DP

14451

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

CATALASE, OXIDASE AND IONIZABLE CONSTITUENTS OF THE TOMATO AS INFLUENCED BY THE SOIL REACTION

BY

E. S. Haber

A Thesis submitted to the Graduate Faculty

for the degree of

DOCTOR OF PHILOSOPHY

Major subject Horticulture

Approved

Signature was redacted for privacy.

In charge of Major work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State College

1928

CONTENTS

CATALASE, OXIDASE AND IONIZABLE CONSTITUENTS OF THE TOMATO AS INFLUENCED BY THE SOIL REACTION

INTRODUCTION

The removal of the old soil in greenhouse benches is an expensive procedure. Plant growth is sufficiently better when new soil is placed in the benches to warrant the necessary expenditure for soil renewal at frequent intervals, in many cases as frequently as once a year. One of the important alterations occurring in bench soils in greenhouses is the change from a slightly acid reaction, common to most soils when first placed in the benches to a highly alkaline reaction, due to the addition of alkaline material in watering.

The present problem was undertaken to determine the effect of the soil reaction (pH value), first, on the growth of the tomato plant, second, its effect on catalase and oxidase activity, and third, its effect on ionizable constituents as determined by electrodialysis.

HISTORICAL REVIEW

Catalase and oxidase are usually thought to be associated with the respiratory processes of the plant, but many workers have found results which conflict with this view. Appleman (3) concluded that with a decrease in the respiratory activity in the potato, the catalase activity decreased. The same author (2) in a later work found that catalase activity of the juice of the potato tubers was associated with respiratory activity, but that oxidase activity was not associated with the rate of respiration.

Ezell and Crist (19) working with lettuce, radish and spinach plants found only a slight negative correlation between oxidase activity and growth or size of the plants, but the catalase activity of the same plants was negatively significant. Drain (17) tried to correlate the catalase activity with respiration in a number of varieties of apples but did not find the two parallel in all varieties. Oldenburg was low in catalase activity as compared with Winesap, but the rate of respiration was much higher in the latter variety. The catalase activity was greatest in the skin and subepidermal tissue of the apple, while the greatest oxidase activity occurred near the core. Reed (39)

demonstrated that oxidase and catalase were independent of each other and that in the ripening of fruit catalase increased while oxidase remained constant or nearly so. Magness and Ballard (34) working with Bartlett pears found catalase to increase for a time as the fruit ripened but then decreased much more rapidly than the rate of respiration. Thatcher (46) made tests on diastase, invertase, tannase, esterase, protease, oxidase and emulsion types of enzymes, and concluded that ripening changes in apples were chiefly due to oxidases.

Pathogenic organisms may influence the "respiratory enzymes" as shown by the results of a number of workers. Woods (51) found that mosaic-diseased areas of tobacco plants showed higher oxidase content and that darker green areas of diseased leaves showed less oxidase activity than mosaic areas. According to Bunzell (11), sugar beet tops affected with curly-top disease had two to three times as great an oxidase activity as healthy leaves. When plants were stunted by excessive drouth, or when growth was retarded through unknown agencies, the oxidase activity was increased. The same author (12) found curly-dwarf potato plants to show this same relation. Rose (42) found apple tree bark affected with Illinois canker to have greater oxidase activity than healthy bark. Harvey (25) working on over-growths in

the potato wart disease, due to Bacterium tumefaciens, showed that this abnormality was accompanied by increased catalase content. He was led to believe that the lowered acidity brought about an increased catalase activity since the enzyme is known to deteriorate in acid solutions but is fairly uniform in its properties at reactions between pH 7.0 and 8.0. The same author (24) observed a decrease in catalase activity in mosaic tobacco plants and an increase in hydrogen-ion concentration in the palisade cells of the diseased areas. Weiss and Harvey (50) working with the potato-wart disease produced by Chrysophlyctis endobiotica found the hydrogen-ion concentration greater but the catalase activity greater as well.

Respiratory enzymes, in dormant and germinating seeds have been investigated by several authors. Crocker and Harrington (15) found catalase activity and respiration in the fruits of Andropogon halepensis ran parallel, but they did not find this condition in seeds of Amaranthus. Rhine (41) stated that the early curve for respiration varied from the typical catalase curve for germination. She concluded that catalase could be used as an indicator of metabolism only in cases where there is not a rapid change in respiration. Nemec and Duchon

(37) were able to show a positive correlation between catalase activity and the viability of seeds. Borasio (9) found the opposite to be true, "By comparing the catalase values of a number of samples of rice representing different varieties and different harvests with the germinating power of the seed, no relationship could be established."

Zaleski and Reinhard (52) studied the effect of potassium nitrate, di-potassium carbonate, magnesium sulphate, etc., on the respiration and respiratory enzymes of wheat, maize, peas, rape and lupines. They compared the respiration of plants grown in distilled water with similar ones growing in distilled water to which various amounts of salt solutions had been added. In nearly every instance lowered respiration as well as lowered action of catalase, reductase and zymase occurred in plants grown in the salt solutions.

Catalase activity in relation to growth in fruit trees, especially the apple, has been studied considerably by Heinicke and his co-workers. Heinicke (26) found growth-producing substances increased catalase activity while substances which tended to inhibit vegetative activity had a retarding influence on catalase activity. Organic nitrogenous materials seemed to increase the activity while carbohydrates were believed to be the chief

cause of reduction in catalase activity. The same author (27) found apple trees grown on sandy soil showed less catalase activity in the leaves than those from trees growing on a clay soil, whether the trees were cultivated or grown in sod. Apple trees when grown in sod and given applications of nitrate of soda up to 8 ounces per tree showed an increase in catalase activity of the leaves. Heinicke (28) also determined that fruiting tends to reduce catalase activity in the bark of the apple tree. By applying nitrates to only one side of the trees Auchter (4) obtained increased catalase activity on the nitrated side. Biechy (8) found that an addition of potassium fertilizer decreased the catalase activity of the plant. According to Knott (30) the catalase activity of spinach leaves was not influenced either by vegetative or reproductive type of growth.

Grüss (21) reported that it was impossible to make quantitative determinations of catalase in fresh potato extract on account of the rapid degeneration during and after grinding. Appleman (3), however, discovered that if the potato was ground with calcium carbonate to neutralize the acids freed by the grinding, diluted immediately and kept at 20°C or below, this rapid degeneration was overcome and comparable results

could be secured without any difficulty. Heinicke (26) found that the amount of calcium carbonate equal to the green weight of the tissue was in excess of that needed for the acidity to be corrected, but far more could be added without affecting the reaction. Becking and Hampton (6) using sodium carbonate to neutralize the plant acids concurred in this belief. According to Knott (31) catalase activity of the tomato and spinach decreased more slowly at cool temperatures.

According to Ezell and Crist (19) samples of tissue prepared for the determination of oxidase activity should be allowed to stand for about six hours before using. Oxidase activity of the sample increased for about six hours and then remained constant for ten or twelve hours, after which there was a slow decline.

Within recent years electrodialysis as a means of studying certain chemical and physical phenomena has come into use. Dhere and Gorgelewski (16) and Bernhard and Beaver (7) used this method as a means of determining the composition of serums. Lisbonne and Vielquin (33) and Fricke et al. (20) used this means of studying enzyme activities. The active and inactive constituents of insulin were separated by means of electrodialysis, by Taylor, Brown and Scott (45). Hoffman and Gortner (29) split free agar acid from its calcium salt by this means.

König, et al. (32) studied the replaceable bases of soils by the same method. Mattson (35) by the use of a three-chambered cell improved the method by which the replaceable bases of the soils might be studied.

Moore, Reeves and Hixon (36) made use of the Mattson cell in studying apple tissue affected with Jonathan-spot as compared with normal tissue and substantiated Pentzer's (38) results, that Jonathan-spot was accompanied during storage by a loss of acids in the diseased area.

Bradfield (10) by means of the Mattson cell, using K Cl, K_2SO_4, and K H_3PO_4, all normal solutions with respect to the potassium content, concluded that in every case the cation was removed more quickly than the anion. The rate of removal of the cation was influenced by the nature of the anion with which it was combined, while the rate of removal of the anions was in the order of $Cl > SO_4 > H_2PO_4$. In every case the cation was removed quantitatively, but the time required was greater, especially in the case of the phosphate ion. He suggested that the rate of removal of anions would be facilitated by the substitution of a positive membrane for the negative parchment membrane on the anode side.

MATERIALS AND METHODS

New compost soil was placed in the greenhouse bench. The individual plots were separated by boards that extended the entire depth of the bench in order to prevent the soil of one plot from mixing with that of another. The reaction (pH value) of the soil when placed in the benches was 6.5.

Since the soil was always acid when placed in the bench and became highly alkaline due to the addative effect of the salts in watering, three reactions (pH values) were decided upon, one extremely alkaline, pH 8.5-9.0, one neutral or nearly so, pH 6.5-7.0, and one extremely acid, pH 4.0-4.5. These plots were all run in duplicate. To secure the alkaline reaction, the soil was treated with hydrated lime in sufficient quantity so that the pH value was about 9.0 a week after treatment when a fair degree of equilibrium was reached. For the neutral plots the soil was not treated, since it was nearly neutral without treatment. The acid reaction was secured by adding phosphoric acid (H_3PO_4) so that the reaction was 4.0 a week after treatment.

The tomato plants used were of the Bonny Best variety. The seed was sown in a flat, the seedlings pricked off when one and one-half inches high and planted

in two-inch pots, later shifted to four-inch pots and finally transferred to the treated plots ten days after the soil had been treated. The soil used in potting was ordinary compost with a pH value of 6.0-6.5.

The fall crop was placed in the greenhouse bench October 1 and completed its growth February 1. The spring crop was placed in the bench February 20. Determinations of the pH values of the soil of the various plots were made at ten-day intervals after the crop was benched. Small amounts of hydrated lime or phosphoric acid were added from time to time to keep the pH within the desired range.

To secure the desired information regarding growth and fruit production, yields were recorded by weighing the fruits when ripe. Relative growth on the various plots was secured after the fruit had been harvested. The plants were dug, the roots washed free of soil with tap water and then washed with distilled water. Roots, stems and leaves were separated from each plant and air-dried in the laboratory for four weeks with the temperature ranging from 75° to 85°C., and then weighed to determine the relative amount of growth. Catalase and oxidase activity were measured on fresh material of leaves and fruit on both spring and fall crop.

Measurements of ionizable material by electrodialysis were made only on the fall crop. Electrodialysis of the fruit was made with samples picked from the vines and used immediately. Ionizable constituents of the root, stem and leaf were determined from air-dried material.

Measurement of Catalase

Essentially the same method was employed for preparation of samples as that used by Ezell and Crist (19). A composite sample from several plants was made by means of a Ganong leaf punch. The leaves from which samples were taken were just reaching vegetative maturity and samples were taken from the same aged material each time to secure comparable results, since young tissue had been found by numerous investigators to be more active with regard to most enzymes than old tissue. One gram of leaf tissue weighed immediately after removal from the plant was used for all leaf determinations. Samples of the fruits were taken by punching out a cylinder by means of a cork borer one centimeter in diameter. Fruits of approximately the same size and degree of maturity were used and the sample weighed immediately. The sample of both leaf and fruit was mixed with an equal weight of dry calcium carbonate, then 2 cc. of distilled water added

and the mixture ground gently in a mortar until a uniform creamy mixture was obtained. Distilled water was then added so that the fresh ground tissue was suspended in 25 cc. of water. The solution was then placed in a tightly stoppered bottle and kept on ice until used.

Catalase activity was determined by Harvey's (23) modification of the Bunzel oxidase apparatus. Two cc. of the plant solution were placed in the short arm of the tube and 5 c.c. of hydrogen peroxide in the long arm of the tube. The tube was suspended in a DeKhotinsky water bath held constant at 35°C. Uniform shaking was accomplished by means of a motor-driven mechanical shaker. The oscillations were timed so as to cause the solution to flow from one end of the tube to the other at the rate of 90 times per minute. Before shaking commenced the tube containing the materials was placed in the bath and allowed to stand for ten minutes until it had reached the temperature of the bath. The tube was then shaken for three minutes and the amount of oxygen evolved measured.

Measurement of Oxidase

Portions of samples prepared for catalase determinations were used for oxidase determinations. The procedure was essentially the same as that used by Ezell and Crist (19). Two c.c. of the prepared sample were

placed in the short arm of the tube, while 5 c.c. of a fresh one percent pyrogallol solution were placed in the long arm of the tube. An alkali vile containing 1 c.c. of normal sodium hydroxide was put in place and the manometer adjusted. The reaction tube was placed in the bath 10 minutes before shaking to allow the materials to reach the temperature of the bath. The reading of the manometer at the end of one hour was taken as a measure of oxidase activity.

Checks were run on all samples for both catalase and oxidase. All results given are from samples which checked within 0.4 c.c. Samples from the same plot taken the same day checked within this range. All results given are averages from four samples.

Measurement of Ionizable Constituents

The Mattson (35) cell for electrodialysis as modified by Clark, Humfeld and Alben (14) was used for this purpose. The procedure was similar to that of Moore, Reeves and Hixon (36) with the exceptions of size of samples, time intervals and voltage which are noted in the tables. In running samples of the root system it was necessary to make a composite sample of two root systems, since 3 grams of the ground tissue were used and the root system of one plant did not furnish adequate

material. In all cases of stems and leaves 3-gram samples of individual plants were used. The air-dried material was ground in a Wiley mill and passed through a 60-mesh sieve. In the case of the fruits, samples of fresh material composed as near as possible of equal-sized fruits were made up. Tests were run on both ripe and green fruit. The green fruits were picked just as a faint trace of yellow color appeared at the blossom end. By this means it was possible to get composite samples of fruits of about the same maturity. When very green fruits were picked, it was impossible to determine the degree of maturity. Some blossoms were tagged the day they were hand pollinated, but since all blossoms pollinated on the same day did not mature their fruits anywhere near the same time, this guage of maturity was not reliable. Both ripe and green fruits were run through a food chopper until they were of a creamy consistency. It was impossible to attain this condition with very green fruits, which was another reason for using the fruit just as the first trace of color appeared at the blossom end. Fruits used for analysis when just showing a faint trace of color at the blossom end will be referred to henceforth as "green mature."

In case of the ground tissue of the plant 3 grams were placed in 300 c.c. of distilled water in the middle

compartment and 275 c.c. of water in each of the anode and cathode compartments. The parchment paper used to separate the compartments was dialyzed 1 hour in distilled water to remove ionizable constituents. The parchment paper was kept in a humid atmosphere before using it in the cell, the swelling was so great after the water was added as to cause the papers to be limp and flacid.

Electrodialysis of fruit, leaf, stem and root rendered none of the pigments soluble, so no discoloration of parchment paper occurred. Consequently, the same parchment paper was used until broken or torn rather than change to new parchment paper because if the paper was stretched tightly originally, the samples checked much closer. After the sample had been dialyzed, the compartments were filled with distilled water and paper redialyzed to remove any ions remaining from the previous sample. With the fruits 250 grams of the green fruit or 275 grams of the ripe fruit, after making up to volume of 300 c.c. with distilled water in a 500 c.c. graduate, were placed in the middle compartment, and 275 c.c. of distilled water were used in each of the cathode and anode compartments. 105 to 110 volts of direct current from storage batteries for all the root, stem and leaf samples were passed through the cell. The voltage used on the fruits varied and is given in the tables.

All data given are the results of three to five analyses on samples from each plot. These checked within narrow limits when conditions were as nearly alike as possible. In order to obtain comparable samples, the platinum electrodes must always occupy the same position in the cell and the parchment membranes must be stretched taught and not allowed to bulge. When these precautions were observed it was relatively easy to obtain checks within 2 to 4 c.c. where the total N/10 titrateable acid or base would run as high or higher than 200 c.c. The material which came out on the basic side (anolyte) was titrated with N/10 H_2SO_4 and on the acid side (catholyte) with N/10 NaOH. At the end of the designated time the anolyte and catholyte were drained and the current shut off. It required about 2 minutes to drain and refill the anode and cathode compartments and then the current was turned on again and the time was recorded from the starting and stoppage of the flow of current. This method differed from Moore, Reeves and Hixon's work (36) in that they left the current flowing while draining and refilling to prevent a return of the ions in the middle compartment. However, closer checks were obtainable where the current was shut off and the same length of time used each period for draining and refilling. Titrations on

the acid side (catholyte) were titrated with N/10 NaOH, but are given in the results as the amount of titrateable acid present in the plant tissue. Titrateable base determined with N/10 H_2SO_4 are given in terms of N/10 base present in the tissue.

EXPERIMENTAL WORK

Effect on Growth and Yield

As will be noted in table I the soil reaction had considerable effect on both yield and growth of the tomato.

Table I

Effect of Soil Reaction on Growth and Yield of Tomato Plants

Soil Reaction	Yield per plant	Average weight per plant Material air-dried			
		Roots	Stems	Leaves	Total
pH 8.5-9.0	2.52 lbs.	2.52 gms.	32.90 gms.	56.90 gms.	92.32
pH 6.5-7.0	4.06 lbs.	2.30 gms.	31.25 gms.	79.80 gms.	113.35
pH 4.0-4.5	3.04 lbs.	2.34 gms.	24.74 gms.	57.84 gms.	84.92

Two plants on one of the acid plots and three plants on the alkaline plots showed evidence of mosaic, and were discarded. One of the vines on an acid plot in the series became infected with wilt and was likewise

discarded.

The largest yield per plant was secured on plots where the soil reaction had a pH value of 6.5-7.0 and the smallest yield on the alkaline plots, pH 8.5-9.0. Maximum root growth as measured by the weight of the air-dried material occurred on the alkaline plots. There was very little difference in root growth between plants grown on the neutral or acid plots. The greatest amount of total dry matter was secured on the plots with a neutral soil reaction, while the alkaline plots produced only 81.4 percent as much total dry matter as the neutral plots, and the acid plot only 74.9 percent as much.

Effect of Catalase and Oxidase Activity

Measurement of catalase and oxidase activity were made on the leaves and fruit of both fall and spring crop. Tables II to V, inclusive, give the results of the findings with respect to oxidase and catalase activity for the fall crop.

Differences in catalase activity were most pronounced in the case of the green mature fruits. Fruits on plants from soils with a reaction of pH 6.5-7.0 consistently showed less catalase activity than those from soils with pH 8.5-9.0 and 4.0-4.5. Fully ripe fruits

TABLE II

Catalase and Oxidase Activity of Tomato Fruits of Different Stages of Maturity Grown in Soils With Different pH Values.

December 20

Soil Reaction	Oxidase c.c. of Hg displaced at end of 60 minutes	Catalase (c.c. of water displaced) Time in minutes		
		1	2	3
Green Mature Fruit				
pH 8.5-9.0	1.70	1.1	1.3	1.5
pH 6.5-7.0	1.50	0.8	0.9	0.9
pH 4.0-4.5	1.30	2.7	3.3	3.7
Ripe Fruit				
pH 8.5-9.0	1.65	0.9	1.1	1.3
pH 6.5-7.0	1.75	1.3	1.5	1.7
pH 4.0-4.5	1.35	1.4	1.7	1.9
Green Fruit				
pH 8.5-9.0	1.10	0.6	0.7	0.7
pH 6.5-7.0	1.25	0.7	0.9	1.0
pH 4.0-4.5	1.30	0.7	0.8	0.9

TABLE III

Catalase and Oxidase Activity of Tomato Fruits of Different Stages of Maturity Grown in Soils With Different pH Values.

January 5.

Soil Reaction	Oxidase c.c. of Hg displaced at end of 60 minutes	Catalase (c.c. of water displaced) Time in minutes		
		1	2	3
Green Mature Fruit				
pH 8.5-9.0	1.40	1.6	1.8	2.0
pH 6.5-7.0	1.55	1.0	1.2	1.3
pH 4.0-4.5	1.70	2.7	3.0	3.3
Ripe Fruit				
pH 8.5-9.0	2.00	2.3	2.7	2.9
pH 6.5-7.0	1.95	0.8	1.0	1.1
pH 4.0-4.5	2.10	0.9	1.1	1.2
Very Green Fruit				
pH 8.5-9.0	.95	0.5	0.7	0.8
pH 6.5-7.0	1.05	0.5	0.6	0.6
pH 4.0-4.5	1.25	0.7	0.9	1.0

TABLE IV

Catalase and Oxidase Activity of Tomato Fruits of Different Stages of Maturity Grown in Soils With Different pH Values.

January 19.

Soil Reaction	Oxidase c.c. of Hg displaced at end of 60 minutes	Catalase (c.c. of water displaced) Time in minutes		
		1	2	3
Green Mature Fruit				
pH 8.5-9.0	1.80	2.2	2.4	2.6
pH 6.5-7.0	1.75	1.0	1.2	1.3
pH 4.0-4.5	1.90	2.4	2.7	2.9
Ripe Fruit				
pH 8.5-9.0	2.10	0.9	1.0	1.1
pH 6.5-7.0	2.18	0.9	1.0	1.1
pH 4.0-4.5	1.90	1.0	1.3	1.4
Green Fruit				
pH 8.5-9.0	1.00	0.7	0.9	1.0
pH 6.5-7.0	.90	0.7	0.8	0.9
pH 4.0-4.5	.90	0.6	0.7	0.7

TABLE V

Catalase and Oxidase Activity of Tomato Fruits of Different Stages of Maturity Grown in Soils With Different pH Values.

February 1.

Soil Reaction	Oxidase c.c. of Hg displaced at end of 60 minutes	Catalase (c.c. of water displaced) Time in minutes		
		1	2	3
Green Mature Fruit				
pH 8.5-9.0	1.90	2.0	2.2	2.4
pH 6.5-7.0	1.90	1.2	1.3	1.3
pH 4.0-4.5	1.80	2.4	2.7	2.9
Ripe Fruit				
pH 8.5-9.0	1.75	1.0	1.3	1.5
pH 6.5-7.0	1.90	1.3	1.5	1.6
pH 4.0-4.5	2.00	1.4	1.7	1.9
Green Fruit				
pH 8.5-9.0	1.10	0.6	0.7	0.7
pH 6.5-7.0	1.15	0.7	0.8	0.9
pH 4.0-4.5	1.25	0.7	0.9	1.0

also showed less activity from the neutral plots than from the acid or alkaline plots, but the differences were not so marked as in the green mature fruit. No consistent differences in catalase activity were noted in the very green fruits, but catalase activity was at the minimum at this stage of maturity; so if there were any differences, they were not significant.

Oxidase activity was greater in ripe than in the very green or green mature stages, but this was independent of the soil reaction or growth and yield. The oxidase activity of ripe fruits from acid, alkaline or neutral plots was practically the same.

