on soils containing as little as 1.8 p.p.m. pf water-soluble potassium (1:1 water-soil ratio),35-36 p.p.m. of replaceable potassium and 60-97 p.p.m.

of Neubauer potassium, while soils in which peaches have grown successfully for 100 years contained 5.2 p.p.m. of water-soluble potassium, 72 p.p.m. of replaceable potassium and 228 p.p.m. of Neubauer potassium.

Studies on root distribution of four- to five-year-old peach trees in sandy clay loam by Savage and Cowart(31) shows that horizontal distribution of roots less than 2 mm. in diameter is mostly within the distance between 1 to 4 feet from the trunk, and that over 90 percent of the total tree roots and about 75 percent of the roots less than 2 mm. in diameter are located within 18 inches of the soil surface. With younger trees, an even greater percentage of the total tree roots are located within this depth(9). Hinricks and Cross(17) assumed that in order to produce a well developed root system of peach trees, the pore space of soil should be above 40 percent.

Davidson(14) concluded from his pot experiment that potassium absorbed by roots in the surface soil may be made available to roots in the subsoil by translocation through the root systems of trees. In fact, Davidson even suggested that orchard cultural practices which favored the development of extensive and active root growth in the surface soil should lead to economy and efficiency in the use of potash fertilizers. Judging from his experiment, the distribution of root system in soil, might not be so important in regard to the absorption of nutrients by peach trees, but it is certainly important in water absorption.

Failure of normal growth of some of the replanted peach orchards leads to the common belief that peach trees should never be planted on land that has grown peach trees within three years. Some ascribed the detrimental effect to the diseases carried over from the preceding planting(19), while Proebsting (29) found it was the root bark of the old tree which was toxic to the young peach trees. It seems quite possible that exhaustion of plant nutrients by the preceding trees is very probably one of the main causes.

III. Experimental

Soil Sampling:

Soil samples used in the present study were from an important peach producing district in Berrien County, Michigan. The peach orchard from which the soil samples were taken was on the Clarence Butzbach Farm of Bainbridge Township. The soil in this orchard is a well drained sandy loam. The trees (Elberta) are now five years of age. Field observations made in the previous year by farmers and horticulturists showed some of the trees were in a poor and abnormal growth condition while others were making good and normal growth. However, no detailed description of the appearance or abnormality which might aid in diagnosing the trouble was reported.

Soil samples were taken near two representative trees. One of which was in poor growth condition, while the other survived normally. The trees were free from crotch, trunk, crown and any other mechanical injury. They were not far apart. Neither pathological infection of fungi nor insect injury was evident.

Samples were taken at different locations and to different depths around the tree trunk. The first location was at a distance of three feet from the tree trunk, the second was under the leaf-drip, and the third one,about in the middle between tree rows, all being on one side of tree trunk. To the opposite side of tree trunk, the fourth, fifth and sixth locations were chosen in the same manner. At each location, four samples were taken from four different depths. Thus for each tree, twenty four soil samples were collected for analysis.

Samples thus collected were numbered according to the following system. The first figure of the sample number denotes the tree number; no. 5 is the peach tree showing abnormal and poor growth, while no. 10 is the tree showing normal and good growth. The second figure denotes the location of samples around the tree trunk. The third figure represents the depth of sampling, the first depth being 0-5 inches, the second,5-10 inches, the third, 10-20 inches and the fourth, about 40 inches from the surface. Thus, for illustration, soil number 10-2-2 is the soil sample taken under the leaf-drip of tree no.10(normal growth) at a depth of 5-10 inches from the surface of the soil. Figure 1 shows the location and numbering of the soil samples around the tree trunks.

All samples were air dried and passed through a 20 mesh sieve. No grinding other than that ~~is~~ necessary to break up lumps was practiced. All analysis were made on air-dried soil sample and the results of analysis are expressed on oven dry soil basis.

Methods of Analysis:

Measurement of pH value: The pH value of soil was measured by a Beckmann pH meter(glass electrode) with an appro-