Since the least catalase activity occurred in fruits taken from plots of pH 6.5-7.0, it was thought that this difference in activity might be due to differences in pH value of the fruit in various stages of ripening. The juice of the fruits was squeezed out through several layers of cheese cloth and the pH value of the juice determined by the quinhydrone method. The following table shows the results.

Table VI

The pH Value of the Tomato Fruit in Different Stages of Ripening.

Soil Reaction	Condition of fruit	pH January 13	pH January 20
pH 8.5-9.0	Ripe	4.25	4.11
	Mature Green	4.03	3.91
	Green	4.11	3.98
pH 6.5-7.0	Ripe	4.25	4.11
	Mature Green	3.75	3.94
	Green	3.96	4.08
pH 4.0-4.5	Ripe	4.29	4.13
	Mature Green	4.04	3.95
	Green	4.06	4.03

In general, the changes in pH value were not great, but this might be expected in a well-buffered solution such as that of the fruit juice. In ripe, mature green and very green samples taken from the same plot the pH value was slightly lower in the green mature stage than in the very green or ripe stages. However, the differences were not great enough to account for the increase or decrease in catalase activity at any particular stage of development of the fruit or from any particular soil reaction.

Catalase and oxidase activity in the leaves were measured first on December 20 when the fruits were beginning to ripen; again on January 12 when about one-half of the crop had been picked and again on February 1

when practically all of the crop had matured.

The oxidase activity of the leaves was not influenced by the soil reaction or resulting growth. Catalase activity of the leaves showed the same relationship with reference to soil reaction and resulting growth as the green mature fruits, i.e., the least catalase activity occurred in the plants from plots with a soil reaction of pH 6.5-7.0. Measurements made on December 20 showed less catalase activity on all plots than those made on January 12 and February 1.

Since the soil reaction and resulting growth apparently had no effect on the oxidase activity of fruits or leaves for the fall crop no measurements were made on the spring crop. Catalase activity in the leaves was measured at two-week intervals, on March 30, April 12 and April 26. Determinations were made on the fruits only on one date, namely April 27. When leaf samples of March 30 and April 12 were taken only small green fruits were present in the first three clusters. Results are given in table VIII.

Results on catalase activity in the spring crop agree with those secured on the fall crop. Catalase activity of the leaves was less on the neutral plots (pH 6.5-7.0) and greater on the acid (pH 4.0-4.5) and alkaline (pH 8.5-9.0) plots. Both ripe, very green and

TABLE VII

Catalase and Oxidase Activity of Tomato Leaves Grown in Soils With Different pH Values

Soil Reaction	Oxidase c.c. of Hg displaced at end of 60 minutes	Catalase (c.c. of water displaced) Time in minutes		
		1	2	3
December 20				
pH 8.5-9.0	1.55	4.0	5.2	5.7
pH 6.5-7.0	1.55	3.3	4.3	4.8
pH 4.0-4.5	1.40	3.3	5.3	5.9
January 12				
pH 8.5-9.0	1.30	5.1	6.5	7.4
pH 6.5-7.0	1.40	2.8	3.8	4.4
pH 4.0-4.5	1.25	8.8	8.6	9.7
February 1				
pH 8.5-9.0	1.50	4.5	6.8	7.6
pH 6.5-7.0	1.40	3.3	5.1	5.6
pH 4.0-4.5	1.45	4.5	6.9	7.8

TABLE VIII

Catalase Activity of Leaves and Fruit of the Spring Crop of Tomatoes.

Date	Sample	Soil Reaction	Catalase (c.c. of water displaced) Time in minutes		
			1	2	3
March 30	Leaves	pH 8.5-9.0	3.8	5.1	5.6
		pH 6.5-7.0	3.0	4.1	4.9
		pH 4.0-4.5	3.9	5.2	5.8
April 12	Leaves	pH 8.5-9.0	4.6	5.4	6.1
		pH 6.5-7.0	2.9	3.6	3.8
		pH 4.0-4.5	3.1	4.5	5.7
April 26	Leaves	pH 8.5-9.0	4.2	5.1	5.9
		pH 6.5-7.0	2.0	2.5	2.9
		pH 4.0-4.5	4.1	5.2	5.6
April 27	Green Mature Fruit	pH 8.5-9.0	1.1	1.7	2.1
		pH 6.5-7.0	0.8	0.9	1.0
		pH 4.0-4.5	2.8	3.5	3.8
April 27	Ripe Fruit	pH 8.5-9.0	1.2	1.5	1.8
		pH 6.5-7.0	0.9	1.1	1.3
		pH 4.0-4.5	1.4	1.7	1.9
April 27	Green Fruit	pH 8.5-9.0	0.7	0.8	0.9
		pH 6.5-7.0	0.6	0.7	0.7
		pH 4.0-4.5	0.7	0.9	1.0

green mature fruits showed the same relation to soil reaction and growth as the leaves, though the difference in the case of the very green fruit may be within the limits of experimental error. As with the fall crop catalase activity was greater in the leaves than in the fruit.

Effect of Soil Reaction on Ionizable Material

Table IX includes some physical and chemical measurements of ionizable material in the ripe fruits. The voltage given is the initial voltage recorded at the beginning of the period of dialysis. A small drop in voltage occurred where the amperage ran above 1.0, but at no time was the drop more than five volts by the end of the period. The dialysate was drawn off frequently enough to prevent the temperature from going above 30°C. Titrateable acid and base are given in c.c. and are figured on a basis of N/10.

Differences in acid and basic constituents due to soil reaction were very small in the ripe fruit. Within 5 hours and 20 minutes all of the basic constituents were removed fruits taken from plants grown on the alkaline plots and within 4 hours from the neutral and acid plots. There was 4.48 percent more N/10 base present

TABLE IX

Results of Electrodialysis of Ripe Tomato Fruit from Soils of Different pH Values.

	Soil pH 8.5-9.0				Soil pH 6.5-7.0			Soil pH 4.0-4.5		
Time Min.	Volts	Amperes	Base c.c.	Acid c.c.	Amperes	Base c.c.	Acid c.c.	Amperes	Base c.c.	Acid c.c.
10	82	1.30	19.2	10.2	1.50	25.4	12.8	1.40	23.4	10.5
10	82	1.30	20.2	10.2	1.10	20.4	11.7	1.30	22.4	10.6
20	82	3.40	86.6	29.9	3.05	82.4	28.6	3.50	81.4	30.1
20	82	1.15	37.9	17.3	1.05	39.0	17.7	1.10	39.0	18.1
20	108	0.85	21.4	15.8	0.80	15.0	14.6	0.90	15.0	16.5
40	108	1.10	14.2	21.2	0.80	10.8	18.2	0.80	10.8	21.9
40	108	1.00	10.3	18.3	0.40	8.7	15.6	0.20	1.7	18.9
80	108	0.55	3.7	26.1	0.65	3.7	27.0	0.30	1.7	28.1
80	108	0.25	1.1	17.9	0.25	0.0	20.7	0.10	0.0	15.6
80	108	0.15	0.0	14.3	0.10	0.0	17.5	0.10	0.0	18.8
400			214.6	181.2		205.4	184.4		195.4	189.1

in the samples from the plots with alkaline reaction than in those from the neutral plots. Conversely, there was 4.87 percent less N/10 base in the fruits from the acid plots than in fruits from the neutral plot. Fruits from plants grown on the acid soil contained very little more acid than fruits grown on the highly alkaline soil.

On the other hand, the acid constituents were removed much more slowly than the basic ones. Again differences due to soil reaction were noted, but they were very small and probably not significant, since all of the acid constituents were not removed in the time allowed for electrodialysis. The fruit from plants on the alkaline plots contained 1.73 percent less acid than fruits from the plants on the neutral plots, but fruit from the acid plots contained 2.54 percent more acid than fruits from the neutral plots.

The acid constituents were removed at a more uniform rate than the basic constituents as shown in figures 1 and 2. Electrometric titrations were run on the anolyte and catholyte and are given in the appendix.

Positive correlation between the soil reaction and ionizable acids and bases of the green mature fruit is shown in table X.

Differences in the ionizable acids and bases in the green mature fruit, depending on the soil

Figure 1

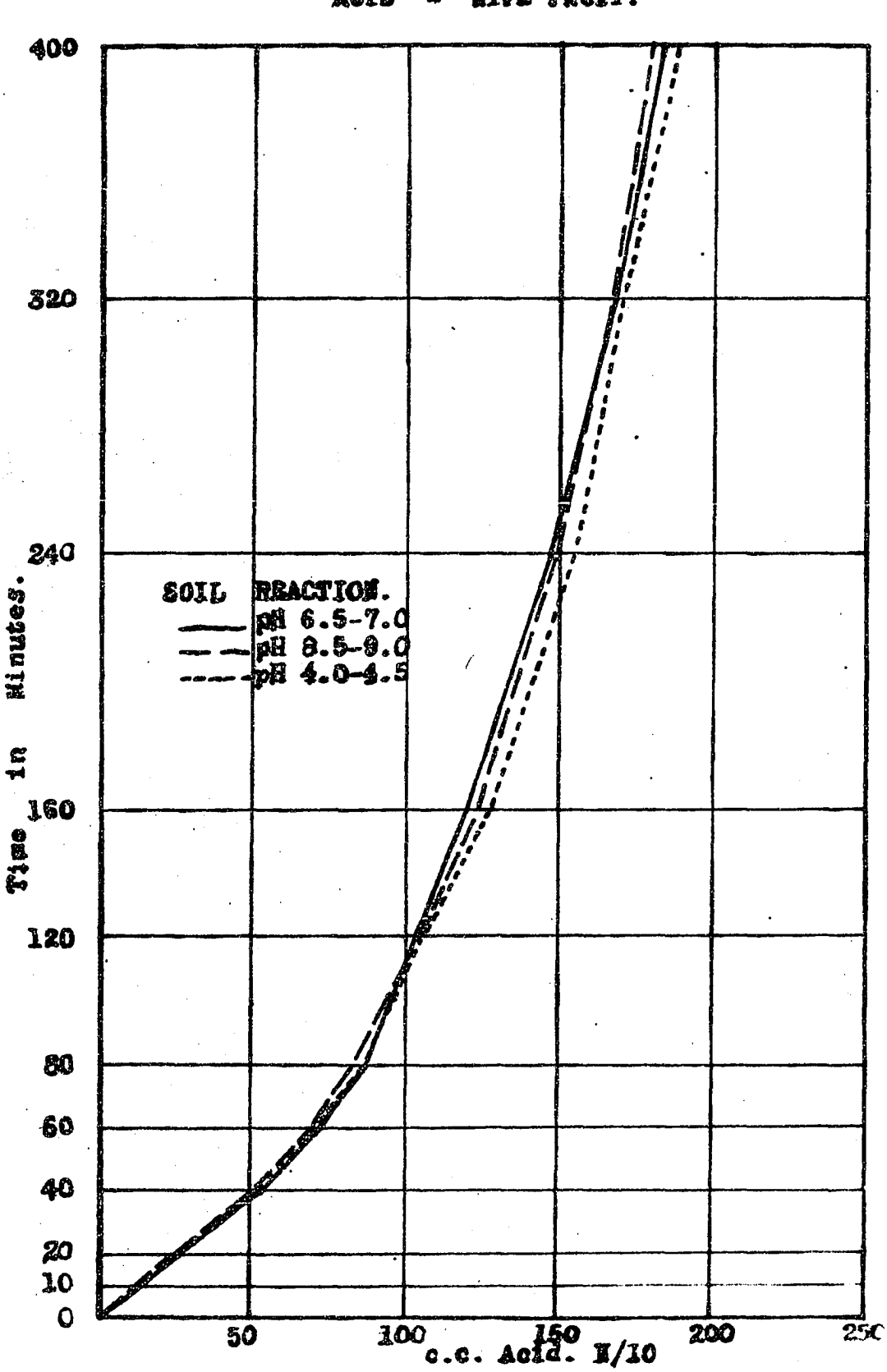

ACID - RIPE FRUIT.
400
320
240
160
120
80
60
40
20
10
0
Time in Minutes.
SOIL REACTION.
pH 6.5-7.0
pH 8.5-9.0
pH 4.0-4.5
50
100
150
200
250
c.c. Acid. N/10

Figure 2

BASE - RIPE FRUIT.

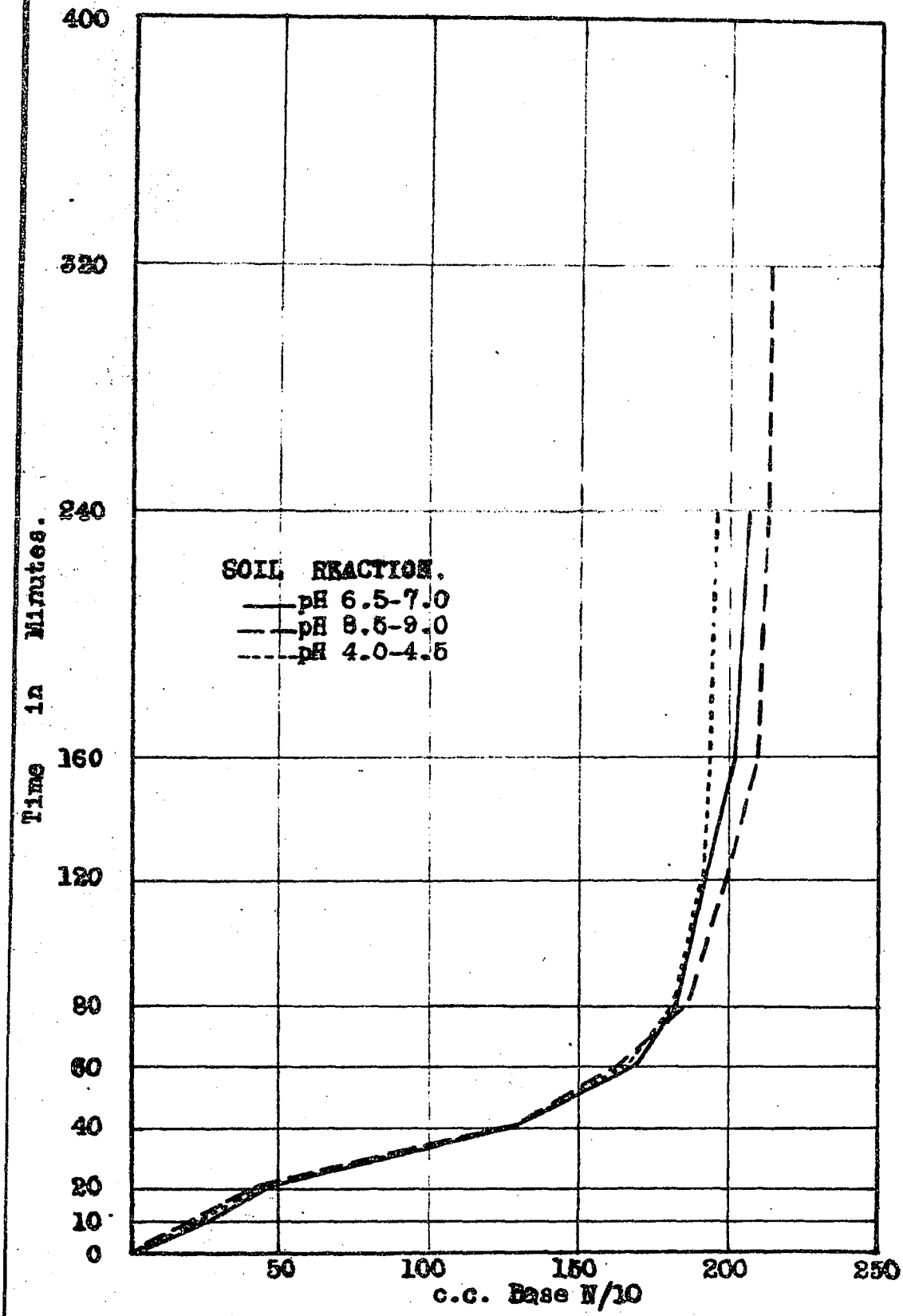


TABLE X

Results of Electrodialysis of Green Mature Tomato Fruit from Soils of Different pH Values.

	Soil pH 8.5-9.0				Soil pH 6.5-7.0				Soil pH 4.0-4.5			
Time Min.	Volts	Amperes	Base c.c.	Acid c.c.	Amperes	Base c.c.	Acid c.c.	Amperes	Base c.c.	Acid c.c.
10	82	1.90	27.0	12.3	1.15	21.1	9.2	1.60	20.0	14.4
10	82	1.70	25.0	10.9	0.80	14.6	8.2	1.00	13.8	13.8
20	82	3.50	76.3	28.6	3.20	72.2	23.1	3.30	71.3	30.1
20	82	1.20	40.8	16.5	1.50	45.2	17.4	1.10	38.9	17.2
20	108	1.10	28.1	14.4	1.10	22.8	14.2	1.00	25.1	14.8
40	108	1.00	18.6	24.1	1.00	22.8	21.2	1.00	22.9	22.5
40	108	0.50	4.6	14.3	0.35	5.3	14.2	0.40	5.3	16.9
80	108	0.70	4.5	25.2	0.75	9.6	28.0	0.70	4.3	27.6
80	108	0.20	0.6	17.9	0.40	3.7	26.6	0.50	4.9	25.8
80	108	0.10	0.0	13.9	0.40	2.9	25.4	0.30	2.8	20.1
400			225.5	178.1		220.2	187.5		209.3	203.2

reaction, were similar to those found for the ripe fruit. Basic constituents were 2.4 percent greater in fruits from plants of the alkaline plots and 4.95 percent less in the fruits from plants of the acid plots as compared with those from the neutral plots. There was 5.01 percent less acid in fruits from the alkaline plot and 8.37 percent more acid in the fruits from the acid plots as compared to the neutral plots. The percentage differences were greater for acids in the green mature fruit from the acid and alkaline plots compared to the neutral plots than in the case of the ripe fruit.

Bases were removed from the tissue at a much faster rate than the acids, and although the rate of removal of the acids was much slower it was at a more uniform rate as shown in figures 3 and 4. The electrometric titrations of anolyte and catholyte are given in the appendix. Since the acid constituents were removed much more slowly than basic ones, electrodialysis of the green mature fruits was carried on for approximately 27 hours to determine if the relative differences of acid or basic comstituents, depending on the soil reaction, were changed by electrodialysis over a longer period. As shown in table XI, the relative differences between basic and acid constituents were practically the same as

Figure 3

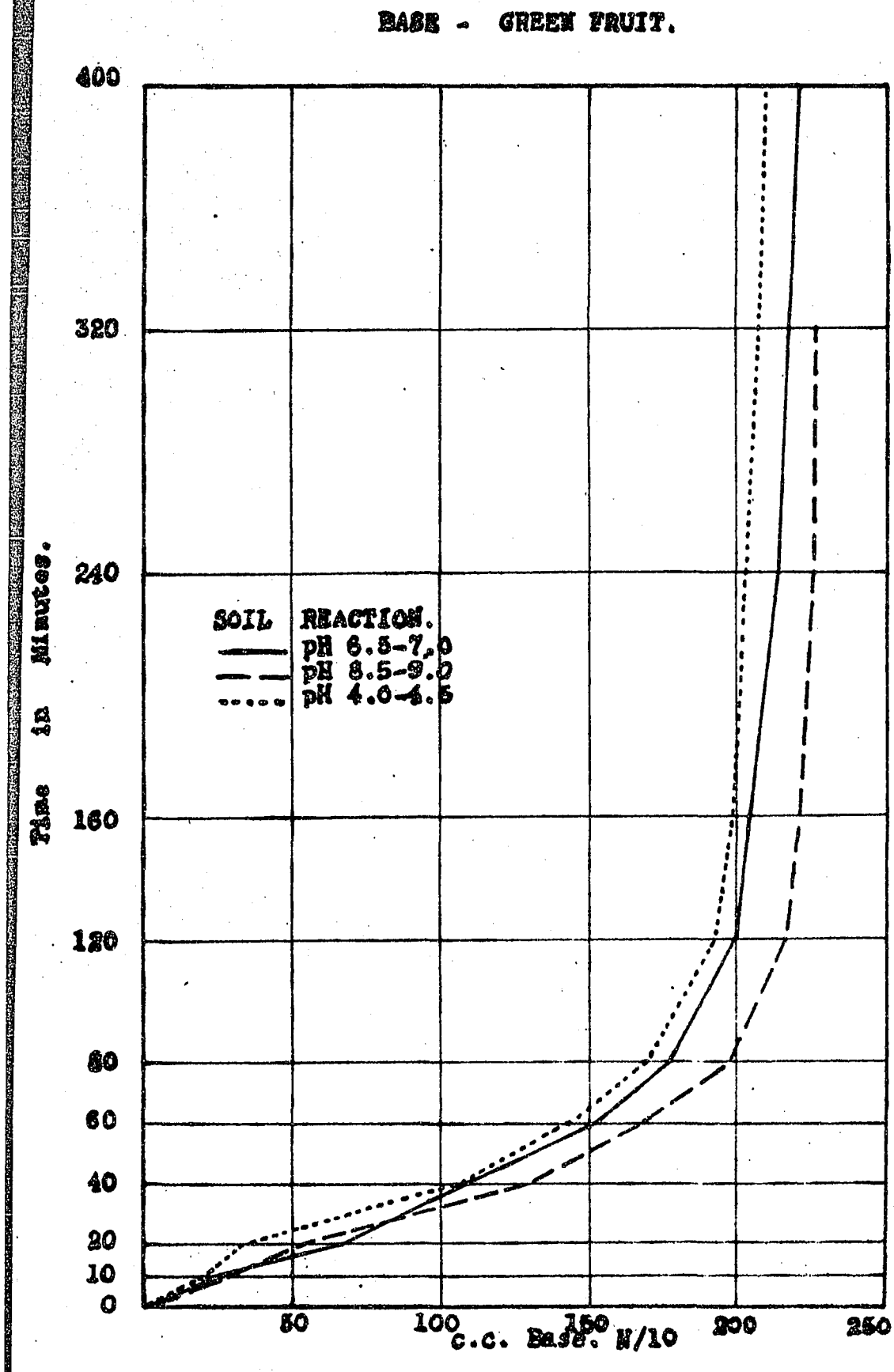

BASE - GREEN FRUIT.
400
320
240
160
120
80
60
40
20
10
0
Time in Minutes.
SOIL REACTION.
pH 6.5-7.0
pH 8.5-9.0
pH 4.0-4.5
50
100
150
200
250
c.c. Base. N/10

Figure 4

ACID - CRUDA FRUIT.

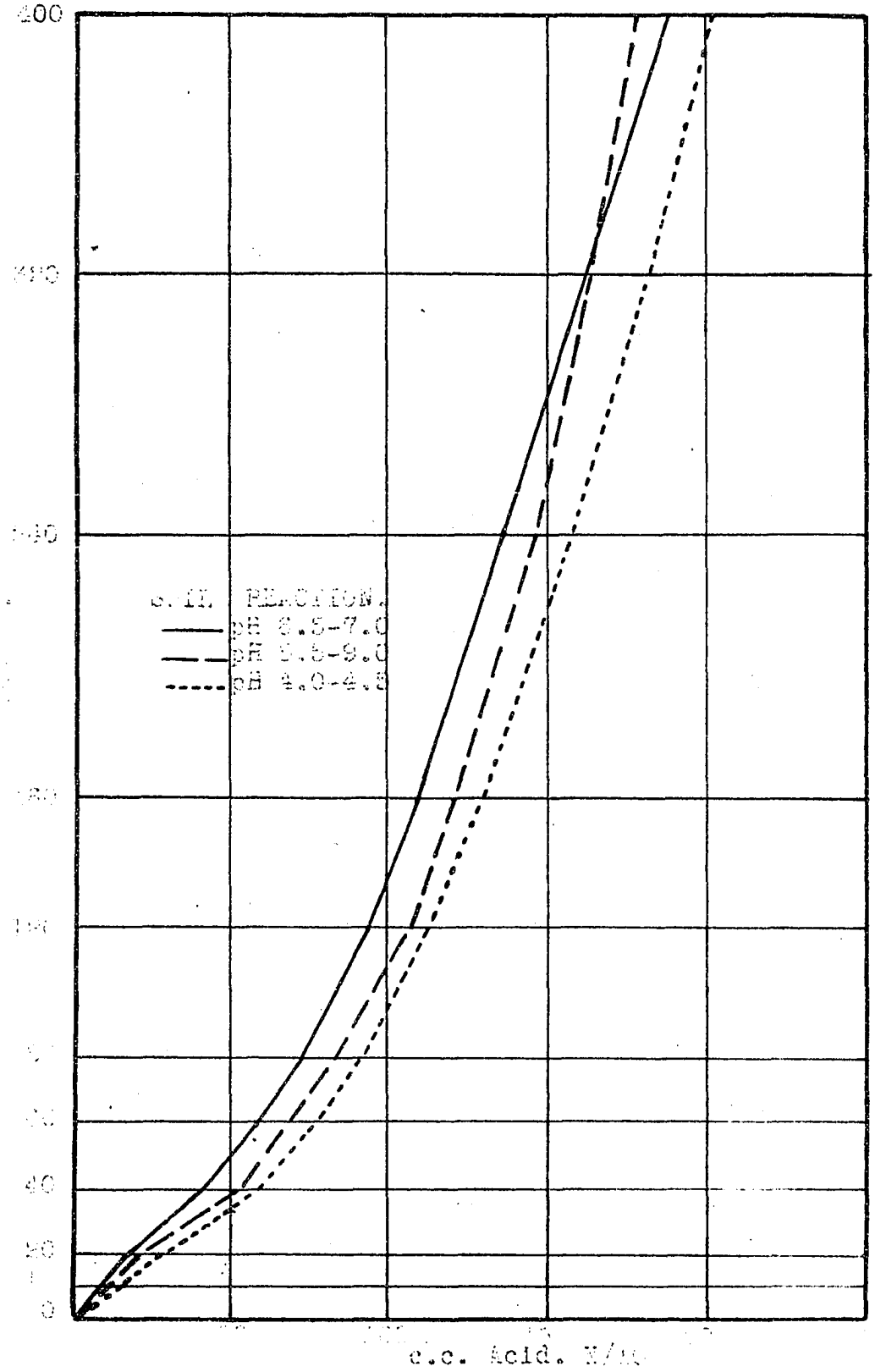


TABLE XI

Results of Electrodialysis of Green Mature Tomato Fruit for Twenty-seven Hours.

Time	Volts	Soil pH 6.5-7.0 Amperes	Base c.c.	Acid c.c.	Soil pH 4.0-4.5 Amperes	Base c.c.	Acid c.c.
10 min.	82	1.90	28.0	12.9	1.50	20.1	15.6
10 "	82	1.80	28.8	11.6	1.10	14.2	14.7
20 "	82	3.00	78.9	24.4	3.20	72.0	26.5
20 "	82	1.00	33.3	14.8	1.50	43.0	18.8
20 "	108	0.50	18.6	14.8	1.00	22.8	18.7
40 "	108	1.05	22.0	18.7	1.10	22.8	20.7
40 "	108	0.40	3.7	12.3	0.60	7.3	12.3
80 "	108	0.40	2.8	30.4	0.80	8.8	28.1
80 "	108	0.35	2.2	20.7	0.20	0.0	19.2
80 "	108	0.20	0.0	22.9	0.20	0.0	22.6
150 "	108	0.10	0.0	21.7	0.25	0.0	29.4
13 hrs.	108	0.10	0.0	66.4	0.30	0.0	56.6
3 "	108	0.05	0.0	8.8	0.10	0.0	13.0
2 "	108	0.05	0.0	5.7	0.10	0.0	10.9
1630 min.			218.3	286.1		211.0	307.1

those given in table X for the green mature fruit from the neutral and acid plots when electrodialysis was carried on for the short period.

The bases were removed in 5 hours and 20 minutes from the neutral plots and in 4 hours from the acid plots. This corresponds to the length of time required for the removal of bases, as given in table X, in which case electrodialysis was carried on for 6 hours and 40 minutes. Although the acids were not completely removed at the end of the long period, there was a difference of 7.34 percent between the fruits from the neutral and alkaline plots as compared with a difference of 8.37 percent for the short period. The rates of removal of acids and bases are shown graphically in figures 5 and 6.

A comparison of the ionizable constituents of the leaves from the three series of soil reactions given in table XII shows a tendency similar to that of the fruit. The leaves from the plants from the plots with an acid reaction contained more acid and less base than leaves from plants from the neutral plots, while leaves from plants grown on soil with an alkaline reaction contained less acid and more base than leaves from plants grown in neutral soil. The rate of removal of acid and base is shown in figures 7 and 8.

Figure 5

BASE - GREEN FRUIT.
1620 MINUTES.

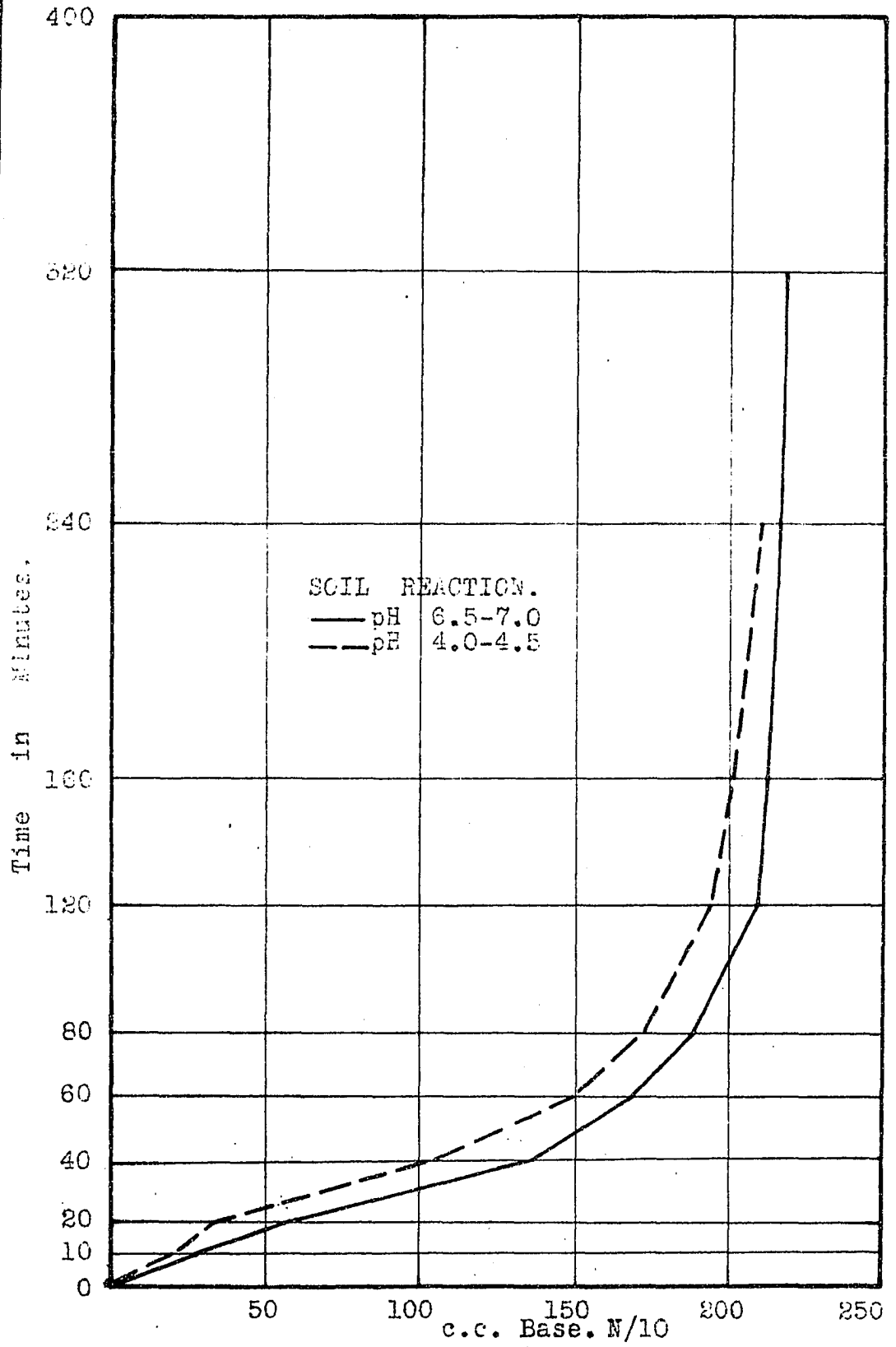


Figure 6

ACID - GREEN FRUIT.
1630 MINUTES.

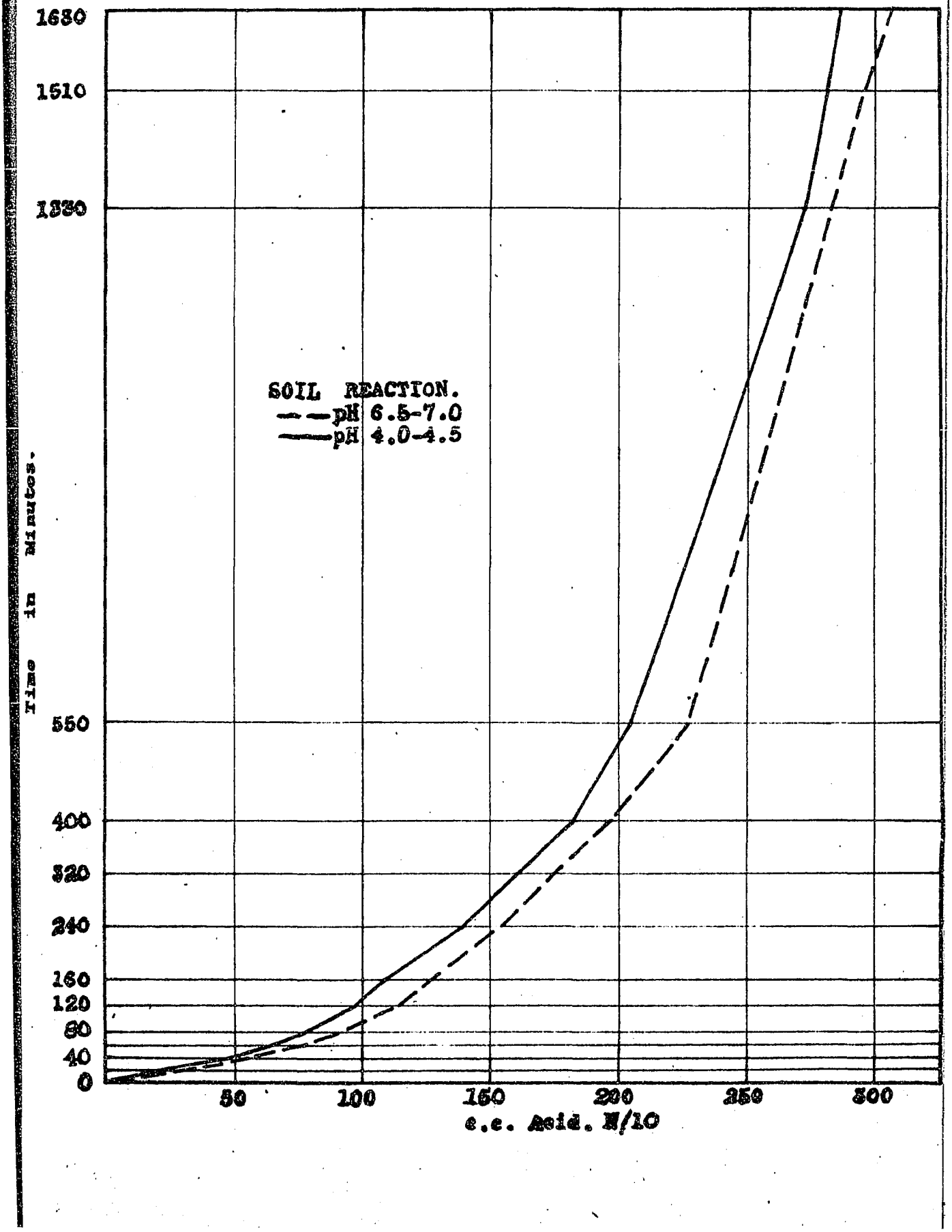


TABLE XI

Results of Electrodialysis o
from Soils of Different pH V

			Soil pH 8.5-9.0					
Time Min.	Volts	Amperes	Base c.c.	pH	Acid c.c.	pH	Amperes	Base c.c.
10	108	2.30	32.7	11.14	7.0	2.70	0.85	21.
10	108	2.40	33.9	11.11	8.6	2.67	1.20	24.
15	108	2.60	53.6	11.59	15.8	2.52	2.20	45.
30	108	1.10	24.0	10.72	20.5	2.34	1.95	29.
30	108	0.70	19.1	10.59	10.0	2.73	0.60	19.
60	108	0.80	11.5	9.92	16.8	2.33	0.65	19.
120	108	0.30	7.1	9.61	15.5	2.43	0.40	10.
120	108	0.20	10.7	9.88	9.8	2.74	0.20	10.
395			192.6		104.0			181.

TABLE XII

trodialysis of Tomato Leaves
lfferent pH Values.

Soil pH 6.5-7.0					:	Soil pH 4.0-4.5				
Amperes	Base c.c.	pH	Acid c.c.	pH	:	Amperes	Base c.c.	pH	Acid c.c.	pH
0.85	21.5	11.07	6.8	2.68	:	1.40	28.7	11.07	8.3	2.94
1.20	24.1	11.04	7.2	2.73	:	2.15	26.0	10.97	10.9	2.57
2.20	45.7	11.53	13.6	2.40	:	3.90	47.7	11.46	27.3	2.38
1.95	29.9	11.10	28.5	2.33	:	1.40	27.0	11.10	19.2	2.44
0.60	19.9	10.65	10.9	2.79	:	0.65	17.0	10.65	19.5	2.48
0.65	19.3	10.58	14.9	2.73	:	0.30	11.1	9.80	17.1	2.57
0.40	10.8	9.28	17.4	2.48	:	0.20	9.6	9.19	10.2	2.94
0.20	10.7	9.19	10.6	2.65	:	0.10	8.5	8.74	8.7	3.07
	181.9		109.9		:		175.6		121.1	

Figure 7

BASE - LEAVES.

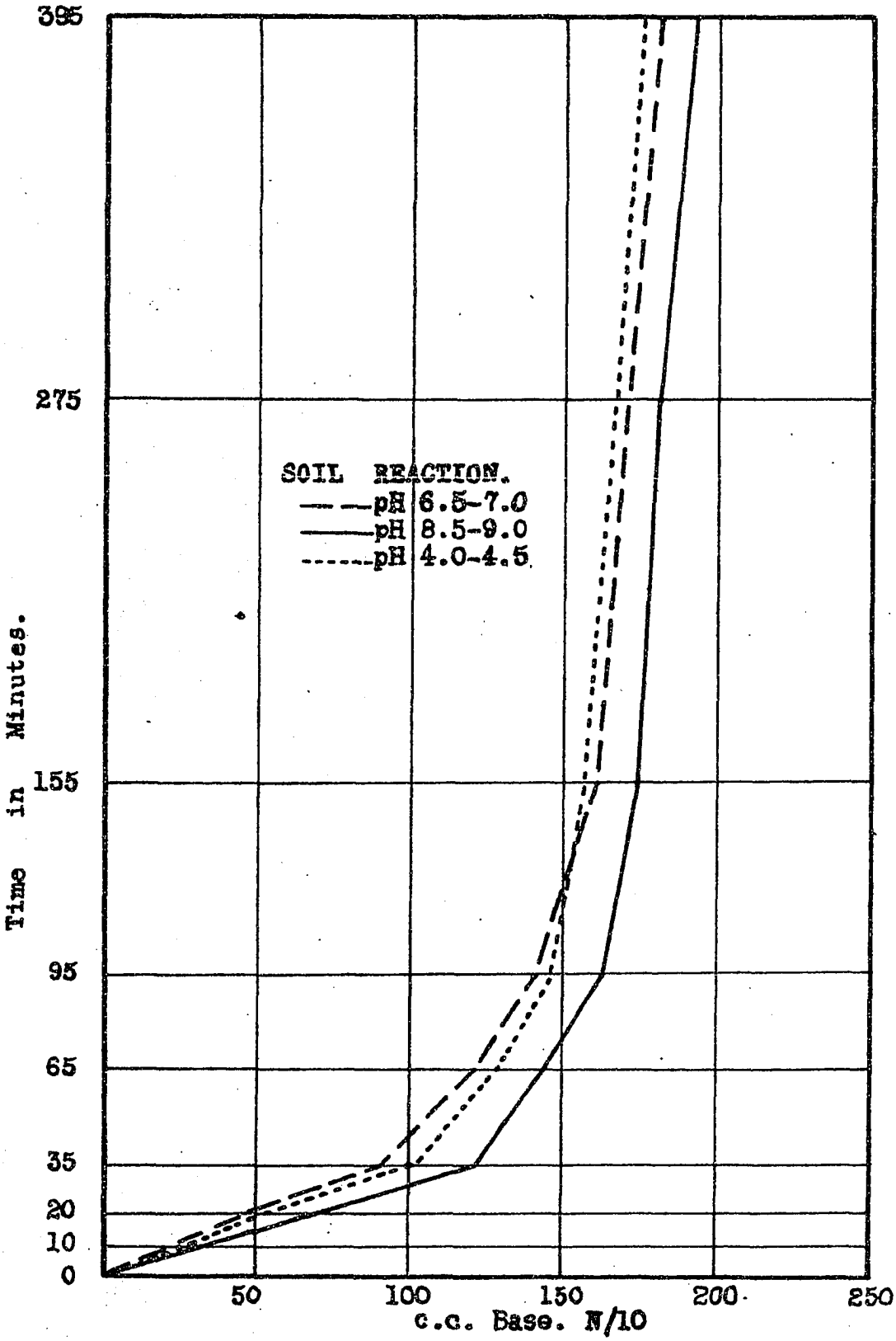
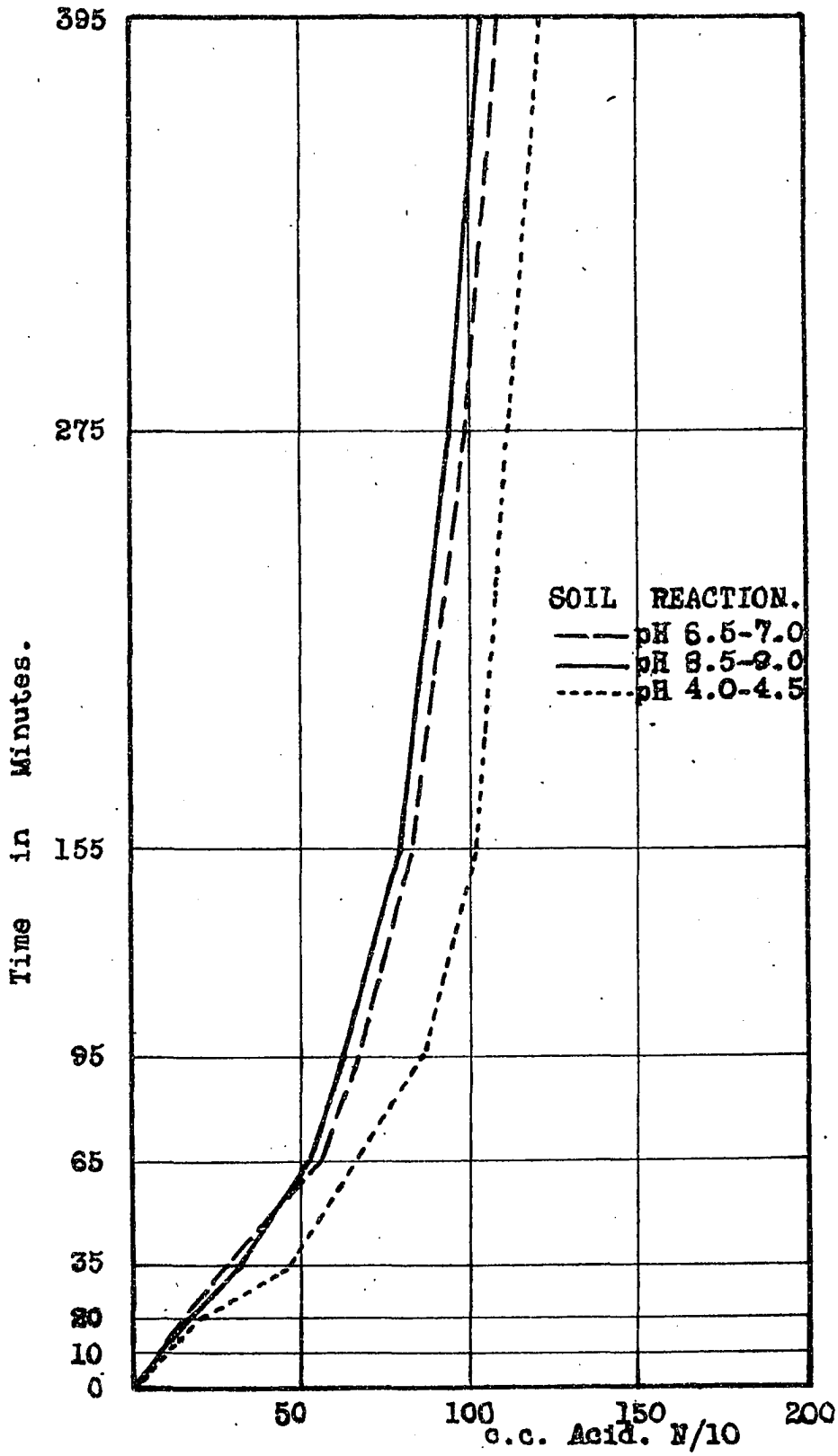


Figure 8

ACID - LEAVES.