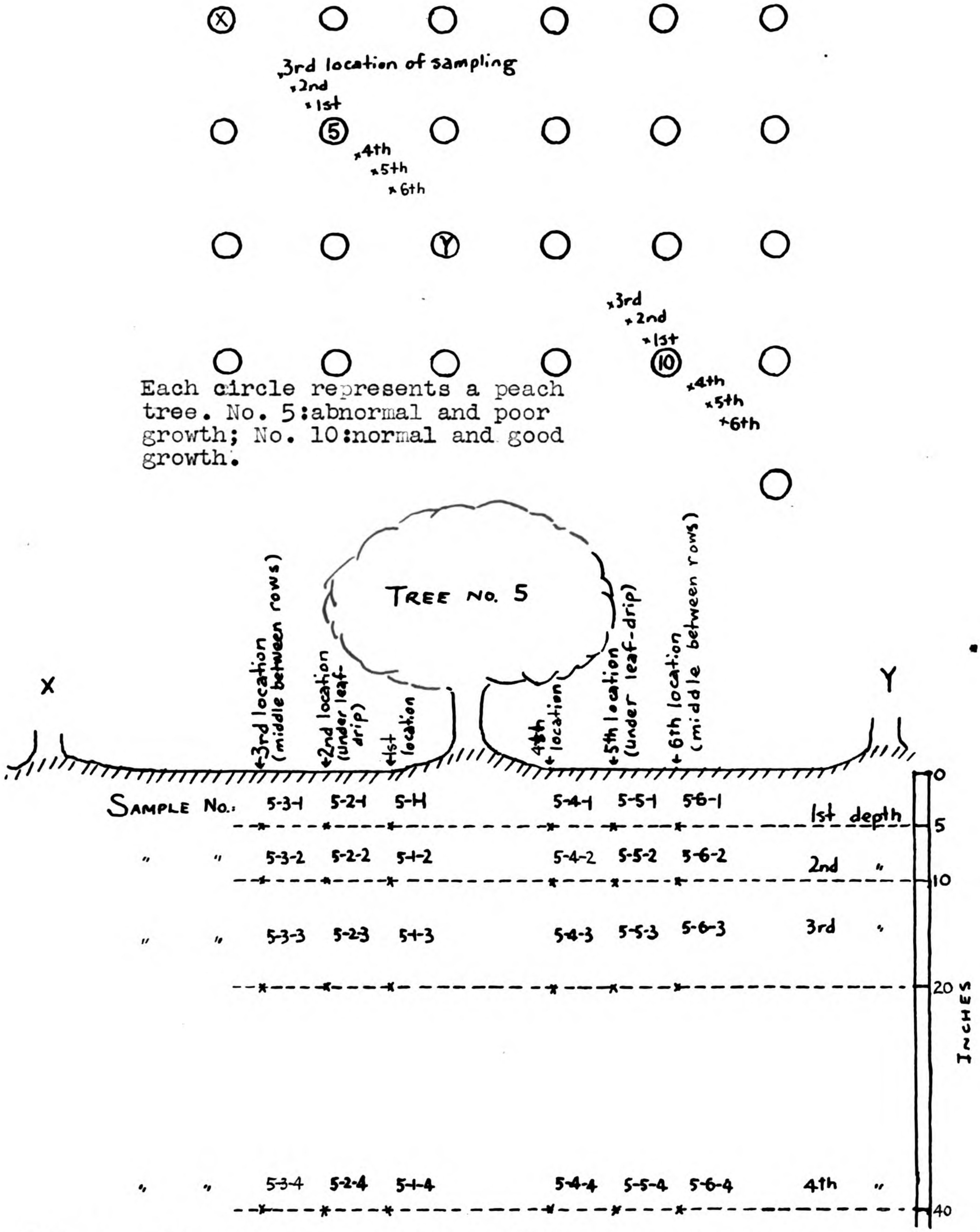

Fig. 1. Diagrams showing the location of samples around peach tree and the system of the numbering of the samples. (upper: plane view; lower:cross-sectional view.

ximate soil water ratio of 1.5 to 1. After the addition of water to the air dry soil sample, it was well stirred to form a medium paste, and allowed to stand for half an hour, then stirred again. Immediately after stirring the pH meter reading was taken.

Total adsorbed and acid soluble phosphorus: Bray's method for the determination of total adsorbed and acid soluble phosphorus, as very recently described by him(5), was used. In this method, neutral ammonium fluoride was used as a reagent for removing the adsorbed forms of phosphate, and any phosphates extracted by 0.1 N HCl were considered to be acid soluble. In developing the molybdenum blue color for photoelectric colorimeter measurement, the following order of adding reagents was practiced(7). To the 10 ml. of ammonium molybdate reagent in a test tube, 15 ml. of 0.8 M H_3BO_3 was added. It was diluted with water and then a 10 ml. aliquot of clear soil extract added. With this modification, the reproducibility of the results is better, possibly because in so doing the interference of silica which is quite soluble in ammonium fluoride solution becomes practically insignificant(7).

Base exchange capacity: Chapman and kelly's neutral ammonium acetate method(8) was used for the determination of base exchange capacity. 50 grams of air dry soil were used for each determination. After leaching with 1000 ml. neutral N NH_4Ac solution in a Büchner funnel, 500 ml. of ethyl alcohol was used to wash the ammonium-saturated soil. The adsorbed ammonium was determined by distillation after extraction with 450 ml. 15 % KCl solution(24).

Exchangeable potassium: Determination of exchangeable potassium was made in the ammonium acetate leachates according to Lawton's method(20). It is an indirect procedure in which a definite amount of the intensely colored reagent, lithium dipicrylaminate is used as a precipitating reagent for potassium. Precipitation of potassium is allowed to take place at **near** 0° C., after organic matter and ammonium have been removed from the soil extract and the residue taken up in water. The concentration of the precipitating reagent remaining in solution is determined in a photoelectric colorimeter (Filter number 420).

Exchangeable calcium and magnesium: Determinations of exchangeable calcium and magnesium were made in the 0.5 N acetic acid soil leachate according to the Williams Method(39). After the removal of sesquioxide by adding ammonium hydroxide, calcium and magnesium were determined gravimetrically(1) as usual.

Total exchangeable bases: Half the amount of the acetic acid soil leachate(500 ml.) was evaporated to dryness to expel the acetic acid. It was then ignited in muffle furnace to convert the replaced bases into oxides and carbonates, the value of which was determined by titrating with a standard acid (37).

IV. Results and Discussion

On the supposition that there would be a difference in the chemical characteristics of soils that supported good and poor peach tree growth, soil samples near **the** good and poor peach trees in the same orchard were analyzed for exchangeable calcium, magnesium, potassium, available phosphorus, base exchange capacity and reaction. The results of these analyses are listed in Table 1.

pH values:

A general survey of the pH values shows that regardless of the condition of the growth of peach trees, all soil samples taken from the orchard are acid. The pH value varies from 4.49 to 5.79. Generally speaking, soil samples taken around the good peach tree have higher pH values. They range from 4.69 to 5.79, while soil pH values from the poor tree range from 4.49 to 4.82. For both trees, the average pH values of the subsoils(10-20,and 40 inches) seem to be higher than those of the surface soils(0-5, and 5-10 inches). The difference, however, is not great enough to show any significance statistically. In Table 2 are presented the average pH values of the two soils at different depths. In calculating the averages ,all the pH values were first converted into hydrogen ion concentrations to get the averages of hydrogen ion concentrations which were then converted back again into the pH scale*.

---

*For the convenience of calculating the average pH value of a series of pH determinations, the writer suggests the use of the following formula:-

$$\text{Average pH} = M + \log N - \log\left[1 + \sum_{1}^{N-1} \text{antilog}(M-X)\right]$$

where M = the maximum pH value in the series, N = number of individual pH determinations of the series,i.e. number of samples to be averaged, and X = pH values of individual samples smaller than the maximum pH,M.

Table 1. Chemical analysis of orchard soils as related to growth conditions of peach trees(on dry soil basis).