The pH values of anolyte and catholyte were made by means of the Bailey (5) hydrogen electrode. The E. M. F. readings were converted to pH values from the tables given by Schmidt and Hoagland (43). Differences in titrateable acid of the catholyte between some of the runs from the same tissue were very great, but the relative change in pH was very slight. The range in pH from the catholyte from all the plots was from 2.33 to 3.07. Changes in pH from the anolyte were greater, showing a range from 11.59 to 8.74. Differences in pH corresponded to the differences in titrateable base but the relative differences in the case of the pH values were not as great.

Data presented in table XIII indicate that the ionizable constituents of the stems were influenced by the soil reaction. Percentage differences in titrateable N/10 acid and base, depending on the soil reaction in which the plants were grown, were greater than with leaves and fruit. Differences in pH values of the catholyte were small compared to the amount of titrateable acid. Changes in pH of the anolyte showed a greater positive correlation with changes in titrateable base. The rate of removal of the ions from the stem tissue is shown in figures 9 and 10.

TABLE XIII

Results of Electrodialysis o
From Soils of Different pH V

		Soil pH 8.5-9.0					Soil pH 6.5-		
Time Min.	Volts	Amperes	Base c.c.	pH	Acid c.c.	pH	Amperes	Base c.c.	
10	108	4.70	49.4	11.75	16.2	2.31	3.90	40.5	1
10	108	2.85	26.4	11.32	11.0	2.46	2.10	21.8	1
15	108	2.45	21.6	11.35	12.5	2.31	1.80	12.6	1
30	108	1.50	10.0	10.71	16.1	2.24	1.90	10.6	1
30	108	0.70	5.9	9.73	6.2	2.77	0.60	3.6	
60	108	0.50	5.1	9.16	7.9	2.69	0.50	3.5	
120	108	0.40	6.2	10.02	9.1	2.63	0.50	5.3	
120	108	0.15	2.3	6.93	3.5	3.16	0.25	5.8	
395			126.9		82.5			103.7	

TABLE XIII

lectrodialysis of Tomato Stems
f Different pH Values.

Soil pH 6.5-7.0					Soil pH 4.0-4.5				
mperes	Base c.c.	pH	Acid c.c.	pH	Amperes	Base c.c.	pH	Acid c.c.	pH
3.90	40.5	11.56	13.2	2.48	3.70	36.4	11.53	12.8	2.36
2.10	21.8	11.10	8.9	2.58	3.00	20.0	11.32	12.8	2.36
1.80	12.6	10.78	8.9	2.60	2.50	10.5	11.09	12.2	2.38
1.90	10.6	10.53	14.8	2.34	3.45	10.3	11.05	28.1	1.88
0.60	3.6	5.12	16.4	2.31	0.85	3.7	9.70	10.7	2.60
0.50	3.5	4.85	8.0	2.57	0.65	3.2	9.33	13.6	2.43
0.50	5.3	9.33	13.7	2.48	0.55	3.9	9.61	15.9	2.40
0.25	5.8	9.35	8.4	2.75	0.20	3.4	9.58	5.9	2.96
	103.7		92.5			91.5		112.0	

Figure 9

BASE - STEMS.

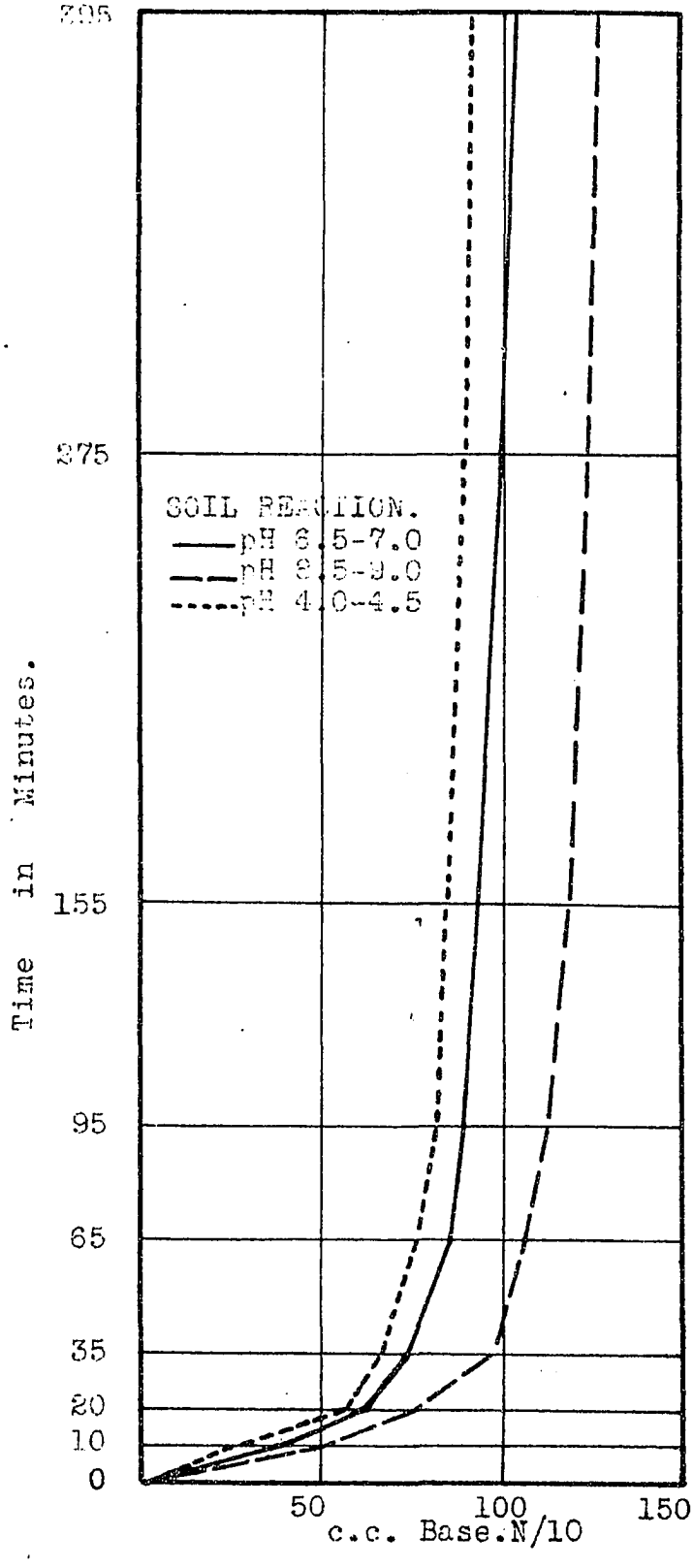
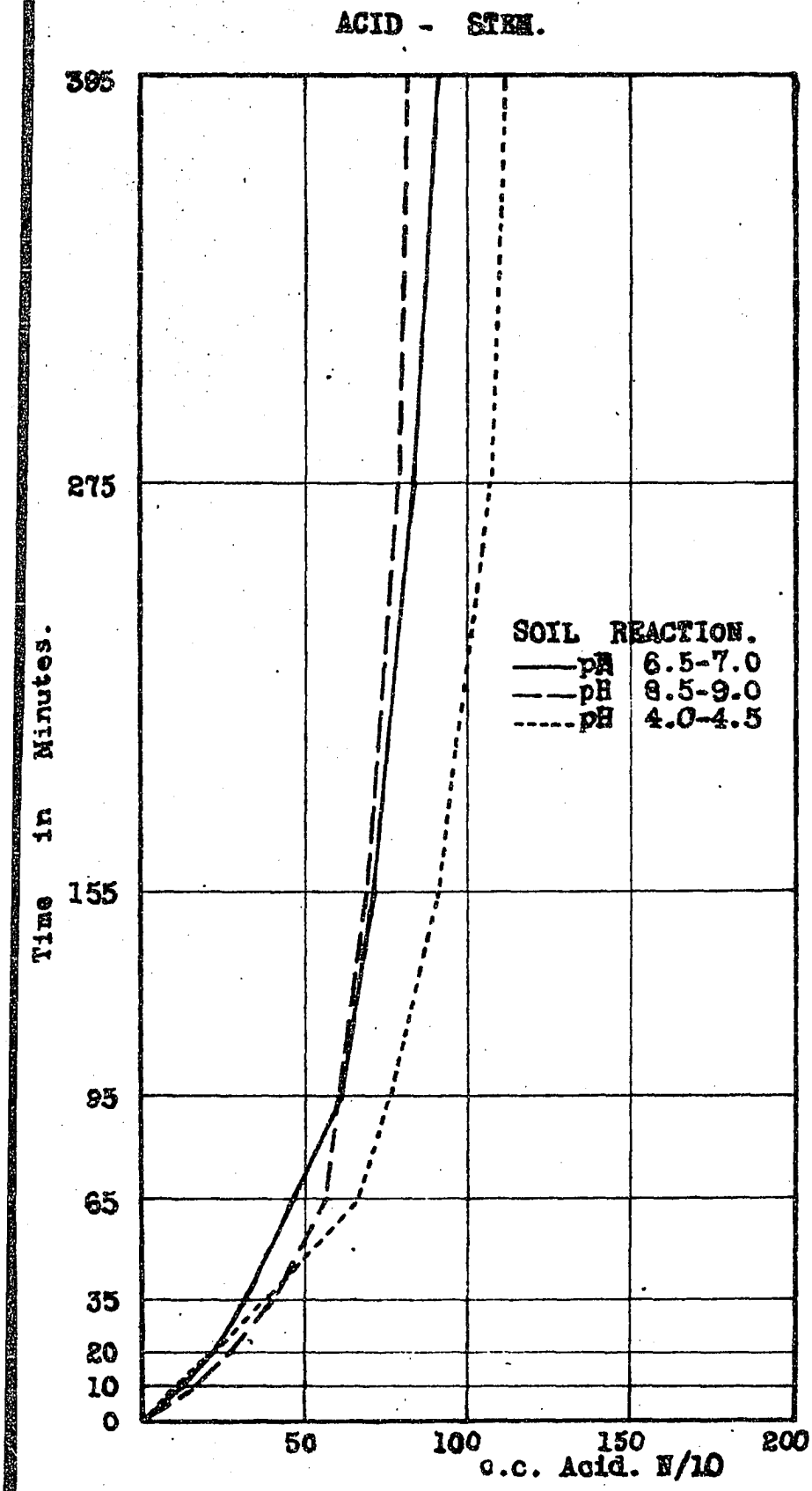


Figure 10


ACID - STEM.
395
275
155
95
65
35
20
10
0
Time in Minutes.
SOIL REACTION.
——pH 6.5-7.0
— —pH 8.5-9.0
-----pH 4.0-4.5
50
100
150
200
c.c. Acid. N/10

The greatest differences between amounts of ionizable acid and base, depending on the soil reaction, were found in the root tissue as shown in table IV. Root tissue from the alkaline plots contained 78.06 percent more N/10 base than like tissue from the neutral plots. However, the tissue from the acid plots contained only 15.19 percent less base. The root tissue contained 60.14 percent more N/10 acid when the plants were grown in an acid soil than when they were grown in a neutral soil. Changes in pH of the catholyte were small, however, differences in the titrateable acid were great. Changes in pH of the anolyte corresponded to changes in titrateable base to a greater degree than with any of the other tissues dialyzed. Figures 11 and 12 indicate the rate at which the N/10 acid and base were removed.

Table XV is a brief summary of the more important findings presented in tables IX to XIV inclusive. Differences in total titrateable N/10 acid and base only are included. Differences in c.c. and percentages of the amount of acid and base contained in the respective tissues are presented. Findings with respect to the amount of ionizable constituents in tissues from plants grown in the neutral plots were taken as a basis of comparison.

TABLE IV

Results of Electrodialysis o
From Soils of Different pH V

	Soil pH 8.5-9.0						Soil pH 6.		
Time Min.	Volts	Amperes	Base c.c.	pH	Acid c.c.	pH	Amperes	Base c.c.	
10	108	1.30	20.8	11.36	5.5	2.90	1.30	21.0	1
10	108	1.10	14.9	11.05	4.9	2.84	0.70	10.2	
15	108	1.35	15.7	11.22	6.0	2.84	0.70	10.8	
30	108	1.20	13.3	10.85	10.0	2.38	1.00	8.1	
30	108	0.40	30.1	11.44	4.0	2.92	0.20	4.3	
60	108	0.25	3.5	5.12	5.7	3.09	0.25	2.0	
120	108	0.30	2.8	4.81	4.1	3.13	0.20	1.1	
120	108	0.15	2.0	5.00	4.5	3.26	0.05	0.4	
395			103.1		44.7			57.9	

TABLE IV

ctrodialysis of Tomato Roots
Different pH Values.

Soil pH 6.5-7.0					Soil pH 4.0-4.5				
eres	Base c.c.	pH	Acid c.c.	pH	Amperes	Base c.c.	pH	Acid c.c.	pH
.30	21.0	10.51	7.0	2.94	1.40	10.0	10.54	6.0	2.84
.70	10.2	8.84	5.8	3.09	0.55	2.7	4.90	6.0	2.89
.70	10.8	8.90	6.5	3.04	1.00	5.5	9.58	7.0	2.84
.00	8.1	7.50	11.0	2.57	3.30	18.7	11.15	25.6	2.08
.20	4.3	4.98	10.6	2.69	0.50	2.4	8.47	6.1	2.75
.25	2.0	4.90	6.0	3.02	1.00	4.3	9.33	13.1	2.40
.20	1.1	4.80	6.2	2.94	0.50	3.1	8.25	16.3	2.31
.05	0.4	4.71	1.6	3.28	0.25	2.4	7.96	7.5	2.73
	57.9		54.7			49.1		87.6	

Figure 11

BASE - ROOTS.

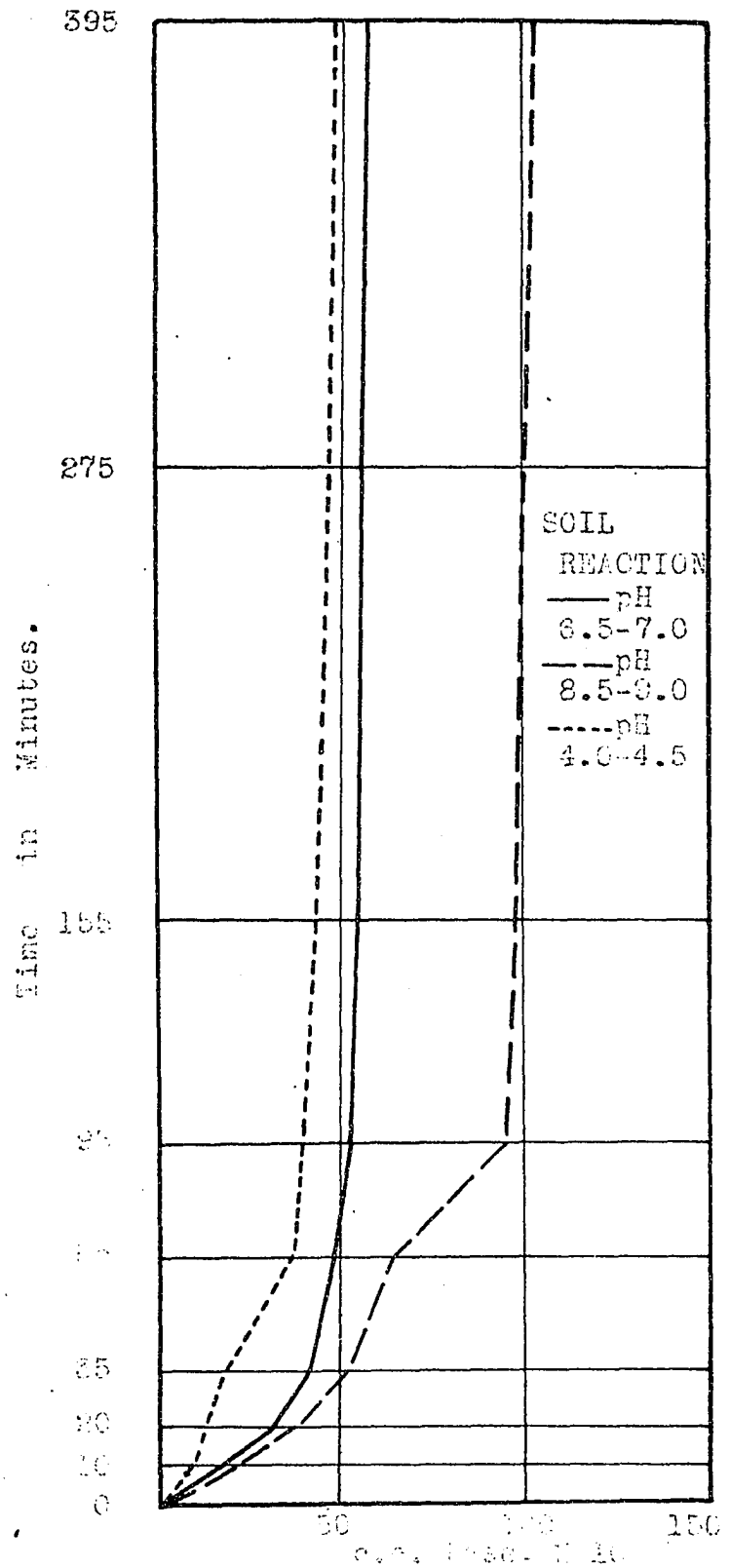


Figure 12

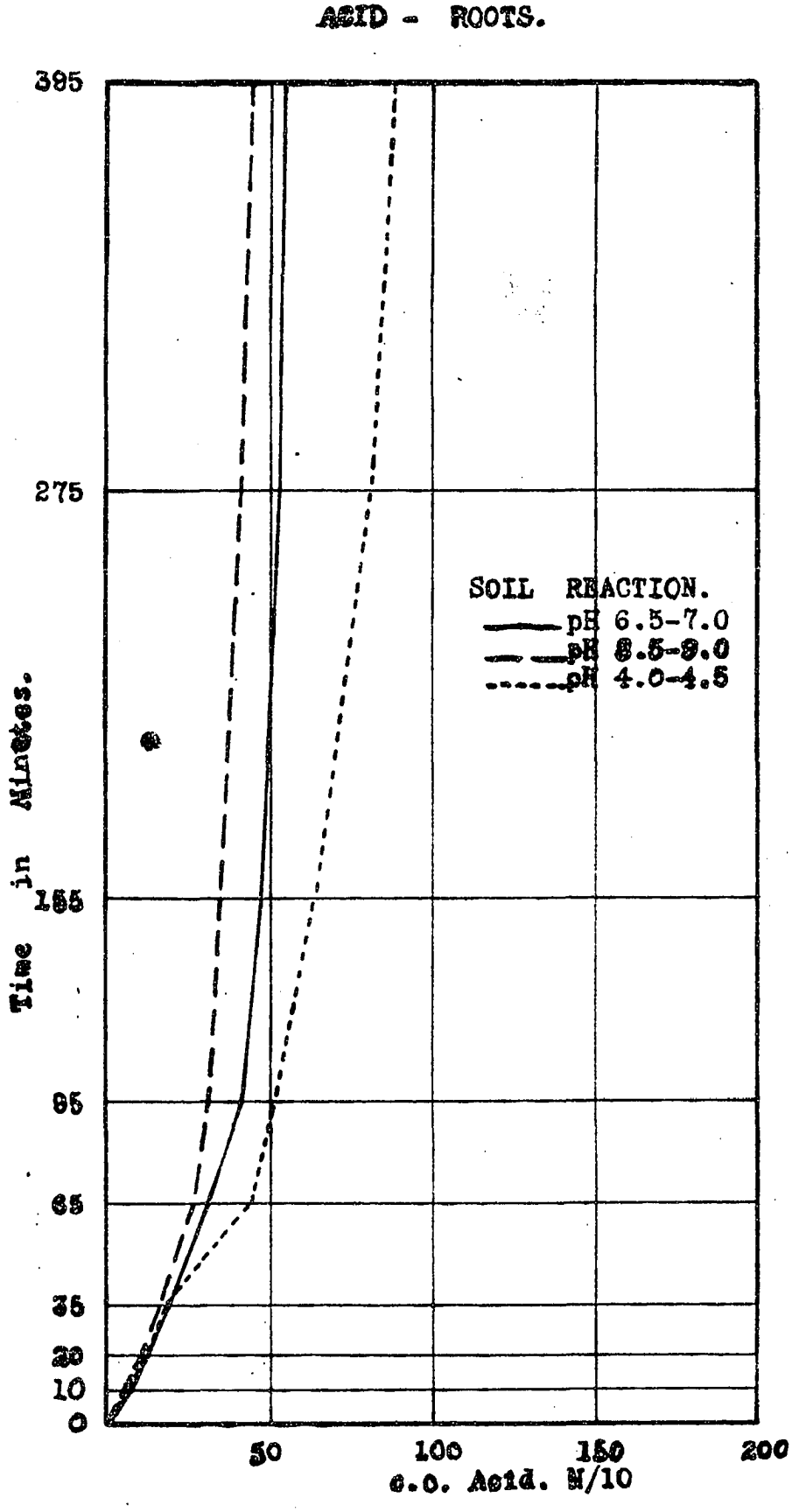

ACID - ROOTS.
395
275
155
65
35
20
10
0
Time in Minutes.
SOIL REACTION.
pH 6.5-7.0
pH 8.5-9.0
pH 4.0-4.5
50
100
150
200
c.c. Acid. N/10

TABLE XV

Differences in Titrateable Acid and Base From Various Parts of the Tomato Plant.

Summary of Tables IX to XIV

Sample	Soil Reaction	N/10 Base c.c.	Difference c.c.	Difference Percent	N/10 Acid c.c.	Difference c.c.	Difference Percent
Ripe Fruit	pH 8.5-9.0	214.6	+ 9.2	+ 4.48	181.2	- 3.2	- 1.73
	pH 6.5-7.0	205.4			184.4		
	pH 4.0-4.5	195.4	-10.0	- 4.87	189.1	+ 4.7	+ 2.54
Green Mature Fruit	pH 8.5-9.0	225.5	+ 5.3	+ 2.40	178.1	- 9.4	- 5.01
	pH 6.5-7.0	220.2			187.5		
	pH 4.0-4.5	209.3	-10.9	- 4.95	203.2	+15.7	+ 8.37
Leaves	pH 8.5-9.0	192.6	+10.7	+ 5.93	104.0	- 5.9	- 5.46
	pH 6.5-7.0	181.9			109.9		
	pH 4.0-4.5	175.6	- 6.3	- 3.46	121.1	+21.2	+19.29
Stems	pH 8.5-9.0	126.9	+23.2	+22.37	82.5	-10.0	-10.81
	pH 6.5-7.0	103.7			92.5		
	pH 4.0-4.5	91.5	-12.2	-11.76	112.0	+19.5	+21.08
Roots	pH 8.5-9.0	103.1	+45.2	+78.06	44.7	-10.7	-19.56
	pH 6.5-7.0	57.9			54.7		
	pH 4.0-4.5	49.1	- 8.8	-15.19	87.6	+ 32.9	+60.14

DISCUSSION

The soils used in the plots were all of the same type, were uniformly prepared by composting and were thoroughly mixed in a highly efficient soil shredder; it was thought that this method would reduce the variable factors to a minimum. The use of soils with natural pH of the desired range was suggested. It was thought that the variations in fertility between the soils from various sources would increase the variable factors which influence growth.

The use of water or sand cultures with pH values of the desired range would no doubt have kept the variable factors to the minimum, but growth of the plants would not have been comparable to that secured when plants were grown in soil. Since this was a study of greenhouse soils, the conditions were more nearly comparable than with water or sand cultures.

By the addition of phosphoric acid to secure the acid reaction and hydrated lime to obtain the alkaline reaction, the calcium, hydrogen, hydroxyl and phosphate ions and the action of these on materials in the soil were factors which might affect the growth and yield of the plant. However, since the respective ions may cause acidity or alkalinity as measured by pH, the acidity or

alkalinity of the soil was considered in general as the factor which caused variation in growth and yield.

Phosphorus is one of the essential elements for plant growth. Only the acid plot was treated with phosphoric acid, but available phosphorus was present in the soil in sufficient quantities on the neutral and alkaline plots to secure normal growth. Repeated tests and observations of plant growth in the compost used in the greenhouse benches showed that it contained enough of the essential elements for plant growth without the addition of any fertilizers. Hence, phosphorus was readily available on all the plots. The same was true for calcium added in the hydrated lime.

Sixteen plots in the greenhouse with soil reactions ranging from pH 5.5 to 9.0, used for another set of experiments, gave similar results with reference to yield and growth as the six plots included in this experiment. The largest yields and maximum growth were secured on the plots with a soil reaction which was neutral or slightly acid.

Van Alstine (48), Tarr and Noble (44), Duggar (18) and Appel (1) reported chlorotic effects from the use of nutrient solutions where the pH was on the alkaline side. This was said to be due to the insolubility of the iron. No such results occurred on the

plants grown in the greenhouse plots in a soil with a similar reaction.

Catalase and Oxidase Activity

The data show clearly that there was a relation between the catalase activity and amount of growth and yield in the tomato. The differences in catalase activity of leaf tissue from plants growing in various soil reactions were greater than in the fruit. Catalase activity was much greater in the leaf tissue than in any stage of maturity of the fruit and may account for these greater differences.

The catalase activity in very green fruits was very low and consequently no consistent difference could be noted between fruits from the various plots. Catalase activity of the fruit appeared to be greatest in the green mature stage, and consistent differences due to conditions of growth were noted. As the fruit ripened catalase activity again decreased for fruits from all the plots.

Knott (30) found in spinach that when the plant changed from a vegetative to a reproductive type of growth the catalase activity decreased. In the experiments reported here yield and growth were associated on the neutral plot and catalase activity decreased under these conditions. Since production of fruit was high on the

neutral plots, the type of growth secured could not be considered a vegetative type. The results reported here with respect to catalase activity were in accord with the results of Ezell and Crist (19) who found a negative correlation between yield and growth and catalase activity in the leaves of the apple. Heinicke (27) found catalase activity was reduced in the bark of the apple tree by fruiting. He concluded that growth-producing substances increased catalase activity, while substances which retarded vegetative activity had a retarding influence on such activity. Ezell and Crist (19) took exception to this since their results, especially with lettuce, showed that as growth increased, catalase activity decreased.

It appears from the present work that increased growth accompanied by increased yield may be associated with decreased catalase activity. Heinicke (27) considered only increased growth as associated with decreased catalase activity and disregarded yield of fruit as a factor.

No correlation was found in the present work between growth, yield and oxidase activity. Reed (39) found catalase and oxidase activity to be independent of each other, and this is substantiated here.

Ionizable Constituents

Three grams of air-dried tissue was used in all cases where roots, stems and leaves were dialyzed. Fresh material was used with the fruit, 250 grams of the "green mature" and 275 grams of the ripe fruit. According to Wehmer (49), the ripe tomato fruit contains 92-94 percent of water. Therefore, the fruit samples contained 7 to 9 grams on a dry weight basis. This was two to three times as much as the root, stem and leaf samples. Consequently, the roots and fruits contained the least amount of ionizable material and the leaves contained the greatest amount, as measured in terms of N/10 titrateable acid and base.

The various samples of the plant tissue used were as large as practicable in order to obtain a large amount of acid and basic material. Since the titrations were with N/10 H_2SO_4 and N/10 NaOH, the larger the total amount of acid or base required to neutralize the dialysate the smaller the error. The size of the sample was governed by the amperage in a given length of time. It was not deemed advisable to allow the amperage to go above 4 for more than 1 or 2 minutes, and it was preferable to hold it below 2 amperes since with high amperage high temperatures resulted. It may be noted

that the amperage corresponded to the amount of acid and base removed, especially in the early stages of dialysis. The greater the total of ionizable constituents present in the dialysate, the greater the amperage.

The greatest percentage differences of the acid and basic constituents, depending on the acidity or alkalinity of the soil, were found in the root systems. These differences decreased in the order of roots, stems, leaves, green mature fruit and ripe fruit.

It is not surprising to find the greatest differences in acid and basic materials in the root systems of plants grown in acid and basic soils. Since the alkaline soil was treated with hydrated lime, one would expect to find a greater amount of calcium salts present in the plants. The acid soil having been treated with phosphoric acid would contain more acid material. Hartwell (22) found the percentage of phosphorus in turnips to be positively correlated with the amount of available phosphorus in the soil. Truog (47) pointed out that the pH value of the tissue or extract of a number of agricultural plants could be raised by the addition of lime to acid soils in which the plants were growing. This would indicate the intake of a greater amount or proportion of alkaline material. The findings of Reed

and Haas (40) were contrary to this, as they reported no differences in pH values of the sap expressed from walnut seedlings regardless of the reaction of the solution in which they were grown.

As stated previously, the differences between titrateable acid and base, depending on the acidity or alkalinity of the soil, became less in the order of root, stems, leaves and fruit. Burgess and Pember (13) found the highest percentages of aluminum in the roots; considerable in the leaves; a little in the stems and none in the grain of barley. It may be logical to suggest from their results and those reported in these experiments that there is an equalization of base and acid materials by the time the ionizable material reaches the fruit.

The pH values of anolyte and catholyte were taken for roots, stems and leaves, but the differences were small, especially where the amount of titrateable acid and base was large. This might well be expected where the solutions were well buffered. In many instances the pH value on the basic side (anolyte) was less than 7.0 or neutral. The distilled water used was about pH 5.0, so one might expect readings lower than the neutral point.

SUMMARY

Tomatoes grown on soil with a pH value of 6.5-7.0 gave higher yields and made greater growth as measured by total dry matter than tomatoes grown on soils of pH values 4.0-4.5 and 8.5-9.0.

Catalase activity, growth and yield were negatively correlated in the vegetatively mature leaves, green mature fruit and ripe fruit. No apparent differences were observed in very green fruits.

In the tomato fruit catalase activity was lowest in very green fruits, much greater in the green mature stage, and became less in the ripe fruit.

Soil reaction and subsequent growth and yield had no apparent effect on oxidase activity, although oxidase activity was greater in the ripe fruits than in very green or green mature fruits.

Catalase and oxidase activity were apparently independent of each other.

More acid materials as determined by electrodialysis were found in plants grown on acid soil and more basic materials in plants grown on an alkaline soil. The percentage differences were in the order of root, stem, leaf and fruit.

The leaves contained the greatest amount of

ionizable materials, while roots and fruit apparently contained the least.

ACKNOWLEDGMENTS

The writer wishes to express his thanks and appreciation to all who have assisted in any way in the conduct of this work, particularly to Dr. R. M. Hixon of the Chemistry Department and Dr. A. L. Bakke of the Department of Plant Physiology for their helpful criticisms and suggestions; to Professors A. T. Erwin and B. S. Pickett of the Department of Horticulture for constant encouragement and assistance; to Professor H. W. Richey for reading the manuscript and Mr. E. M. Emmert for assistance in the greenhouse and laboratory.

LITERATURE CITED

1. Appel, M. Über den Wert von der Croneschen Nährlosung. Zeitschr. Bot. 10:145-162. 1918.

2. Appleman, Chas. O. Relation of catalase and oxidase to respiration in plants. Maryland Agr. Exp. Sta. Bul. 191. 1915.

3. ---------- Some observations on catalase. Bot. Gaz. 50:182-192. 1910.

4. Auchter, E. C. Is there normally a cross-transfer of foods, water and mineral nutrients in woody plants? Maryland Agr. Exp. Sta. Bul. 257. 1923.

5. Bailey, C. H. A simple hydrogen electrode. Jour. Amer. Chem. Soc. 42:45-48. 1920.

6. Becking, L. G. M. B. and Hampton, H. C. Measurement of the catalytic power of catalase. Amer. Jour. Bot. 7:261-274. 1920.

7. Bernhard, A. and Beaver, J. J. The electrodialysis of human blood serum. Jour. Biol. Chem. 69:113-124. 1926.

8. Biechy, Theodor. Konnen Fermentwirkungsmessungen zur Beurteilung der Vitalitat wichtiger Kulturpflanzen herangezogen werden? Fermentforschung 8:135-166. 1926.

9. Borasio, Ligui. Determination of the catalase of rice and its relation to germinating power. Giorn. Risicoltura 14:143-151. 1924. Giorn. farm. chim. 74:29-31, 57-61. 1925. (Abs. in Chem. Abs. 19:1881-1882. 1925) Original paper not examined.

10. Bradfield, Richard. An inexpensive cell for the purification of colloids by electrodialysis. Jour. Ind. & Eng. Chem. 20:79-80. 1928.

11. Bunzell, H. H. A biochemical study of curly-top of sugar beets. U.S.D.A. Bur. Pl. Ind. Bul. 277. 1913.

12. ---------- Oxidase in healthy and curly-dwarf potatoes. Jour. Agr. Res. 2:373-404. 1914.

13. Burgess, P. S. and Pember, F. R. Active aluminum as a factor detrimental to crop production in many acid soils. R. I. Agr. Exp. Sta. Bul. 194. 1923.

14. Clark, Norman A., Humfield, H. and Alben, A. O. Electrodialysis of soils and the Mattson cell. Soil Science. 24:291-295. 1927.

15. Crocker, W. and Harrington, G. T. Catalase and oxidase content of seeds in relation to their dormancy, age, vitality and respiration. Jour. Agr. Res. 15:137-174. 1918.

16. Dhere, C. and Gorgelewski, M. Sur l'obtention, par dialyse electrique, d'un serum extremement appauvri en electrolytes. Acad. Sci. Paris. Compt. Rend. 150:993-996. 1910.

17. Drain, B. D. Temperature and respiratory enzymes of apples. Bot. Gaz. 82:183-194. 1926.

18. Duggar, B. M. Hydrogen-ion concentration and the composition of nutrient solutions in relation to the growth of seed plants. Mo. Bot. Garden. Ann. 7:1-49. 1920.

19. Ezell, B. D. and Crist, J. W. Effect of certain nutrient conditions on activity of catalase and oxidase. Mich. Agr. Exp. Sta. Tech. Bul. 78. 1927.

20. Fricke, R., Fischer, F. A. and Borchers, H. Ueber Fermentreinigung durch Elektrodialyse und Elektroosmose. Kolloid Zeitschr. 39:152-165. 1926.

21. Grüss, J. Enzymwirkungen am Wundrandt der Kartoffelknolle. Zeitschr. Pflanzenkrankheiten. 17:65-79. 1907.

22. Hartwell, Burt L. The percentage of total phosphorus in flat turnips as influenced by the amount available in the soils. R. I. Agr. Exp. Sta. Bul. 154. 1913.

23. Harvey, R. B. An apparatus for measuring oxidase and catalase activity. Jour. Gen. Physiol. 2:253-254. 1920.

24. ---------- Hydrogen ion changes in the mosaic disease of tobacco plants and their relation to catalase. Jour. Biol. Chem. 42:397-400. 1920.

25. ---------- Relation of catalase, oxidase and H + concentration to the formation of overgrowths. Amer. Jour. Bot. 7:211-221. 1920.

26. Heinicke, A. J. Catalase activity in dormant apple twigs; its relation to the condition of the tissue, respiration and other factors. N. Y. (Cornell Univ.) Agr. Exp. Sta. Memoir 74. 1924.

27. ---------- Factors influencing catalase activity in apple leaf tissue. N. Y. (Cornell Univ.) Agr. Exp. Sta. Memoir 62. 1923.

28. ---------- The influence of fruiting on the catalase activity of the bark of apple trees. Amer. Soc. Hort. Sci. Proc. (1926) 23:263-269.

29. Hoffman, W. F. and Gortner, R. A. The electrodialysis of agar. Jour. Biol. Chem. 65:371-379. 1925.

30. Knott, J. E. Catalase in relation to growth and to other changes in plant tissue. N. Y. (Cornell Univ.) Agr. Exp. Sta. Memoir 106. 1927.

31. ---------- Some conditions influencing the determination of catalase activity in plant tissue. Amer. Soc. Hort. Sci. Proc. (1925) 398-407.

32. Konig, J., Hasenbaumer, J. and Glenk, K. Uber die Anwendung der Dialyse und die Bestimmung der Oxydationskraft fur die Beurteilung des Bodens. Landsw. Versuchs. 79-80: 491-534. 1913.

33. Lisbonne, M. and Vielquin, E. Inactivation de l'amylase du malt par la dialyse electrique. Activation par electrolytes. Soc. Biol. Paris. Compt. Rend. 72:936-938. 1912.

34. Magness, J. R. and Ballard, W. S. The respiration of Bartlett pears. Jour. Agr. Res. 32:801-832. 1926.

35. Mattson, Sante. Electrodialysis of the colloidal soil material and the exchangeable bases. Jour. Agr. Res. 33:553-567. 1926.

36. Moore, James C., Reeves, R. G. and Hixon, R. M. Electrodialysis as a means of studying biochemical differences in abnormal apple tissue. Plant Phys. 2:313-324. 1927

37. Nemec, Antonin and Duchon, Frantisek. Sur une novelle methode biochimique pour la determination de la faculte vitale des semences Ann. Sci. Agron. ser. 6, 40:121-150. 1923.

38. Pentzer, W. T. Color pigments in relation to the development of Jonathan spot. Amer. Soc. Hort. Sci. Proc. (1925) 66-69.

39. Reed, G. B. The relation between oxidase and catalase in plant tissues. Bot. Gaz. 62:409-412. 1916.

40. Reed, H. S. and Haas, A. R. C. Nutrient and toxic effects of certain ions on citrus and walnut trees with especial reference to the concentration and pH of the medium. Cal. Exp. Sta. Tech. Paper 17. 1924.

41. Rhine, L. E. Divergence of catalase and respiration in germination. Bot. Gaz. 78:46-67. 1924.

42. Rose, D. H. Oxidation in healthy and diseased apple bark. Bot. Gaz. 60:55-65. 1915.

43. Schmidt, C. L. A. and Hoagland, E. R. Table of pH, H^+ and OH^- values corresponding to electromotive forces determined in hydrogen electrode measurements. Univ. Cal. Pub. Physiol. 5:23-69. 1919.

44. Tarr, L. W. and Noble, S. C. The effect of hydrogen-ion concentration upon the growth of the seedlings. Del. Agr. Exp. Sta. Bul. 131. 1922.

45. Taylor, T. C., Brown, E. E. and Scott, E. L. Studies on the ultrafiltration and electrodialysis of insulin solutions. Amer. Jour. Physiol. 539-565. 1925.

46. Thatcher, R. W. Enzymes of apples and their relation to the ripening process. Jour. Agr. Res. 5:103-116. 1913.

47. Truog, Emil. Soil acidity I. Its relation to the growth of plants. Soil Science 5:169-195. 1918.

48. Van Alstine, E. The interrelation between plant growth and the acidity of the nutrient solution. N. J. Agr. Exp. Sta. Rpt. 1920 395-401.

49. Wehmer, C. Die Planzenstoffe. p. 678. Jena. Gustav Fischer. 1911.

50. Weiss, F. and Harvey, R. B. Catalase, hydrogen-ion concentration and growth in the potato wart disease. Jour. Agr. Res. 21:589-592. 1921.

51. Woods, A. F. Observations on the mosaic disease of tobacco. U.S.D.A. Bur. Pl. Ind. Bul. 18. 1902.

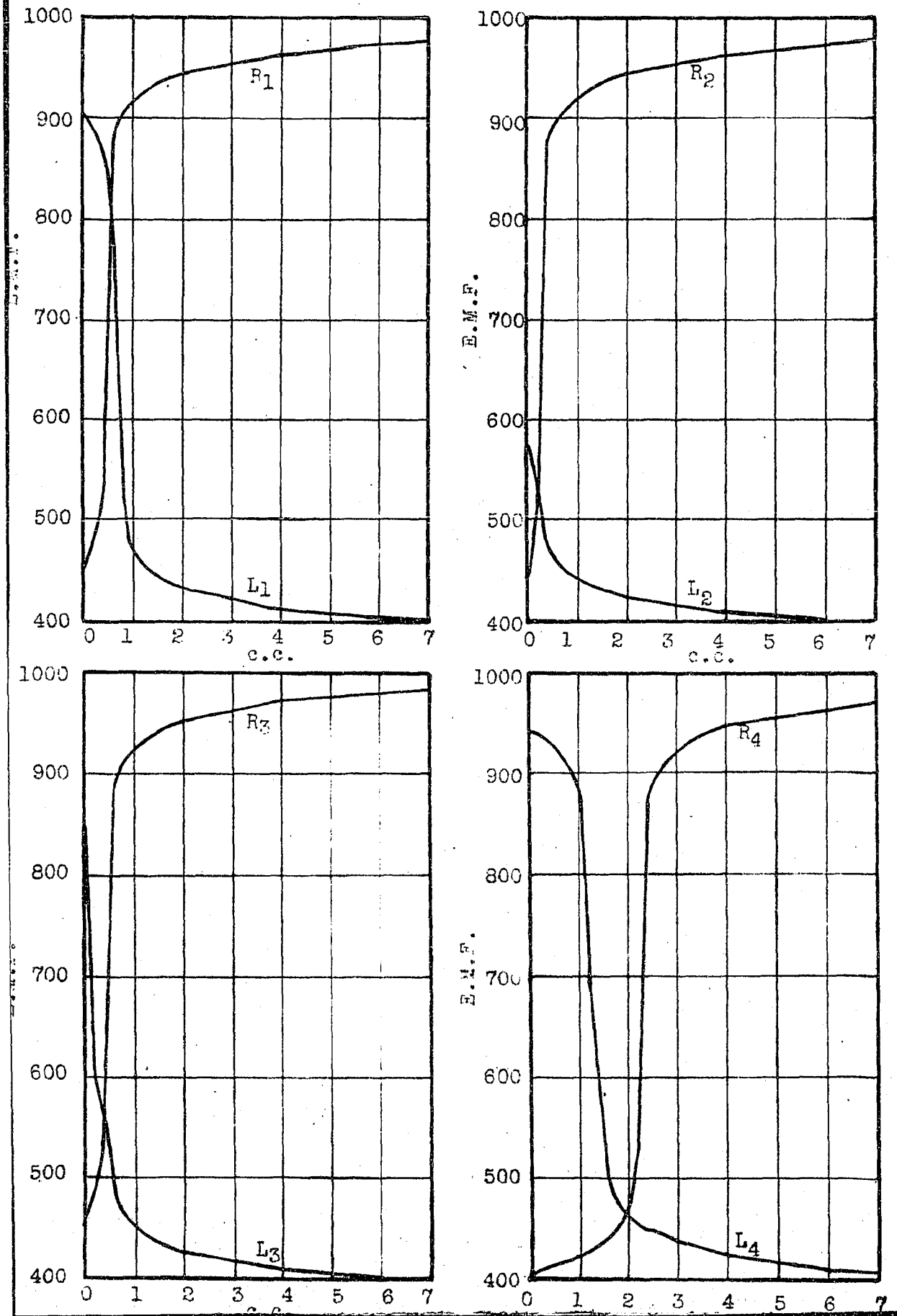
52. Zaleski, W. and Reinhard, A. Zur Frage der Wirkung der Salze auf die Atmung der Pflanzen und auf die Atmungsenzyme. Biochem. Zeitschr. 27:450-473. 1910.

APPENDIX

Electrometric titrations made on the dialysate are ploted in the following graphs. The symbols R_1, R_2-------R_8 refer to the titrations made on the anolyte of the dialysate. The symbols L_1, L_2-------L_8 refer to the electrometric titrations made on the catholyte of the dialysate.