Soil No.	depth of sampling	pH	Available P(p.p.m.) adsorbed	Available P(p.p.m.) acid-solu.	Exchange capacity	Exchangeable bases* total	Ca	Mg	K
			Growth condition of the tree--poor						
5-1-1	0- 5in.	4.80	39	127	9.58	1.65	1.07	.48	.08
5-1-2	5-10 "	4.67	37	125	11.52	1.75	1.35	.28	.11
5-1-3	10-20 "	4.79	47	116	9.67	2.05	1.75	.24	.07
5-1-4	40 "	4.63	26	28	12.54	3.45	2.66	.43	.15
5-2-1	0- 5in.	4.51	44	121	11.40	1.83	1.12	.53	.14
5-2-2	5-10 "	4.59	37	126	10.93	2.29	1.86	.36	.04
5-2-3	10-20 "	4.73	37	132	8.49	2.49	2.10	.22	.13
5-2-4	40 "	4.63	26	39	16.87	3.45	2.63	.55	.20
5-3-1	0- 5in.	4.58	36	103	9.96	1.66	1.06	.50	.09
5-3-2	5-10 "	4.61	32	105	11.84	2.50	2.01	.35	.11
5-3-3	10-20 "	4.76	38	53	11.64	3.32	2.82	.40	.07
5-3-4	40 "	4.73	25	61	12.91	3.67	2.69	.61	.23
5-4-1	0- 5in.	4.55	47	124	10.64	2.01	1.24	.50	.11
5-4-2	5-10 "	4.52	47	109	11.24	1.40	1.07	.20	.06
5-4-3	10-20 "	4.82	33	167	8.68	2.01	1.63	.21	.12
5-4-4	40 "	4.74	22	66	11.67	3.58	2.69	.65	.20
5-5-1	0- 5in,	4.49	51	149	11.30	1.75	1.20	.40	.08
5-5-2	5-10 "	4.59	53	115	12.47	2.66	1.88	.52	.07
5-5-3	10-20 "	4.78	29	126	12.79	3.53	2.89	.45	.19
5-5-4	40 "	4.60	29	70	16.39	3.89	3.00	.50	.29
5-6-1	0- 5in.	4.62	45	163	9.89	2.53	1.66	.73	.12
5-6-2	5-10 "	4.72	41	117	9.53	1.83	1.16	.50	.09
5-6-3	10-20 "	4.75	19	164	13.40	3.32	2.17	.60	.22
5-6-4	40 "	4.62	32	77	15.10	3.58	2.04	.86	.35

Table 1 (Concluded)

Soil No.	depth of sampling	pH	Available P (p.p.m.) adsorbed	Available P (p.p.m.) acid-solu.	Exchange capacity	Exchangeable bases * total	Ca	Mg	K
Growth condition of the tree--good									
10-1-1	0- 5in.	4.91	18	93	4.04	2.01	1.42	.40	.10
10-1-2	5-10 "	5.01	28	106	5.60	2.71	2.09	.43	.07
10-1-3	10-20 "	5.18	28	96	7.89	4.49	3.37	.82	.13
10-1-4	40 "	5.51	33	74	8.42	5.59	4.33	.68	.18
10-2-1	0- 5in.	5.10	39	193	4.22	1.77	1.29	.38	.06
10-2-2	5-10 "	5.46	28	122	4.63	3.13	2.16	.50	.10
10-2-3	10-20 "	5.56	24	65	7.10	4.45	3.54	.45	.14
10-2-4	40 "	5.79	31	112	3.01	2.31	1.61	.63	.05
10-3-1	0- 5in.	4.84	39	101	5.93	1.75	1.24	.40	.07
10-3-2	5-10 "	5.18	28	52	3.98	1.27	.97	.18	.08
10-3-3	10-20 "	5.01	20	52	7.20	3.67	3.00	.42	.23
10-3-4	40 "	5.12	24	80	6.49	4.36	2.83	.85	.24
10-4-1	0- 5in.	4.84	28	107	4.59	1.44	1.08	.22	.16
10-4-2	5-10 "	4.69	14	52	6.86	2.21	1.53	.48	.09
10-4-3	10-20 "	5.11	21	42	13.88	8.04	6.47	1.06	.30
10-4-4	40 "	4.89	23	23	14.48	5.46	4.52	.63	.28
10-5-1	0- 5in.	4.91	26	98	4.14	1.70	1.07	.40	.11
10-5-2	5-10 "	4.69	26	63	5.89	1.75	1.27	.28	.09
10-5-3	10-20 "	4.71	25	51	11.56	3.62	2.02	.83	.34
10-5-4	40 "	4.70	19	50	11.83	3.97	2.39	.94	.34
10-6-1	0- 5in.	4.87	30	109	5.10	1.99	1.31	.51	.09
10-6-2	5-10 "	4.74	21	55	5.25	2.23	1.24	.82	.07
10-6-3	10-20 "	4.75	25	51	9.46	4.43	2.80	.92	.27
10-6-4	40 "	4.74	31	55	9.02	2.97	1.46	.77	.29

* Exchange capacity and exchangeable bases are expressed in terms of m.e. per 100 grams of dry soil.

Table 2. Average pH of orchard soils as related to depths of sampling and growth conditions of peach trees.

Depth of sampling	Growth conditions of peach trees	
	good	poor
Inches	Average pH values	
0- 5	4.90	4.58
5-10	4.88	4.61
10-20	4.96	4.77
40	4.98	4.66

Available phosphorus contents:

The available phosphorus contents are relatively high in both soils. Generally speaking in every location the amount of adsorbed and acid-soluble phosphorus present in the soil decreases with the depth. Apparently a large portion of the available phosphorus in the surface and subsurface soil comes from the addition of fertilizers and the incorporation of organic matters. They tend to be adsorbed by the soil colloidal complexes or fixed with other soil constituents in the form of acid-soluble compounds in the surface layers.

The average values of adsorbed and acid-solible phosphorus of six different soil samples of the same depth around each tree are presented in Table 3. With the exception of the soil from

Table 3. Averages of adsorbed and acid-soluble phosphorus contents in relation to the growth conditions of peach trees. (Average P in p.p.m., on dry soil basis).