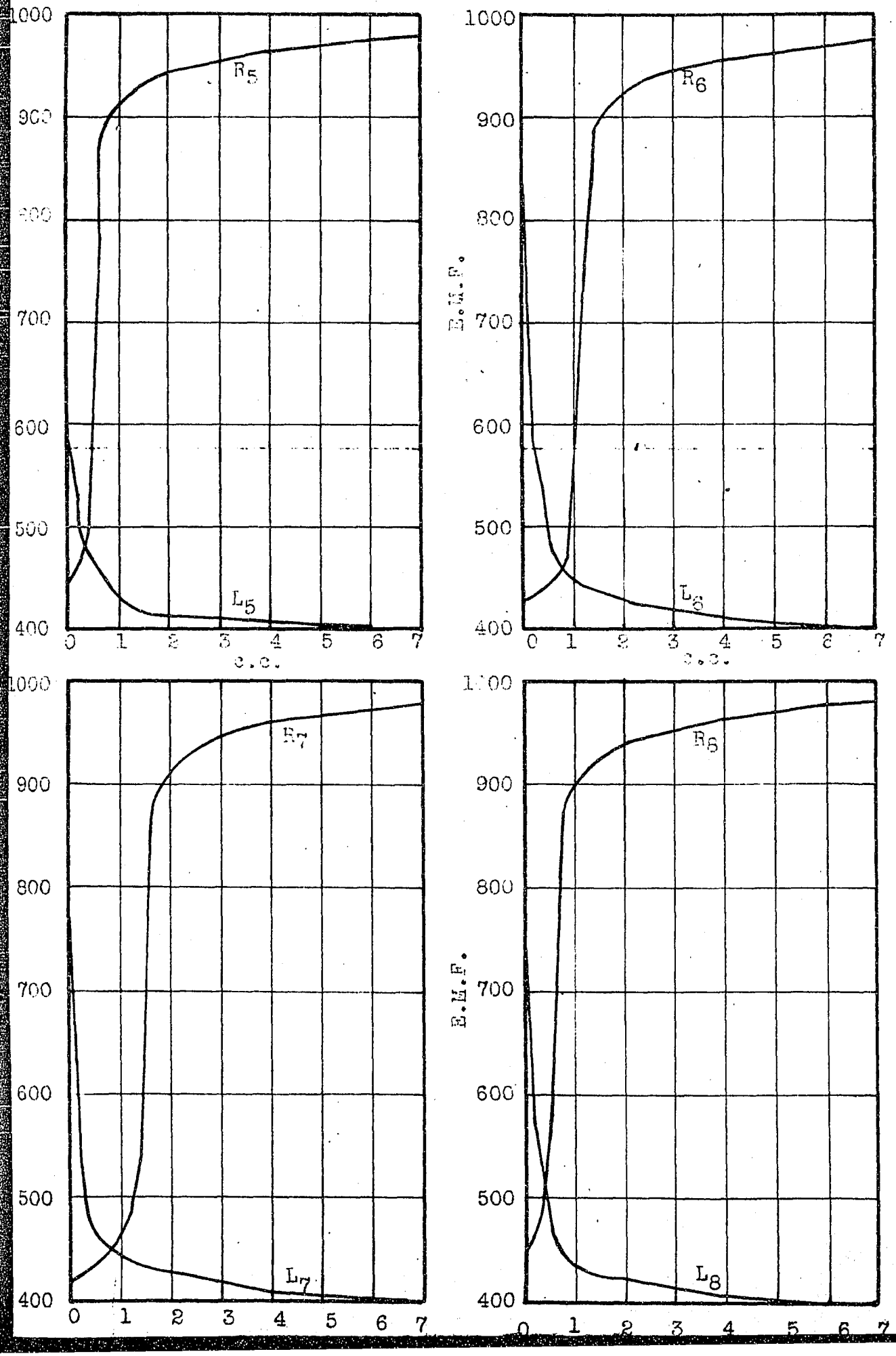
ROOTS.

Soil pH 4.0-4.5

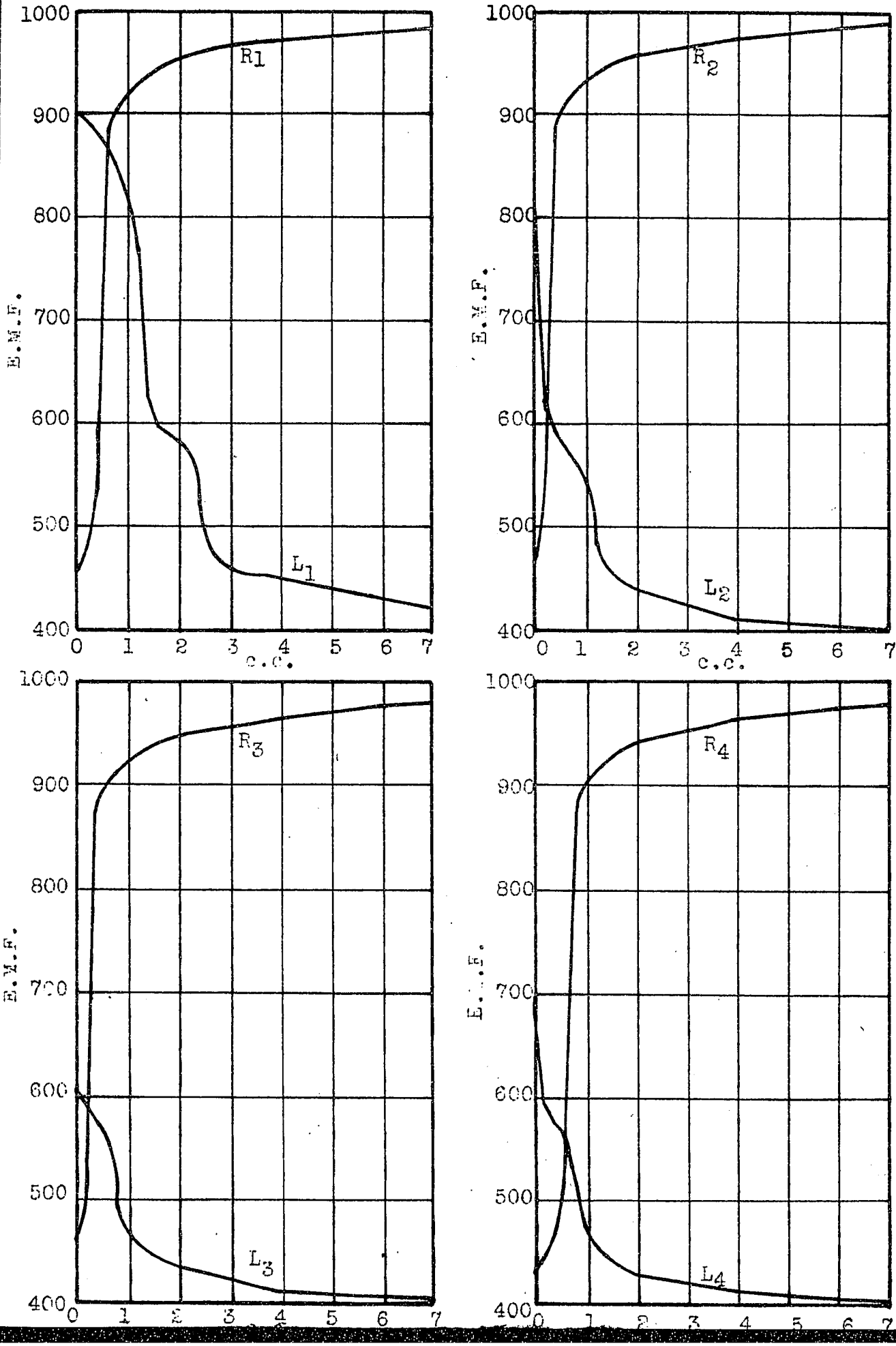


ROOTS.

Soil pH 4.0-4.5

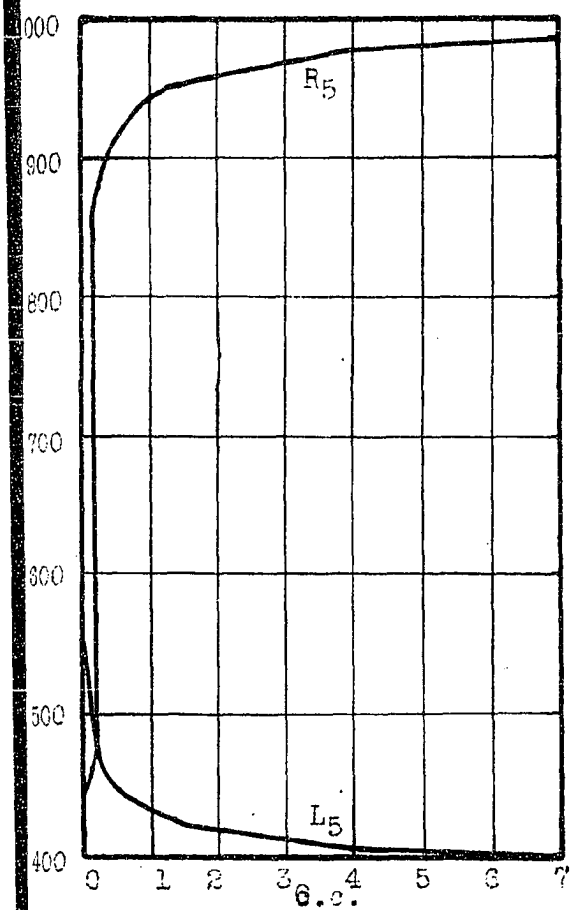


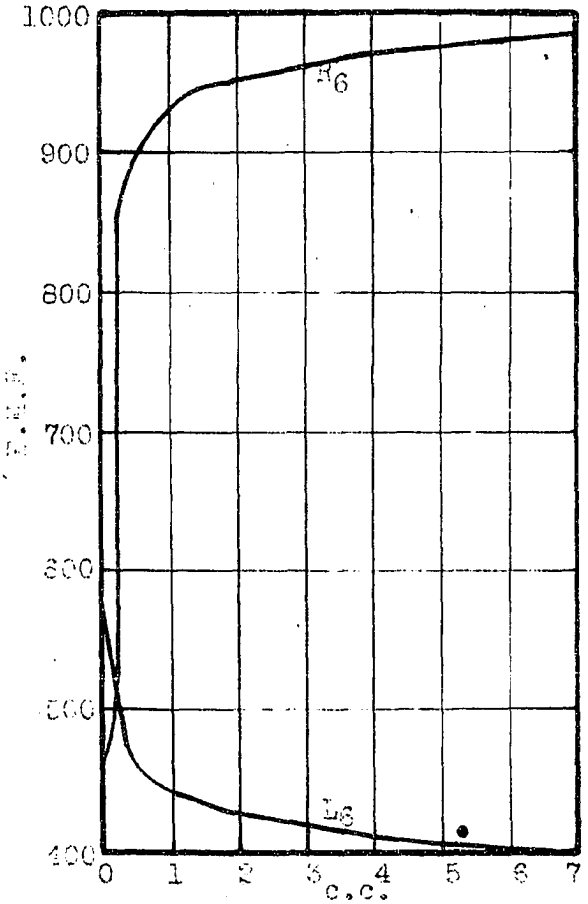
ROOTS.
Soil pH 6.5-7.0

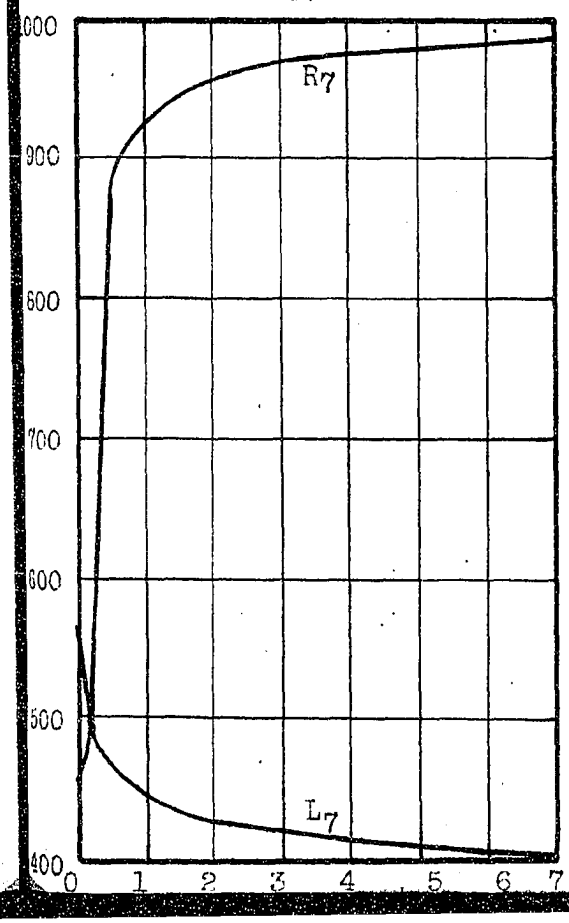


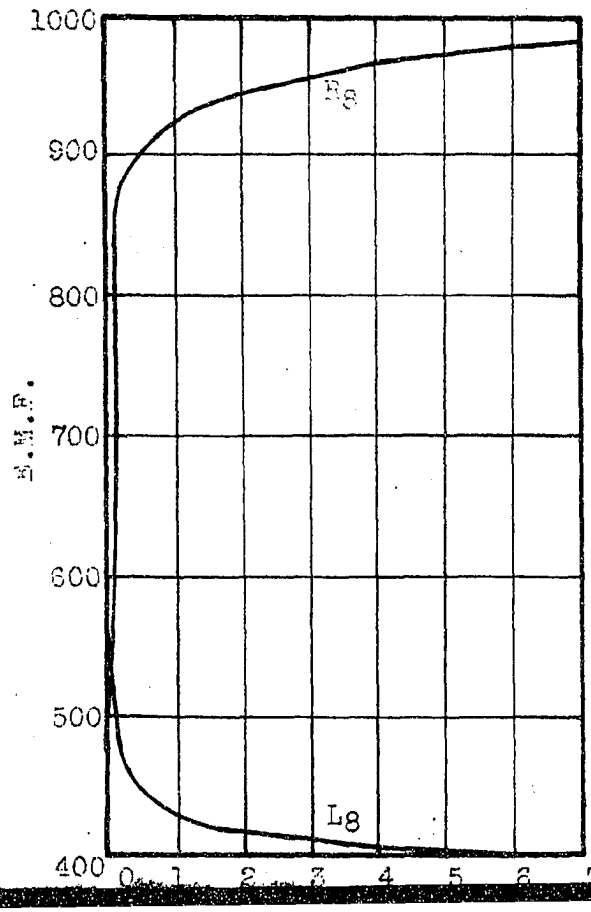
ROOTS.

Soil pH 6.5-7.0



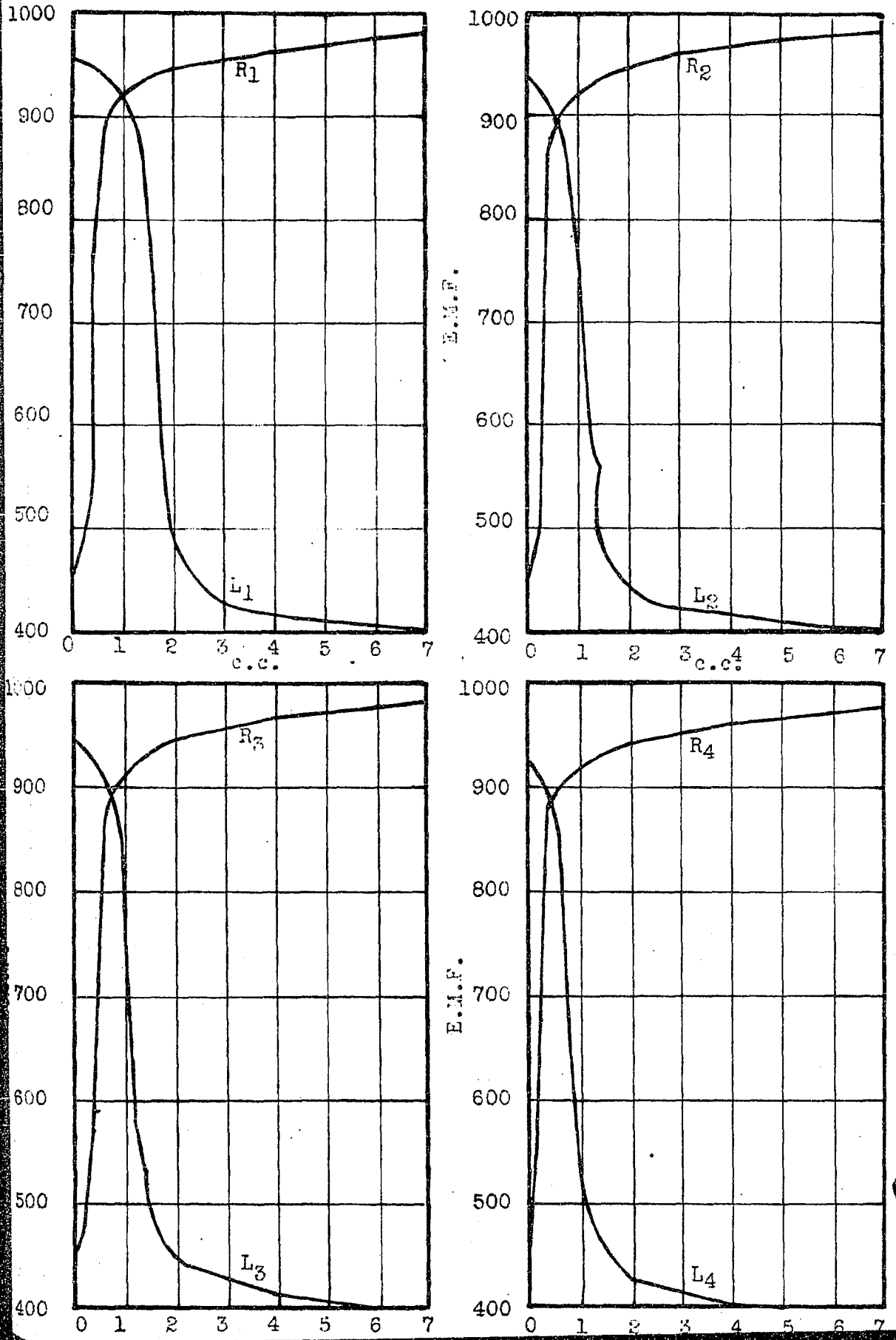






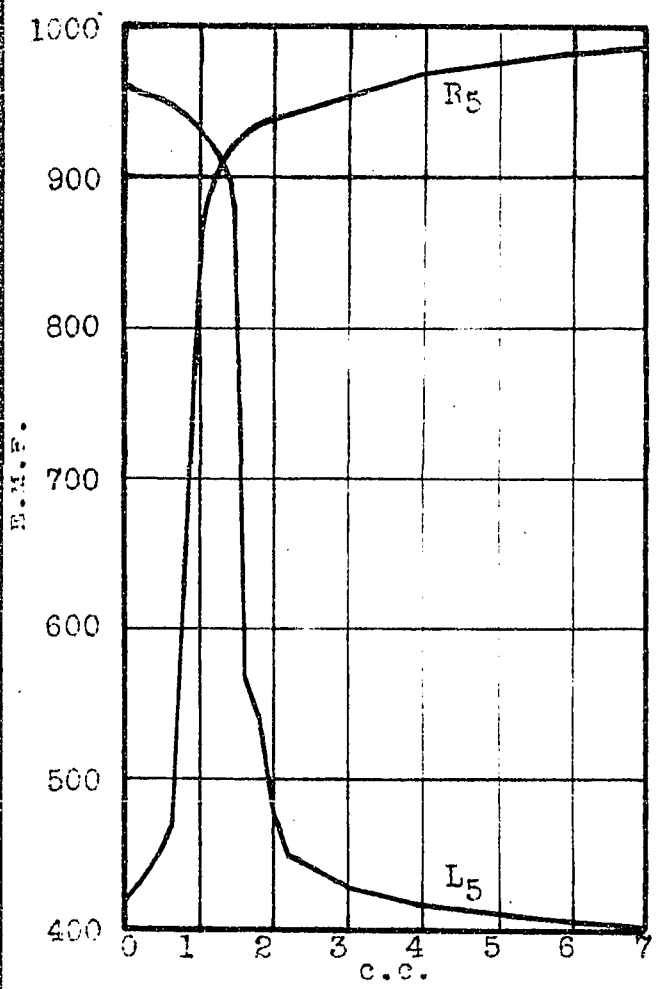
ROOTS.