Depth of sampling (inches)	Adsorbed phosphorus			Acid soluble phosphorus		
	good growth	poor growth	difference	good growth	poor growth	difference
0- 5	30±7.37	44±4.92	14±8.86	117±34.5	131±19.5	14±39.6
5-10	24±5.16	41±6.97	17*±8.67	75±28.2	116± 9.9	41±29.9
10-20	24±2.70	34±8.62	10±9.03	60±17.7	126±38.9	66±41.8
40	27±5.13	27±3.16	0±6.03	66±32.8	57±17.5	9±37.1

*The difference is statistically significant at P =.10(t=1.81).

a depth of 40 inches from the surface, all soil samples taken around the good tree generally contain less (though statistically usually not significant) adsorbed and acid-soluble phosphorus than those taken around the poor tree. The contrast is especially noticiable in comparing the samples of 5-10 and 10-20 inch depths. From the standpoint of soil and plant growth relationships, the difference is possibly due to the different growth conditions of the tree. With normal growth, the tree consumes more phosphorus and other nutrients. Consequently they absorbs more available nutrients from the soil around the active root region. Another interesting point is that the difference in acid soluble phosphorus is much greater than that in adsorbed phosphorus. This can be explained by the different availability of the two forms of phosphorus to the plant. Thus, Bray and Dickman(4) concluded that when present in small amounts adsorbed and acid soluble forms of phosphorus were somewhat similar in effectiveness for plant growth, while Burd and Murphy(6) considered the adsorbed forms more unavailable to plants than acid-soluble forms. The results shown here seem to support the conclusion of Burd and Murphy.

The average differences of total adsorbed and acid-soluble phosphorus contents between the soil samples of the same depth around the two trees are 28 p.p.m. for the 0-5 inches layer, 58p.p.m for the 5-10 inches layer, 76 p.p.m. for the 10-20 inches layer and 9 p.p.m. for the 40 inches layer. If these differences are due to the difference in the root absorption as mentioned before, it follows that the peach trees in question have active root absorption in the soil depths from 5-20 inches, and less so from

0-5 inches. The zone of least absorption is at 40 inches. Such a distribution of root activity of peach trees checks very well with the results reported by Savage and Cowart(31).

It seems that there might be some relationship between the amount of acid-soluble phosphorus and the amount of exchangeable calcium in the soil. The relationship, however, is not statistically significant. Its correlation with the pH value also does not exist.

Amount of Exchangeable Bases:

The amount of total exchangeable bases is low in both soils. Although the soil supporting good tree growth seems to contain some more exchangeable bases, particularly in the deep layers, yet the difference between the two soils is in general only very slight. In fact, in some cases the soil that fails to grow good trees contains even more exchangeable bases and exchangeable calcium in the surface two layers.

Generally speaking the situation of total exchangeable bases and exchangeable calcium is much the same, and with only few exceptions they increase with the depth. No correlation with other chemical properties thus far studied has been found. The anounts of exchangeable magnesium and potassium present in the soil samples also vary with the depth of sampling. They, however, do not show a constant increase or decrease with the depth. In case of the poor tree, the amount of exchangeable magnesium is generally less in the 5-10 and 10-20 inches soil layers. The exchangeable potassium content of both soils is extremely low. It ranges from 0.35 m.e. per 100 grams soil in the deep layer to only 0.04 m.e. in the sub-surface layer(5-10 inches). The vertical distribution in the soil is irregular. In most cases, the least amount is found in the 5-10 inches soil layer, where root absorption for minerals is presumed to be most active.

Base exchange capacity and degree of base saturation:

One of the most important results of the present study is perhaps the significance of base exchange capacity of the soil in relation to the growth conditions of peach trees. Inspite of the fact that the two soils supporting trees of different vigor contain nearly the same amount of total exchangeable bases, exchangeable calcium, magnesium and potassium, the base exchange capacity of the two soils varies greatly. Soils around the poor tree all have the base exchange capacity above 8.49 m.e. per 100 grams of soil, whereas soils around the good tree with exceptions of the six soil samples(out of twenty-four) taken from the deeper layers all have the base exchange capacity below 8.42 m.e. With the same amount of exchangeable bases, this difference will mean different degree of base saturation. From the data available, the percent of total base saturation and also the percentage saturation of individual bases were calculated. The results are shown in Table 4.

From the data, it is apparent that the soil supporting the good tree has much higher degree of saturation of total exchangeable bases as well as individual bases. In case of the total exchangeable bases the degrees of saturation for samples near the good tree runs all above 30%, while for those near the

Table 4. Degree of base saturation of the soil in relation to the growth conditions of peach trees.

Soil No.	Depth of sampling	Percentage saturation of bases			
		Total	Ca	Mg	K
	Inches	Growth condition of the tree--poor			
5-1-1	0- 5	17.21	11.16	5.00	.83
5-1-2	5-10	15.19	11.72	2.43	.95
5-1-3	10-20	21.20	18.10	2.48	.72
5-1-4	40	27.83	21.23	3.43	1.20
5-2-1	0- 5	16.05	9.82	4.65	1.23
5-2-2	5-10	20.95	17.02	3.29	.37
5-2-3	10-20	29.33	24.73	2.59	1.53
5-2-4	40	20.45	15.60	3.26	1.20
5-3-1	0- 5	16.67	10.64	5.02	.90
5-3-2	5-10	21.11	16.98	2.96	.93
5-3-3	10-20	28.52	24.23	3.44	.60
5-3-4	40	28.43	20.74	4.73	1.78
5-4-1	0- 5	18.89	11.65	4.70	1.03
5-4-2	5-10	12.46	9.52	1.78	.53
5-4-3	10-20	23.16	18.78	2.52	1.38
5-4-4	40	30.68	23.05	5.57	1.71
5-5-1	0- 5	15.49	10.62	3.54	.71
5-5-2	5-10	21.33	15.08	4.18	.61
5-5-3	10-20	19.78	22.60	3.52	1.49
5-5-4	40	23.73	18.30	3.06	1.77
5-6-1	0- 5	25.58	16.78	7.38	1.21
5-6-2	5-10	19.20	12.17	5.25	.94
5-6-3	10-20	24.78	16.19	4.48	1.64
5-6-4	40	23.71	13.61	5.70	2.32

Table 4 (Concluded)

Soil No.	Depth of sampling	Percentage saturation of bases			
		Total	Ca	Mg	K
	Inches	Growth condition of the tree--good			
10-1-1	0- 5	49.75	35.15	9.90	2.47
10-1-2	5-10	48.39	37.14	7.68	1.25
10-1-3	10-20	56.91	42.71	10.39	1.65
10-1-4	40	66.39	51.43	8.17	2.14
10-2-1	0- 5	41.94	30.57	9.00	1.42
10-2-2	5-10	67.60	46.65	10.80	2.16
10-2-3	10-20	62.68	49.86	6.34	1.97
10-2-4	40	76.74	53.49	20.93	1.66
10-3-1	0- 5	29.51	20.91	6.75	1.18
10-3-2	5-10	31.91	24.37	4.52	2.01
10-3-3	10-20	50.97	41.67	5.83	3.19
10-3-4	40	67.18	43.61	13.10	3.70
10-4-1	0- 5	31.37	23.53	4.79	3.49
10-4-2	5-10	32.22	22.30	7.00	1.31
10-4-3	10-20	57.93	46.61	7.64	2.17
10-4-4	40	37.71	31.22	4.35	1.94
10-5-1	0- 5	41.06	25.85	9.66	2.66
10-5-2	5-10	29.71	21.75	4.75	1.52
10-5-3	10-20	31.31	17.56	7.18	2.94
10-5-4	40	33.56	20.21	7.95	2.87
10-6-1	0- 5	39.02	25.69	10.00	1.76
10-6-2	5-10	42.48	23.62	15.61	1.33
10-6-3	10-20	46.78	29.57	9.71	2.85
10-6-4	40	32.93	16.19	8.54	3.22

poor tree they all run below 30 % (No. 5-4-4 has a value of 30.68 %). The average values of the degree of base saturation of soils are tabulated in Table 5 in connection with the growth conditions of the trees and depths of the soils.

Table 5. Averages of the degree of base saturation in relation to the depths of sampling and growth conditions of the trees.

Exch. bases	Growth conditions of trees	Depth of sampling: 0- 5 inches		5-10 inches		10-20 inches		40 inches	
Total	Good	38.78	6.72	42.05	13.20	51.10	10.19	52.42	18.05
	Poor	18.32	3.39	18.37	3.40	24.46	4.54	25.81	3.43
	Difference	20.40**	7.53	23.68*	13.62	26.64**	10.79	26.62	18.37
Ca.	Good	26.95	4.68	29.31	9.34	38.00	11.09	36.03	14.54
	Poor	11.78	2.30	13.75	2.80	20.77	3.25	18.76	3.26
	Differnece	15.17***	5.21	15.56	9.75	17.23	11.53	17.27	14.89
Mg	Good	8.35	1.93	8.39	3.66	7.85	1.66	10.51	5.30
	Poor	5.05	1.14	3.32	1.12	3.17	0.73	4.29	1.10
	Differance	3.30	2.24	5.07	3.83	4.68**	1.81	6.22	5.41
K	Good	2.16	.80	1.60	0.34	2.46	0.57	2.59	0.71
	Poor	.99	.16	.72	0.24	1.23	0.40	1.66	0.40
	Difference	1.15	.82	.88*	0.42	1.23*	0.70	.93	0.81

*The difference is statistically significant at P=.10(t=1.81).

**The difference is statistically significant at P=.05(t=2.23).

***The difference is statistically significant at P=.01(t=3.17).

The average values of the degrees of saturation of total bases and exchangeable calcium increases with the depth of the soil. The vertical gradients of the degree of saturation for exchangeable potassium and magnesium, however, do not exist in exactly the same manner. Thus in case of exchangeable potassium, the degree of saturation decreases from the 0-5 inches to 5-10 inches soil layer. Similar change occurs for magnesium in soil supporting the poor tree. Again this may be considered as an indication of the active absorption region of the peach root in thesoil.

From both the theoretical and practical point of view, the percentage base saturation is of considerable importance in relation to nutrient conservation and plant feeding. Pierre (28) in 1939 concluded that base saturation of soils is a valuable criterion for the growth of certain plants. Jenny and Ayres (18) also emphasized the importance of percentage base saturation in relation to plant nutrition.

Studies on the nutrient losses in relation to percentage base saturation were made and the literature reviewed by Peach (23) and Ayres(2). Their data showed that nutrient losses, especially potassium and magnesium decreased with an increase in percentage base saturation.

It was also found by Mehlich(27) that the amounts of magnesium and potassium lost from the surface of sandy soils in the field decreased with increasing base saturation. These nutrients once lost from the surface soils were not retained by the acid subsoils, irrespective of the base exchange capacity. Increasing the percentage base saturation of the subsoil increased the retention of potassium and magnesium. In tests with percolators,Mehlich also found that increasing the base saturation of subsoils through liming increased the retentive power for potassium and magnesium; it also favored root penetration, increased moisture utilization, and increased plant growth. In studying the soils from Florida citrus groves, Peech (22) pointed out the importance of maintaining percent base saturation at as high a level as possible in keeping with other factors in light sandy soils.

According to the opinion of the present writer, the difference in percentage base saturation will mean a difference in the availability or absorbility of exchangeable bases by plant roots. The higher the degree of base saturation in the soil, the easier will be the intake of exchangeable bases by plant roots. Theoretically this is quite reasonable from the standpoint of physical chemistry. As the degree of base saturation becomes less, the electrostatic attraction between the adsorbed cations and soil colloid becomes stronger. Consequently the exchangeable bases are held tighter by the soil colloidal particles and therefore become less available to plant roots.

The data in Table 4 show that some of the differences of the degree of base saturation between soils from different tree standings are highly significant. The difference of calcium in the 0-5 inches layer is the most significant one. Differences of magnesium in the 10-20 inches layer are also great. According to the reasoning given in the previous paragraphs, these differences in the percentage base saturation may be one of the main reasons explaining the different growth condition of peach trees in the same orchard.