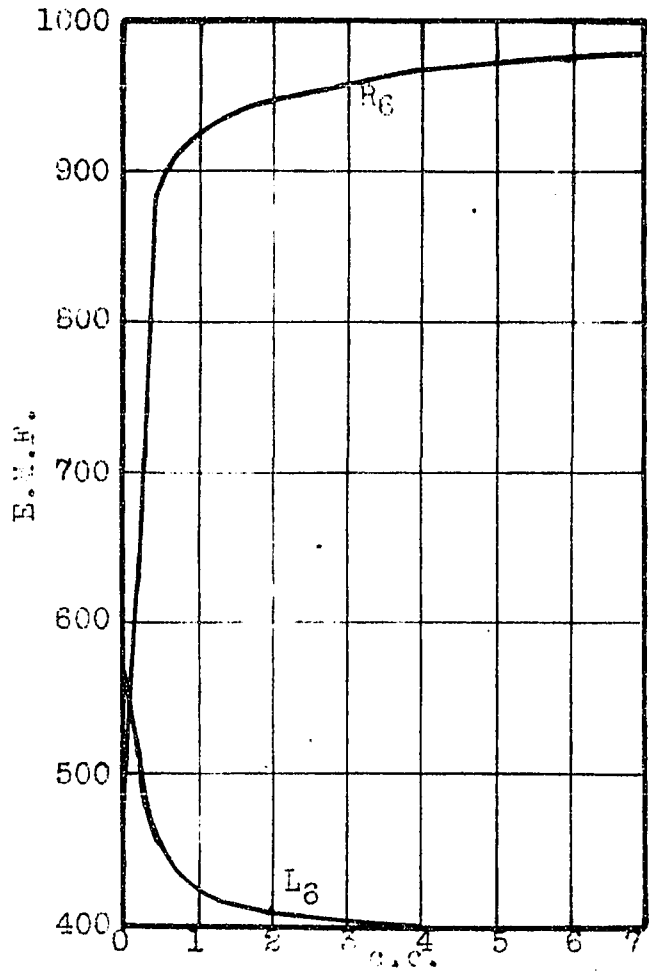
Soil pH 8.5-9.0

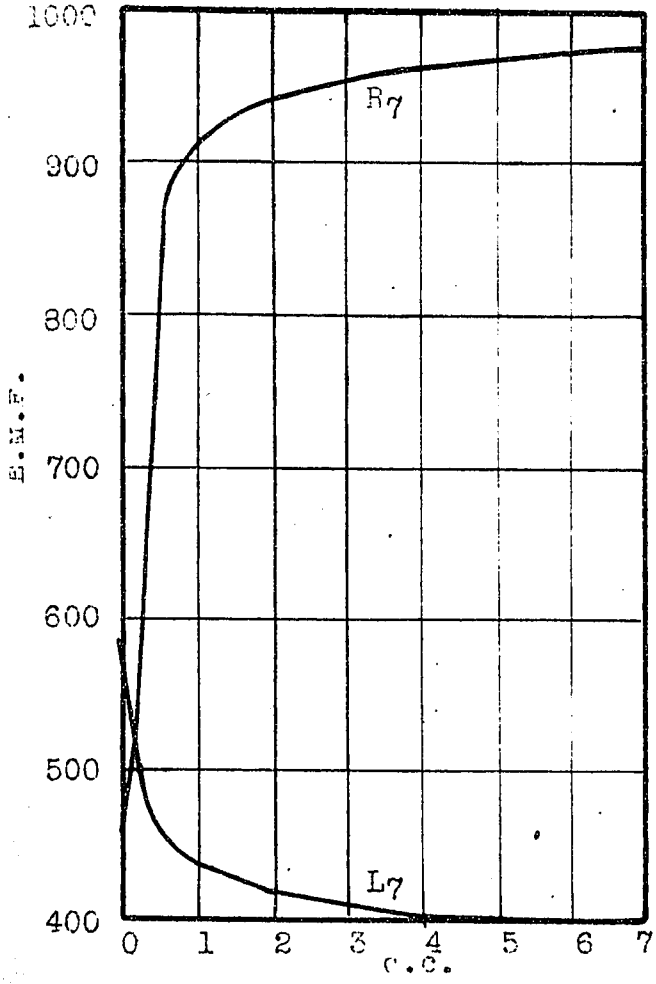


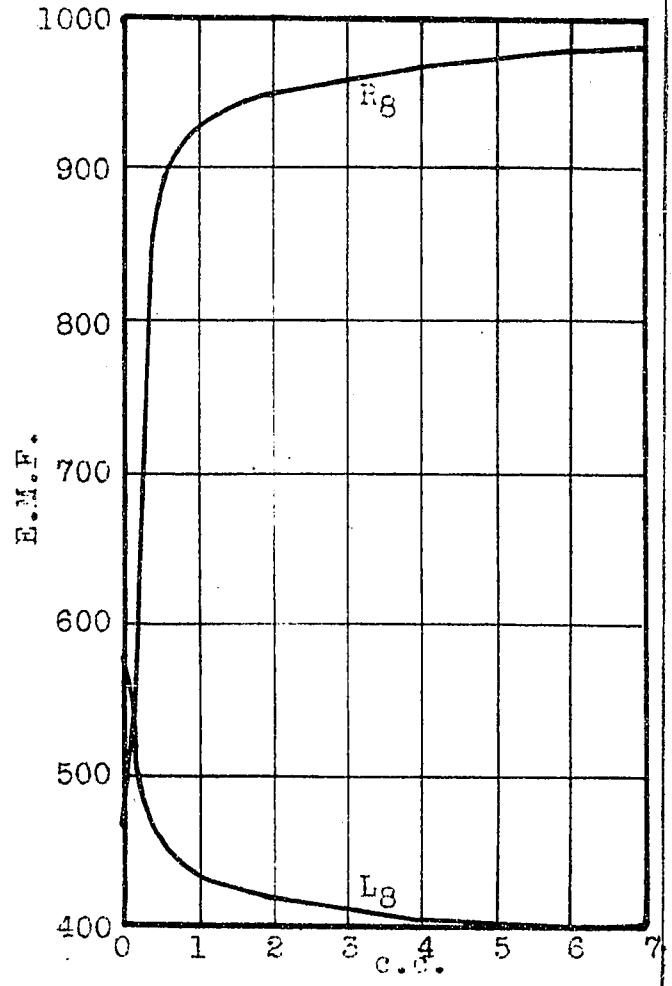
ROOTS.

Soil pH 8.5-9.0



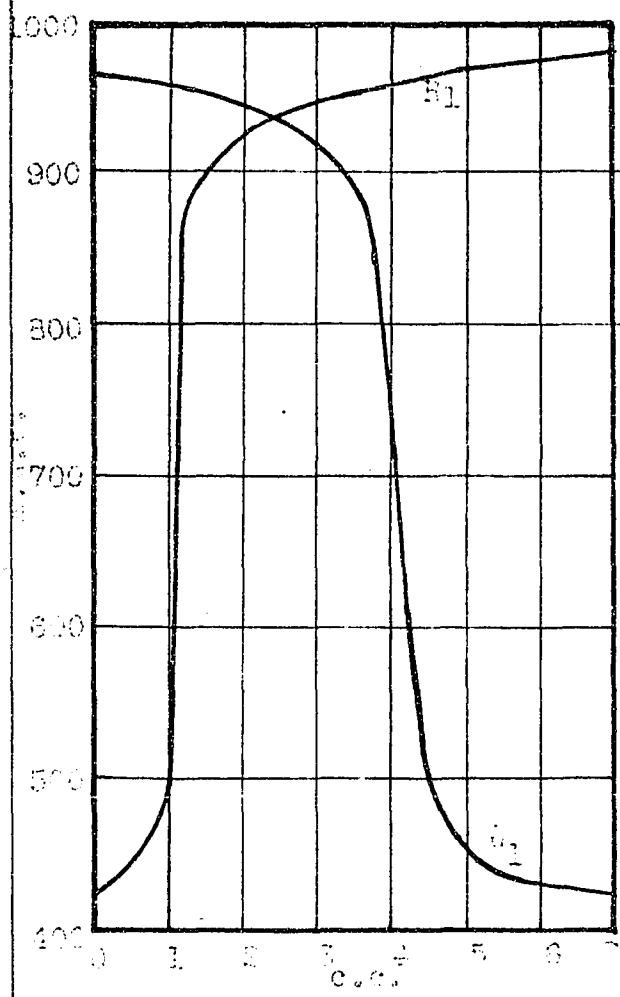


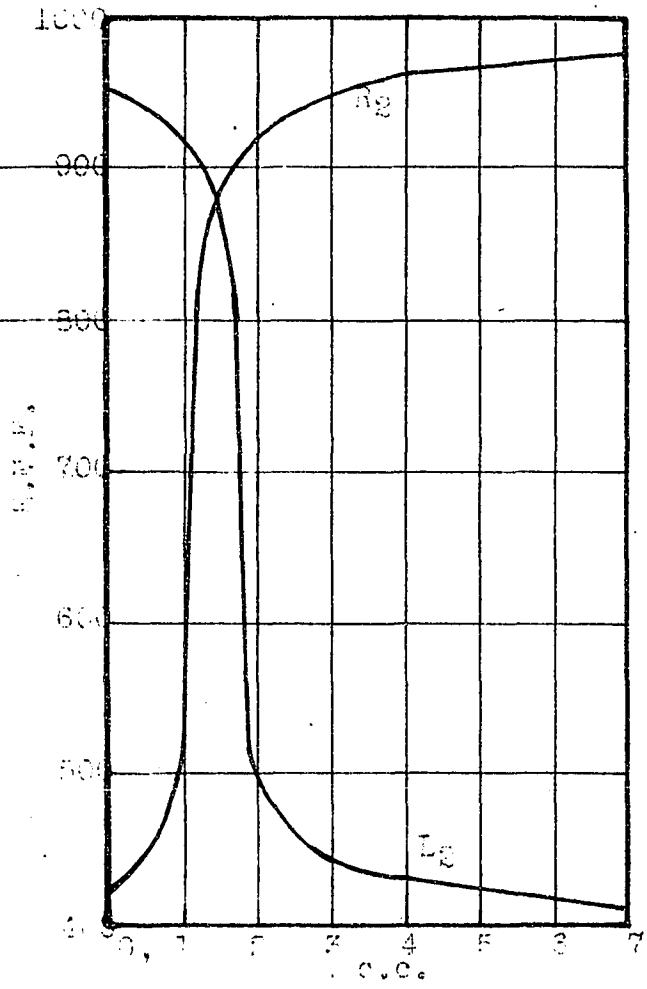


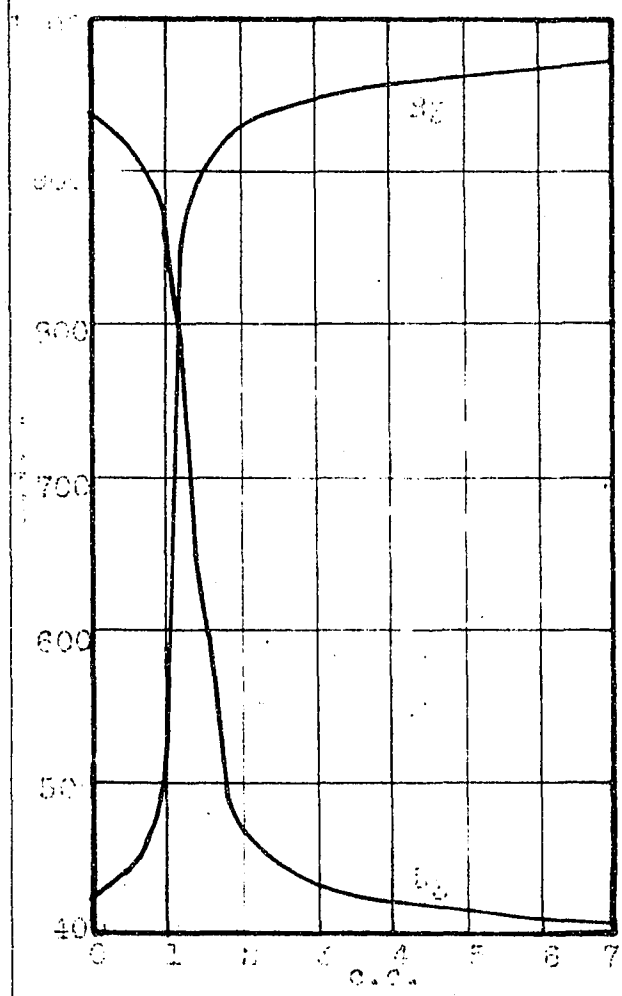


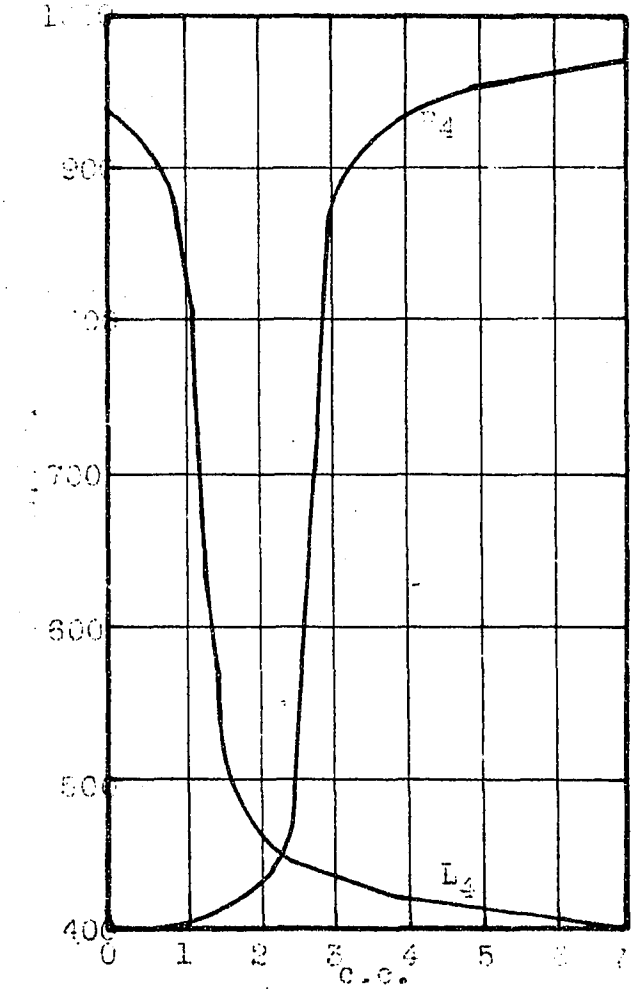
STEAM.