Relationship between percent base saturation and pH value:

There is a general relationship between soil pH and percent base saturation. Using an ammonium acetate extraction, Peech(22) obtained survey data on 194 surface and subsoil samples which indicated that there was a general correlation between pH and the average percent base saturation of all of the soils taken as a group. Volk and Bell(35) also obtained linear correlation between pH and percent base saturation, but the exact relationship depends on the specific nature of the soil. According to Mehlich(25,26), the variations are particularly great in the subsoil. The most direct relationship between pH and degree of base saturation was also found by Mehlich(26) in the soils in which the organic colloid predominates. The relationship will be complicated by partial saturation of certain base exchange constituents by organic compounds as suggested by the findings of Ensminger and Gieseking(16).

In the present study, the coefficient of linear correlation between soil pH and percent base saturation is calculated to be +.8610, which is highly significant. Assuming this linear relationship, the regression line is found by the method of least squares to be:

$$\text{Percent base saturation} = 47.50\text{pH} - 195.79$$

(see Figure 2).

Relationship between base exchange capacity and hygroscopic moisture :

There is a positive correlation between base exchange capacity and the hygroscopic moisture. The coefficient of linear correlation is +.8794, and the regression line is represented by the following equation:

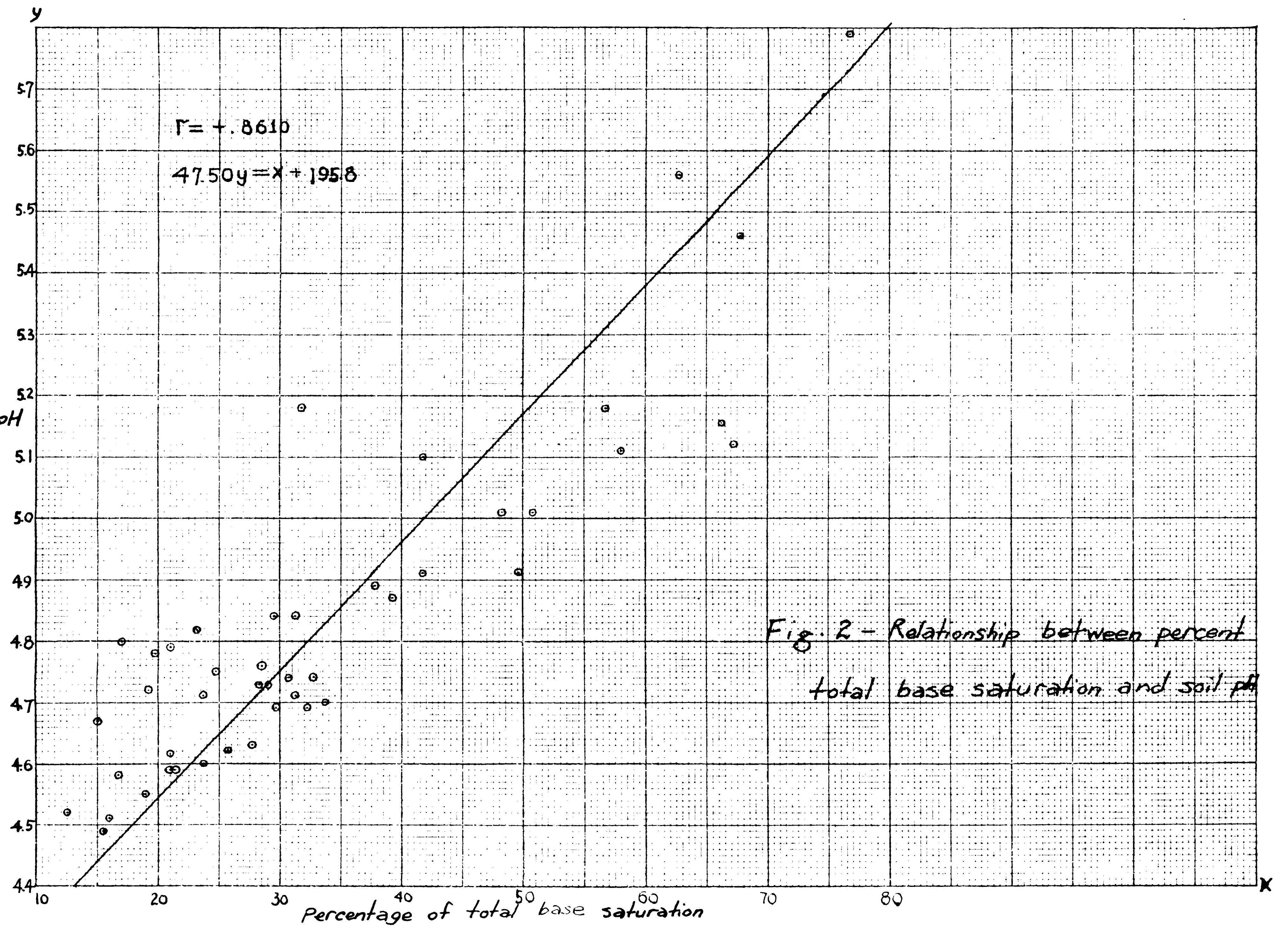

Fig. 2 - Relationship between percent total base saturation and soil pH

$$\text{Percentage hygroscopic moisture} \times 1.22 = \text{m.e. base exchange capacity} + 0.08$$

The relationship is presented in Figure 3. (With a view to save space, the data for hygroscopic moisture have not been presented in the present text). Since both hygroscopic moisture and the total base exchange capacity of soil are primarily functions of soil colloids, the existance of linear correlation between them is quite justifiable.

V. Summary and Conclusions

Chemical analyses of soil samples taken from different depths and at the different locations around good and poor peach trees suggest the following points:-

1. Generally speaking, soil samples from near the good tree are higher in pH, total exchangeable bases, and exchangeable calcium than those from near the poor tree. The differences, however, are slight and are presumed not to be the main cause of the different growth conditions ofthe peach trees.

2. The adsorbed and acid-soluble phosphorus contents are relatively high in both soils. In the soil supporting the good tree growth, the contents are lower than in the soil where the peach tree does not grow well. The difference, presumably due to the different growth vigor of the peach trees isremarkable in the depths from 5-10 and 10-20 inches, where the absorption of nutrients by the roots is the most active. The acid-soluble phosphorus seems to be more available then the adsorbed phosphorus.

3. Both soils are nearly equally low in exchangeable potassium. In most cases, the least amount is found in the 5-10

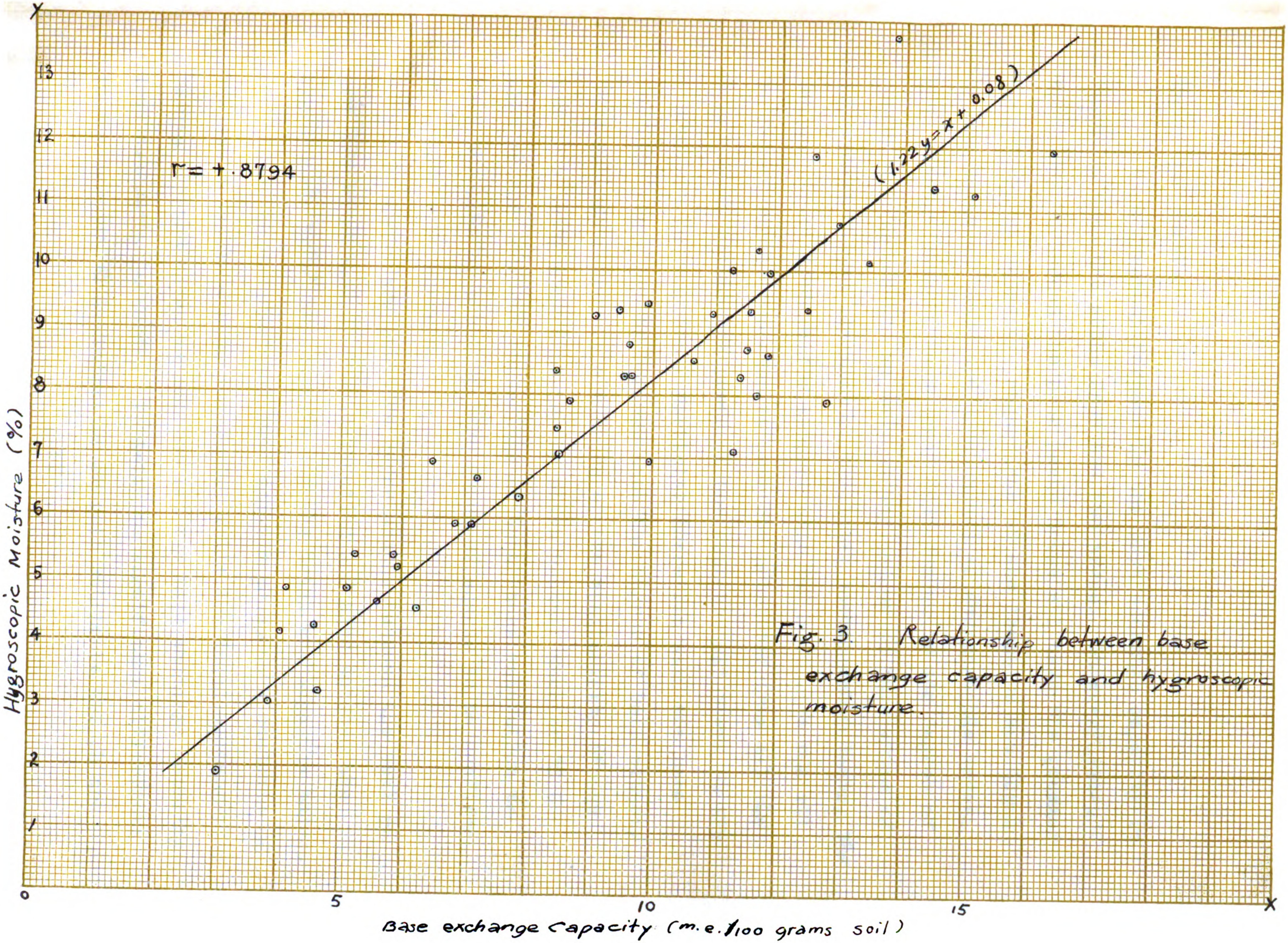

Fig. 3. Relationship between base exchange capacity and hygroscopic moisture.

inch soil layer.

4. A great difference in the base exchange capacity is found between the soils from the two trees. In every case, soil samples around the poor peach trees all have the greater base exchange capacity, regardless of the location and depth of the samples. With the same amount of exchangeable bases, this difference will mean great differences in the degree of total base saturation as well as the degree of saturation of individual bases. In case of the total exchangeable bases, the degrees of saturation for samples near the good tree run all above 30%, while for samples near the poor tree they all run below 30 %. Since the power of the soil to hold bases on the surface of its colloilal particles increases with the base exchange capacity, it follows that the degree of base saturation can also serve as a measure of the availability of the bases or their absorbability by plant roots. Whether 30 % will be the critical percentage of total base saturation to feed the Elberta peach of five years of age is to be confirmed by further research.

5. There are positive correlations between the soil pH and the percentage of base saturation and also between the hygroscopic moisture contents and the total exchangeable bases.

6. The adsorbed and acid soluble phosphorus contents of the soils decrease with the depth, while the total exchangeable bases, the exchangeable calcium and the base exchange capacity increase with the depth. No definite significant differences in the horizontal distribution of soil nutrients and pH are

found around each tree.

7. According to the data presented there seems to be no definite ratio existing between individual exchangeable bases that may have some significance in relation to the growth of peach trees.

VI. Literature Cited

1. A.O.A.C. Methods of Analysis (1935 ed.) p.6-7.

2. Ayres, A.S. 1941 Sorption of potassium and ammonium by soils as influenced by concentration and the degree of base saturation. Soil Sci. 51:265-272.

3. Boynton, D. 1944 Responses of young Elberta peach and Montmorency cherry trees to potassium fertilization in New York. Proc. Amer. Soc. Hort. Sci. 44:31-33.

4. Bray, R. H. and Dickman, S. R. 1941 Adsorbed phosphates in soils and their relation to crop responses. Proc. Soil Sci. Soc. Amer. 6:312-320.

5. Bray, R. H. and Kurtz, L. T. 1945 Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:39-45.

6. Burd, J. S. and Murphy, H. F. 1939 The use of chemical data in the prognosis of phosphorus deficiency of soils. Hilgardia, 12:323-340.

7. Chapman, H. D. The blue colorimetric method for the determination of phosphorus in soils and plants. (Mimeographed). Univ. Calif. Citrus Expt. Sta.

8. Chapman, H. D. and Kelly, N. P. 1930 The determination of the replaceable bases and the base-exchange capacity of soils.

Soil Sci. 30:391-406.

9. Cowart, F. F. 1939 Root distribution and root and top growth of peach trees. Proc. Amer. Soc. Hort. Sci. 36: 145-149.

10. Cullinan, F. P., Scott, D.H. and Waugh, J. G. 1939 The effect of varying amounts of N, K and P on the growth of young peach trees. Proc. Amer. Soc. Hort. Sci.36:61-68.

11. Cullinan, F. P. and Waugh, J. G. 1940 Response of Peach trees to potassium under field conditons. Proc. Amer. Soc. Hort. Sci.37:87-94.

12. Davidson, D. W., and Blake, M.A. 1937 Responses of young peach trees to nutrient deficiencies. Proc. Amer. Soc. Hort. Sci. 34:247-248.

13. Davidson, O. W., and Blake, M.A. 1938 Nutrient deficiency and nutrient balance with the peach. Proc. Amer. Soc. Hort. Sci.35:338-346.

14. Davidson, O.W. 1944 The translocation of potassium among peach roots. Soil Sci. 58:51-59.

15. Dunbar, C. O., and Anthony, R. D. 1937 Two cases of potassium deficiency in peach orchards in South Central Pennsylvania. Proc. Amer. Soc. Hor. Sci. 35:320-325.

16. Ensminger, L. E., and Gieseking, J. E. 1941 The absorption of proteins by montmorillonitic clays and its effect on base-exchange capacity. Soil Sci. 51:125-132.

17. Hinrichs, H., and Cross, F. B. 1943 The relationship of compact subsoil to root distribution of peach trees. Proc. Amer. Hort. Sci. 42:33-38.

18. Jenny, H., and Ayres, A. D. 1939 The influence of the degree of saturation of soil colloids on the nutrient intake by roots. Soil Sci. 48:443-459.

19. Johnston, S. 1941 Peach culture in Michigan. Mich. Agri. Expt. Sta.(Cir.), Bul.177.

20. Lawton, K. 1946 The determination of exchangeable potassium in soils using hexa-nitrodiphenylamine. Proc. Amer. Soil Sci. Soc. 10.(In Press).

21. Lilleland, O., and Brown, J. G. 1937 The potassium nutrition of fruit trees-I.Soil analyses. Proc. Amer. Soc. Hort. Sci. 35:327-334.

22. Peech, M. 1939 Chemical studies in soils from Florida Citrus Groves. Fla. Agri. Exp. Sta.,Bul 340.

23. Peech, M. 1941 Availability of ions in light sandy soils as affected by soil reaction. Soil Sci. 51:473-485.

24. Peech, M., Reed, J. F.,and Alexander, L. T., and Dean, L.A. 1945 Methods of soil Analysis for soil fertility investigations,pp.10-11.

25. Mehlich, A. 1942 Base saturation and pH in relation to soil type. Soil Sci. Soc. Amer.,Proc. 6:150-156.

26. Mehlich, A. 1943 The significance of percentage base saturation and pH in relation to soil type and plant growth. Soil Sci. Soc. Amer., Proc. 7:167-173.

27. Mehlich, A. 1943 Base saturation and pH in relation to liming and nutrient conservation of soil. Soil Sci. Soc. Amer., Pro. 7:353-361.

28. Pierre, W. H. 1939 Hydrogen ion concentration, aluminium concentration in the soil solution, and percent base saturation as factors affecting plant growth on acid soils. Soil Sci. 31:183-207.

29. Proebsting, E. L. 1941 The relation of peach root toxicity to the re-establishing of peach orchards. Proc. Amer. Soc. Hort. Sci. 38:21-26.

30. Rawl, E. H. 1940 Peach tree fertilizer demonstration results. Proc. Amer. Soc. Hort. Sci. 37:85-86.

31. Savage, E. F., and Cowart, F. F. 1942 The effect of pruning upon the root distribution of peach trees. Proc. Amer. Soc. Hort. Sci. 41:67-70.

32. Thompson, R. D. 1916 The relation of fruit growing to soil fertility. Ark. Agri. Exp. Sta., Tech. Bul. 123.

33. Van Slyke, L. L., Taylor, O. M., and Andrews, W. H. 1905 Plant-food constituents used by bearing fruit trees. N. Y. Agri. Exp. Sta. Bul. 265.

34. Van Slyke, L. L. 1937 Fertilizers and Crop production, p. 454. Orange Judd Publishing Co., New York.

35. Volk, G. M., and Bell, C. E. 1944 Soil reaction(pH), Some critical factors in its determination, control and significance. Fla. Agri. Exp. Sta., Bul 400.

36. Waugh, J. G., Cullinan, F. P., and Scott, D. H. 1940 Response of young peach trees in sand culture to varying amounts of N, K and P. Proc. Amer. Soc. Hort. Sci. 37:95-96.

37. Waugh, J. G., and Cullinan, F. P. 1941 The N, P, and K

contents of peach leaves as influenced by soil treatments. Proc. Amer. SOc. Hort. Sci. 38:13-16.

38. Weinberger, J. H., and Cullinan, F. P. 1937 Symptoms of some mineral deficiencies in one-year Elberta peach trees. Proc. Amer. Soc. Hort. Sci. 34:249-254.

39. Williams, R. 1928 The determination of exchangeable calcium in carbonate-free soils. Jour. Agr. Sci. 18:439-445.