Soil pH 4.0-4.5

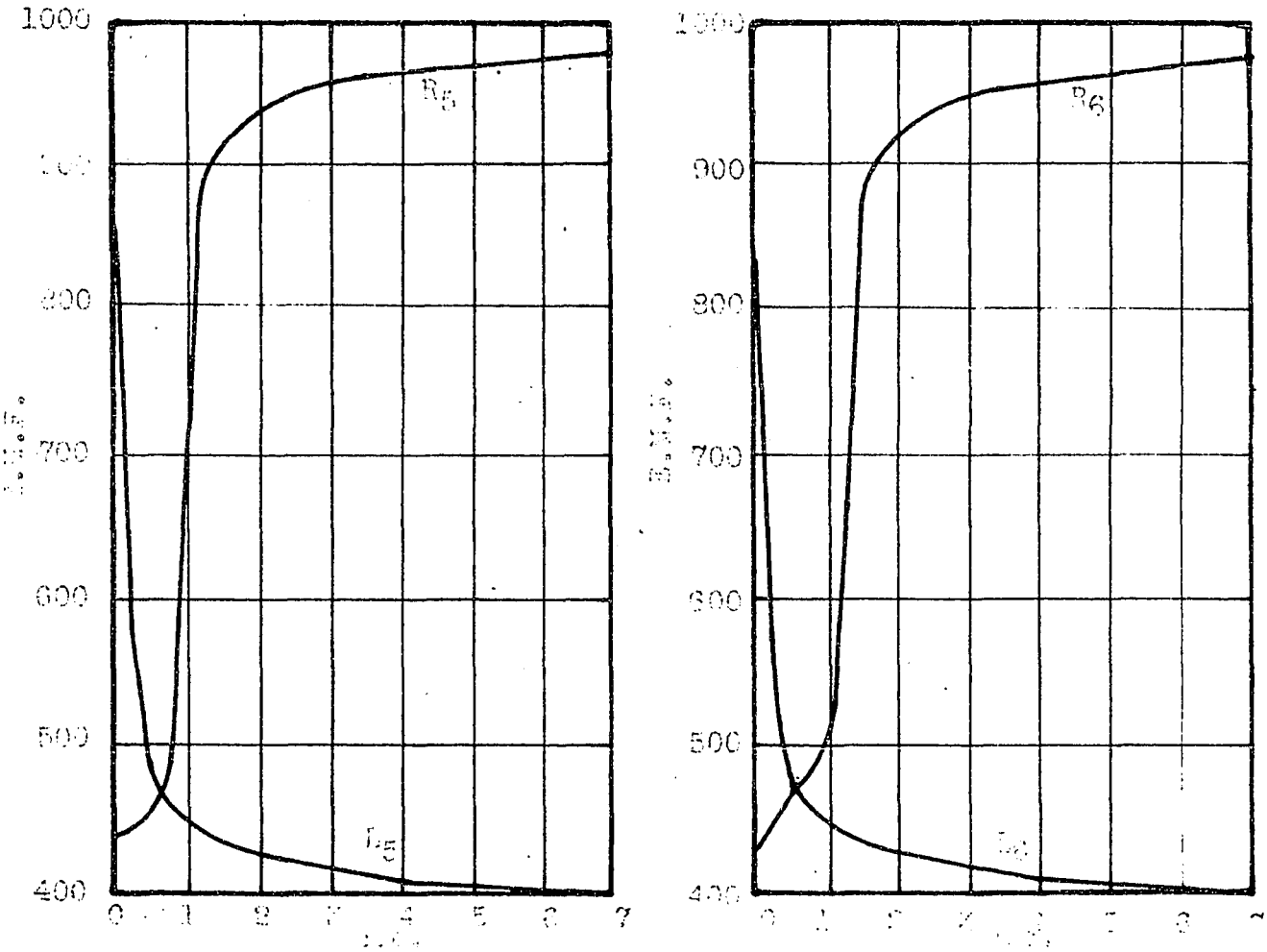


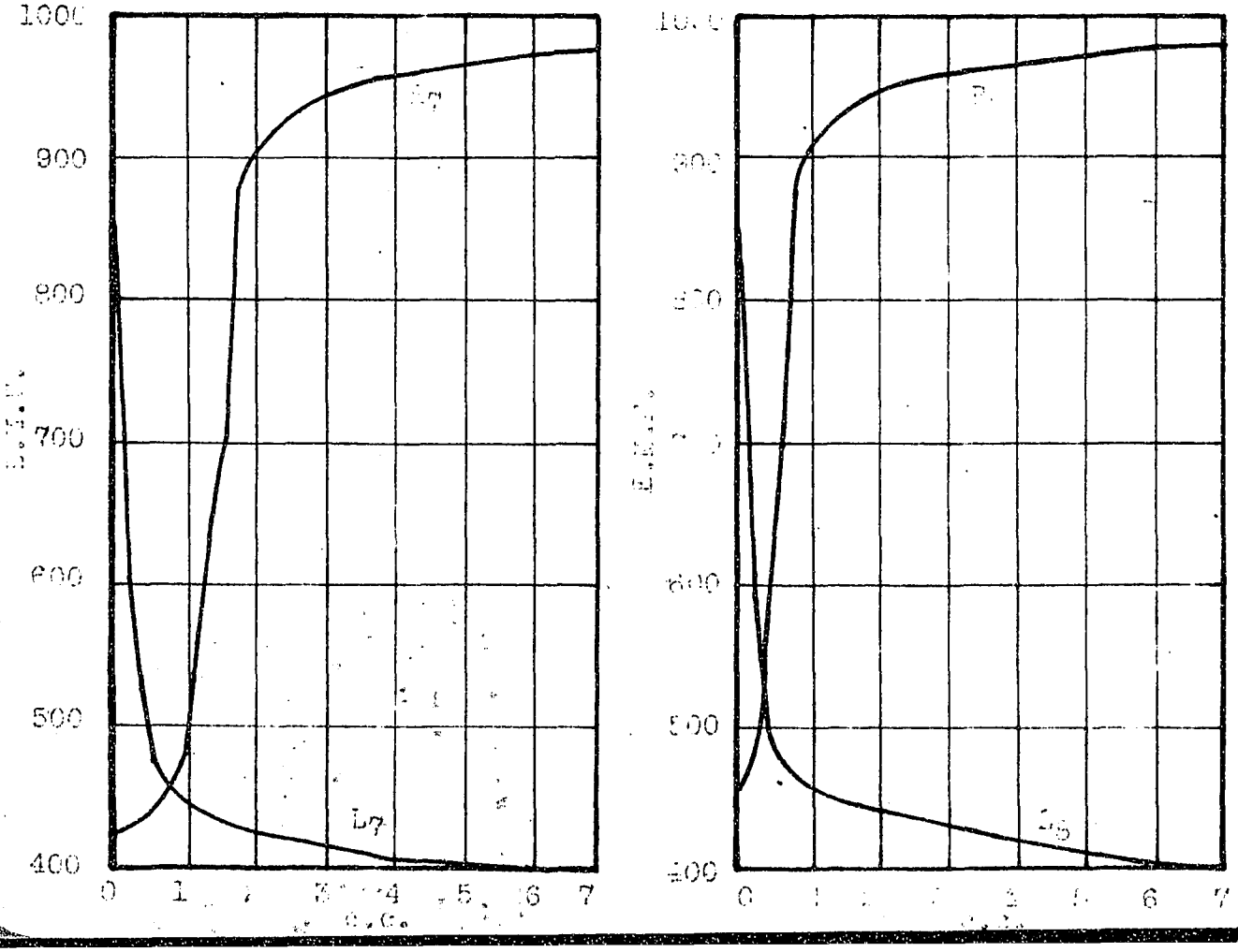




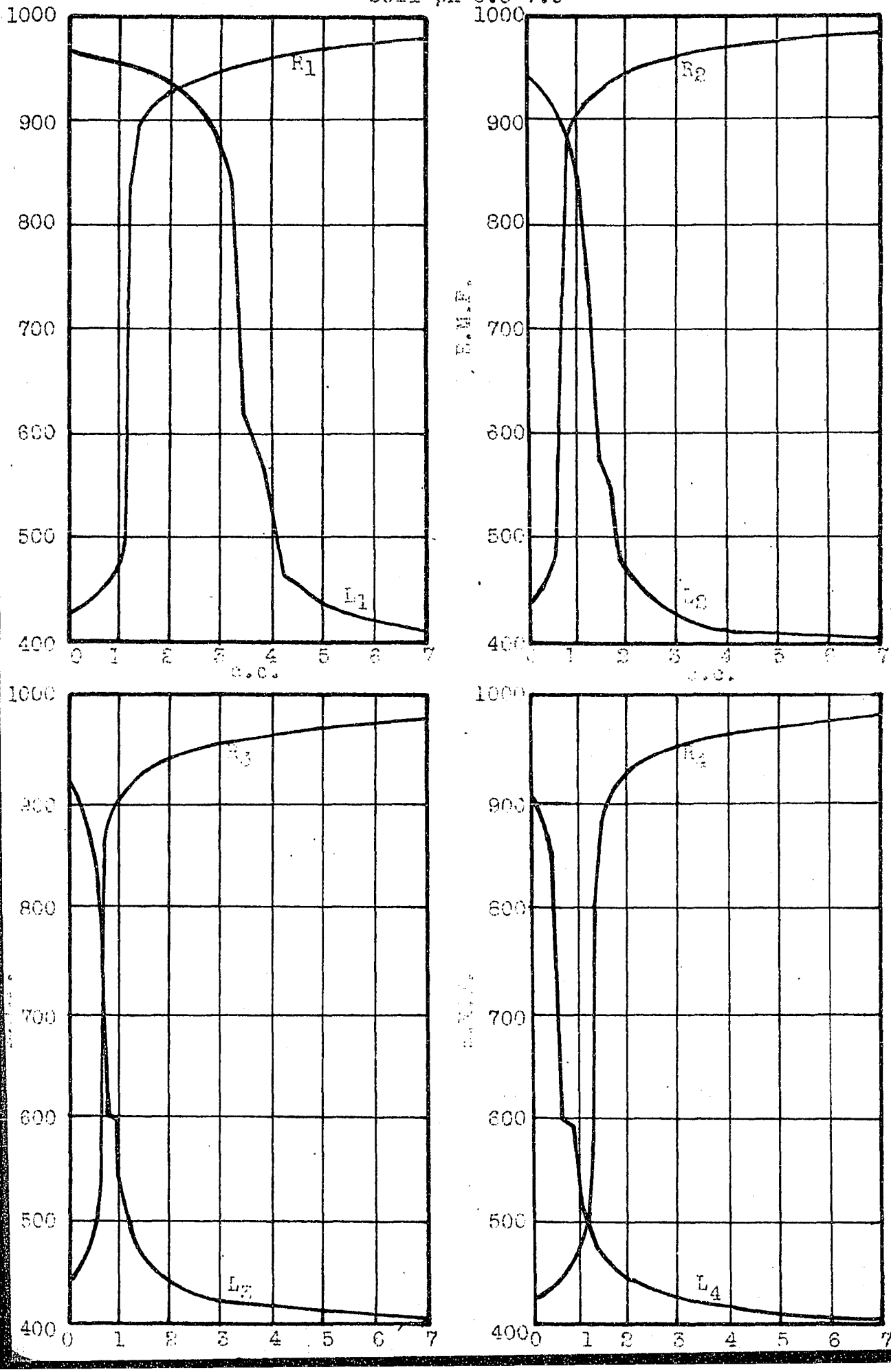


Soil pH 1.0--1.5


1000
900
800
700
600
500
400
R_5
L_5
R_6
L_6

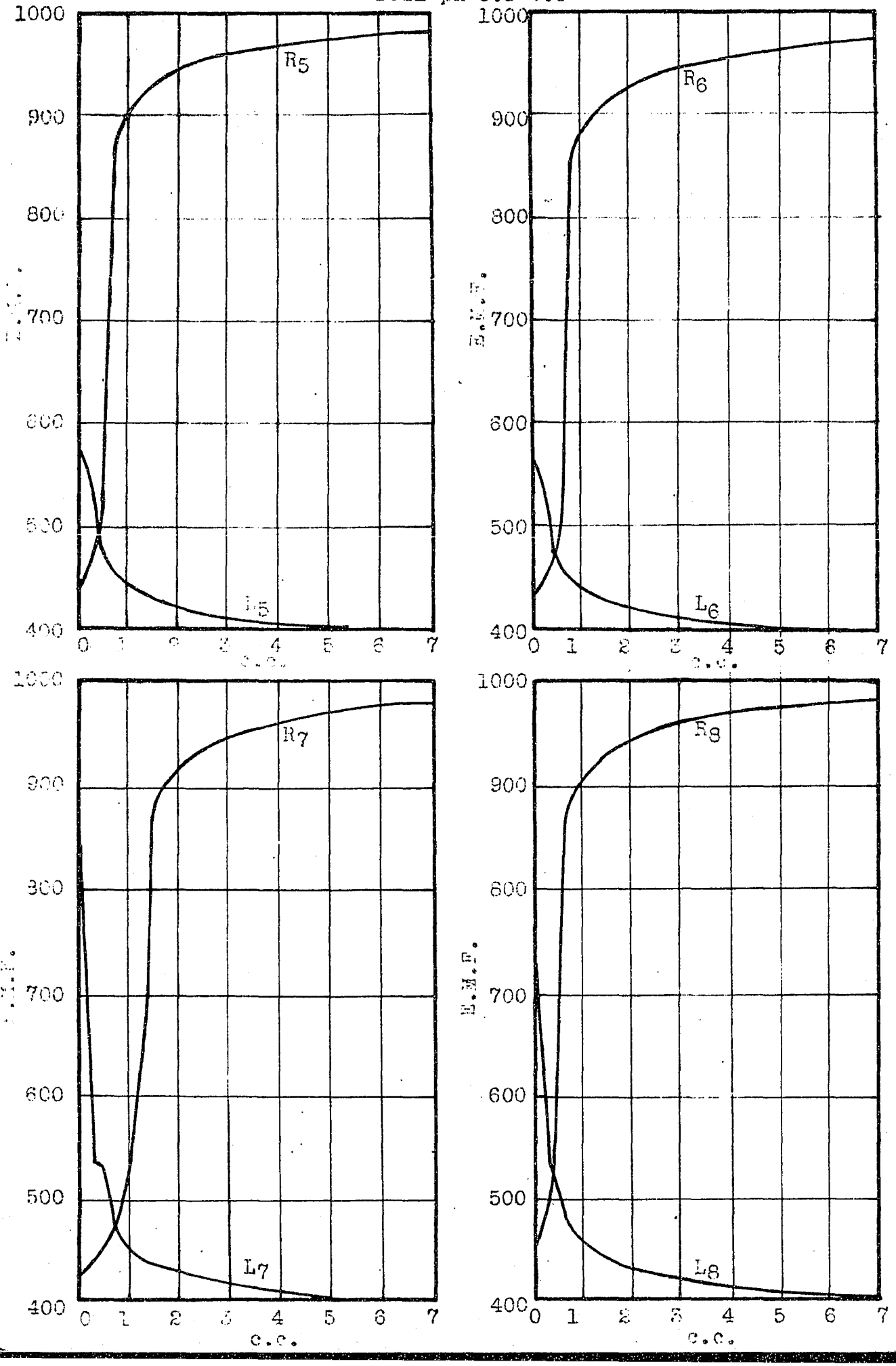

1000
900
800
700
600
500
400
R_7
L_7
R_8
L_8

STEMS.
Soil pH 6.5-7.0



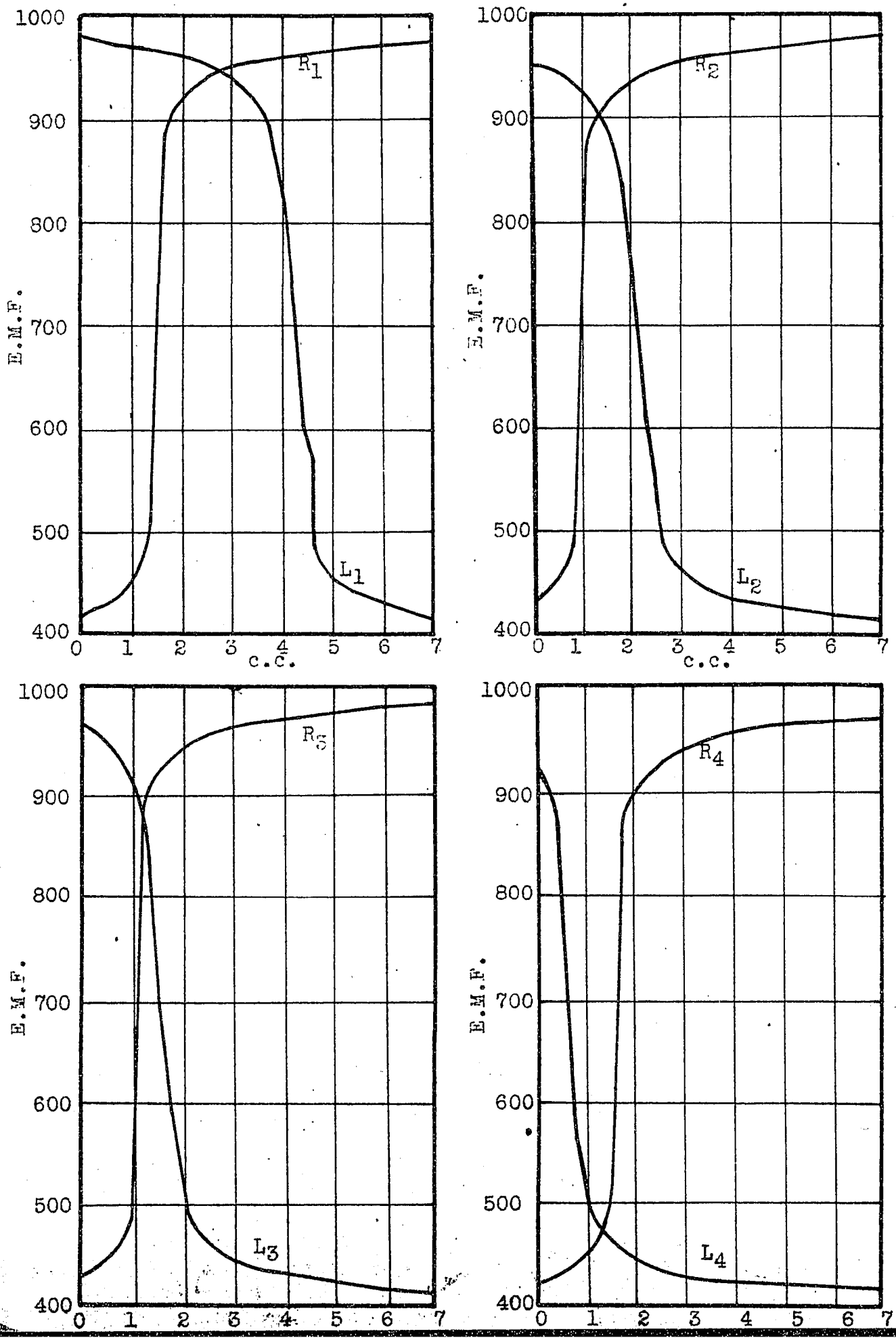
SIEMS.

Soil pH 6.5-7.0



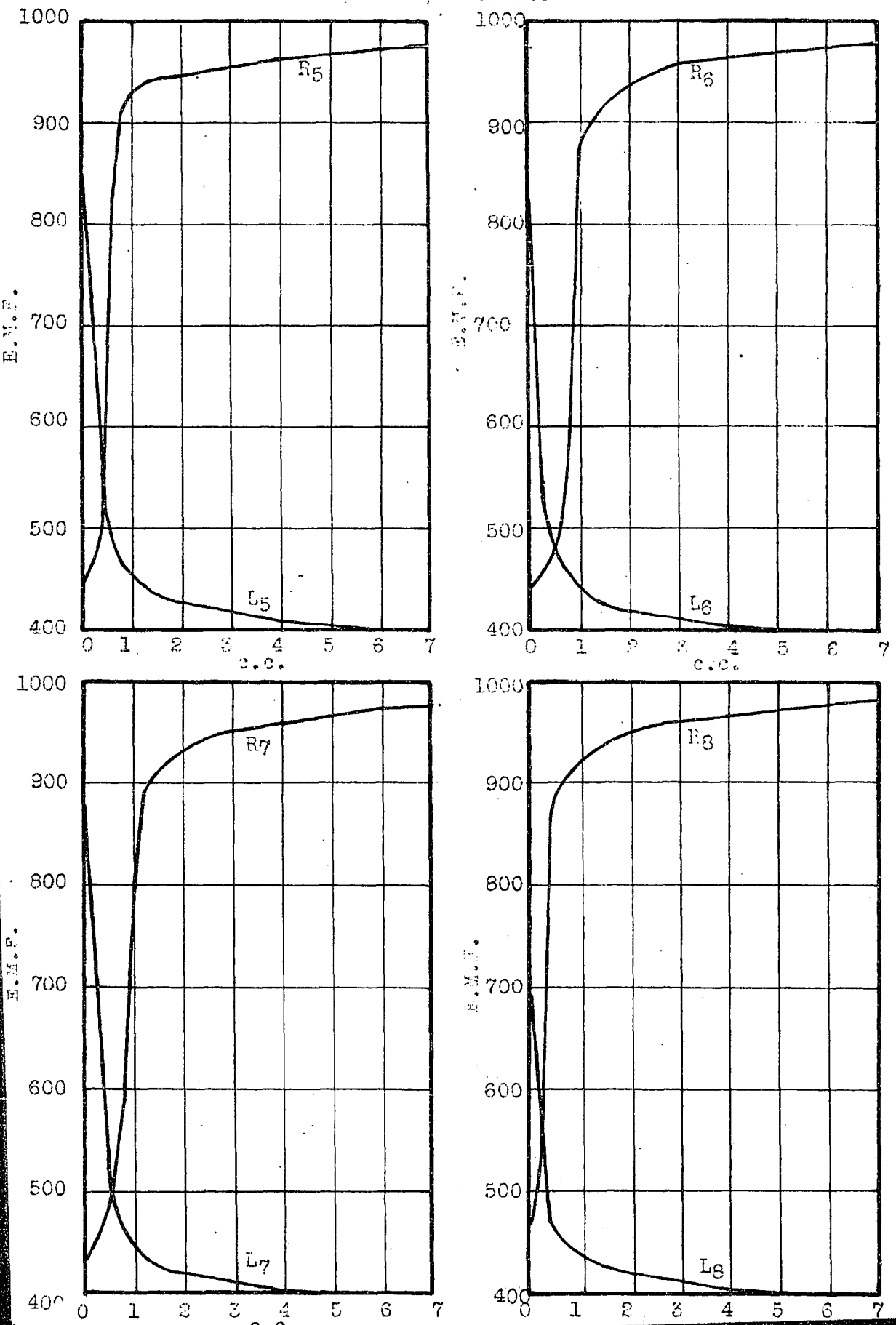
STEMS.

Soil pH 8.5-9.0



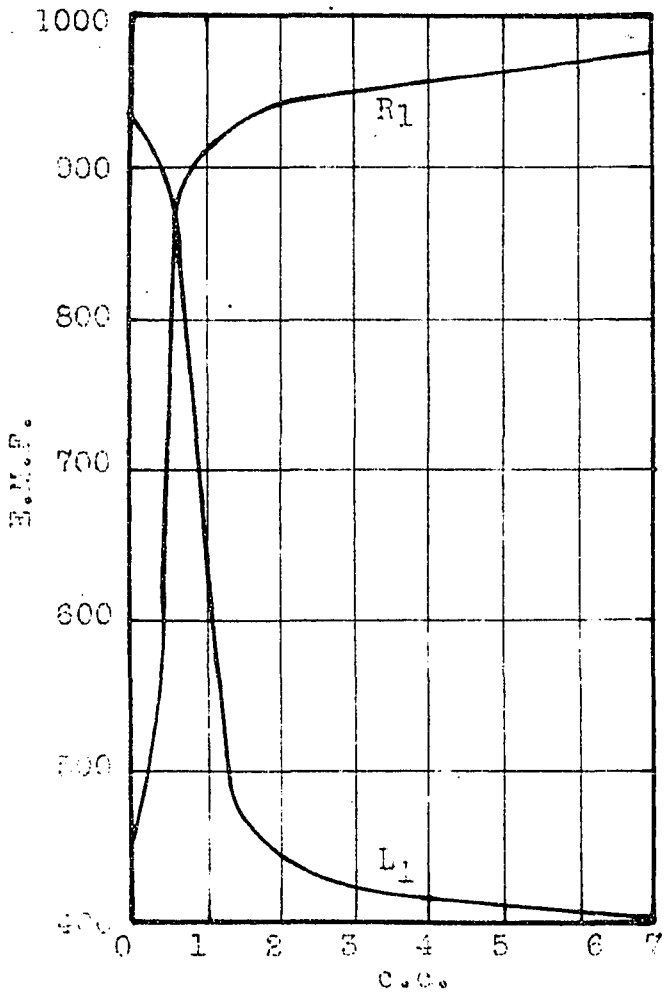
STOKES.

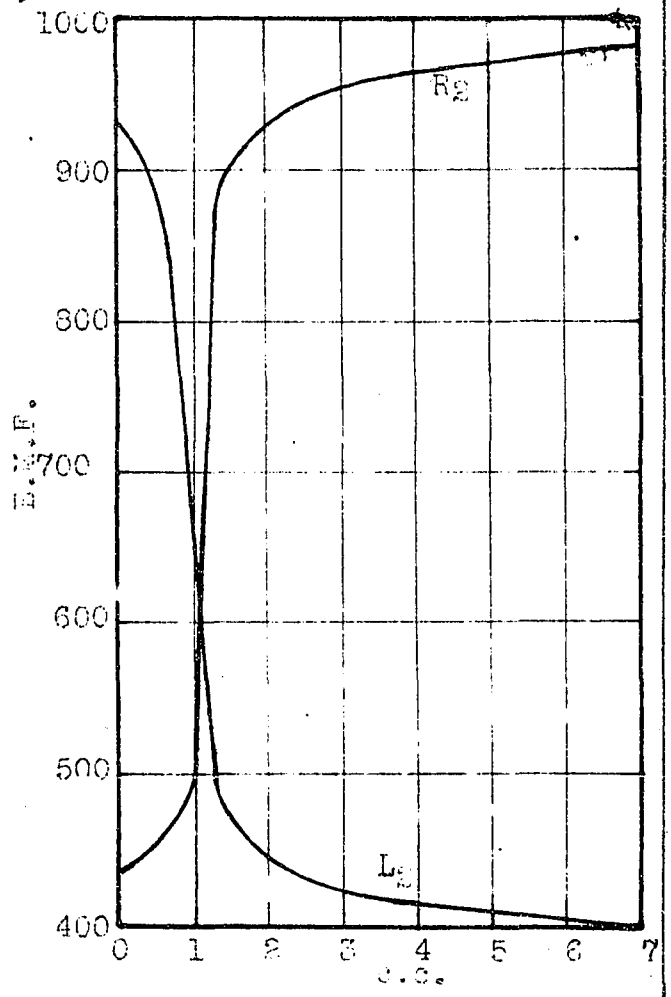
Soil pH 8.5-9.0

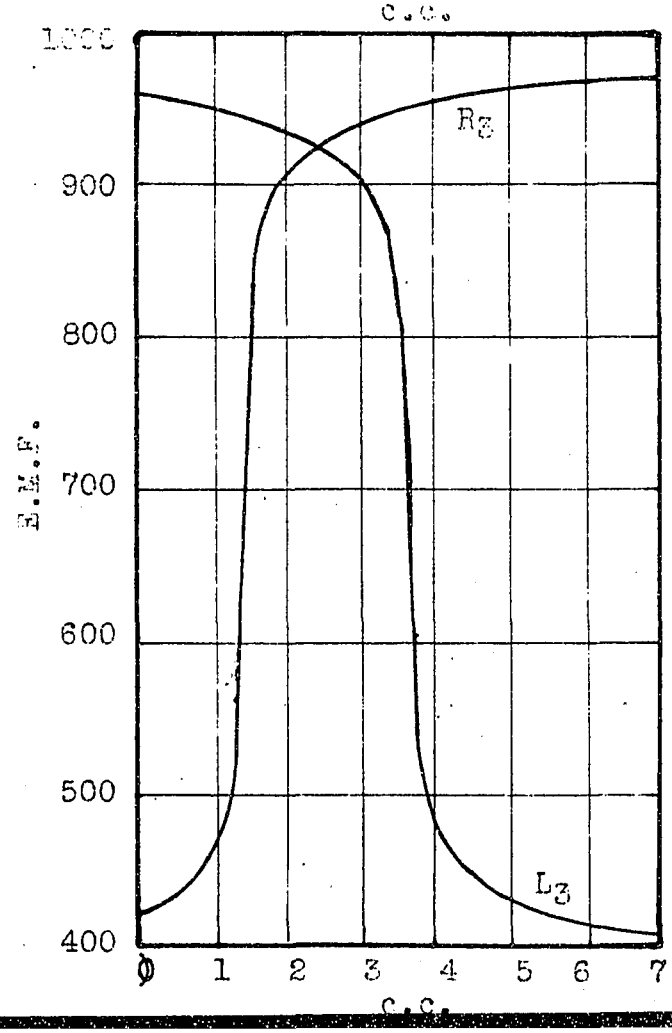


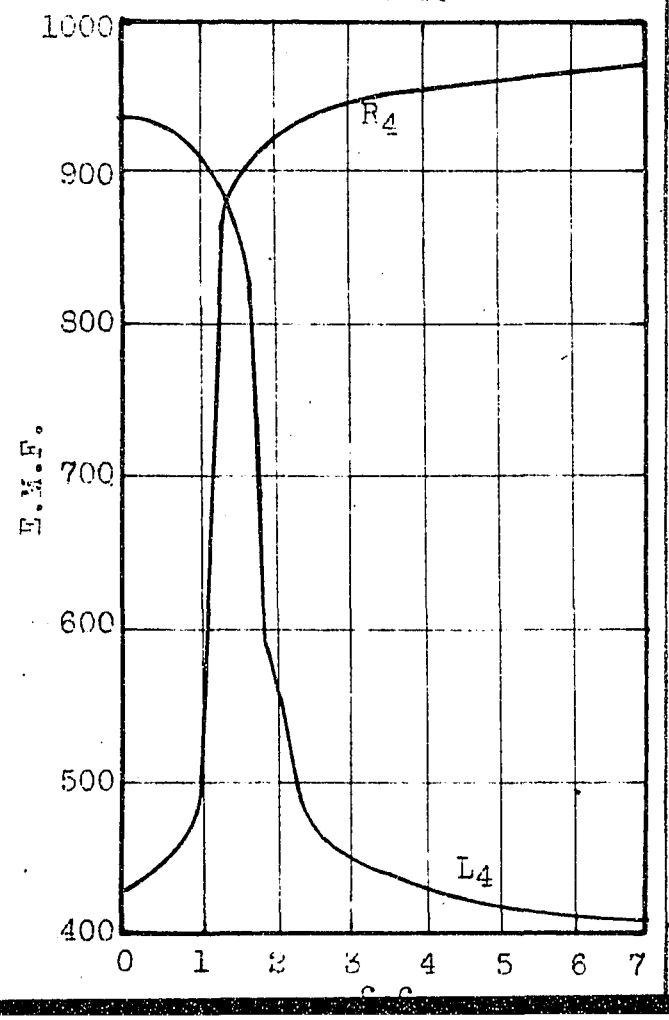
LEAVES.

Soil pH 4.0-4.8

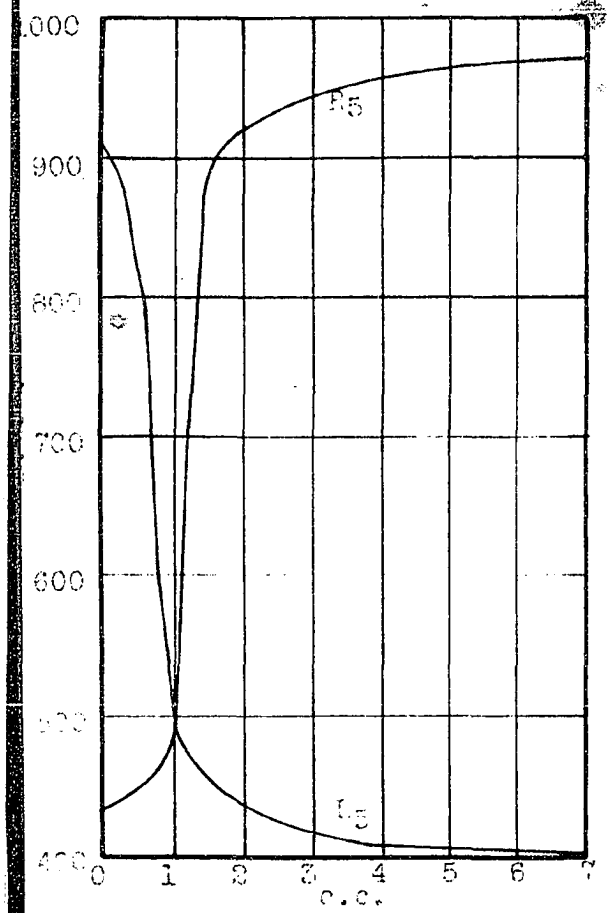


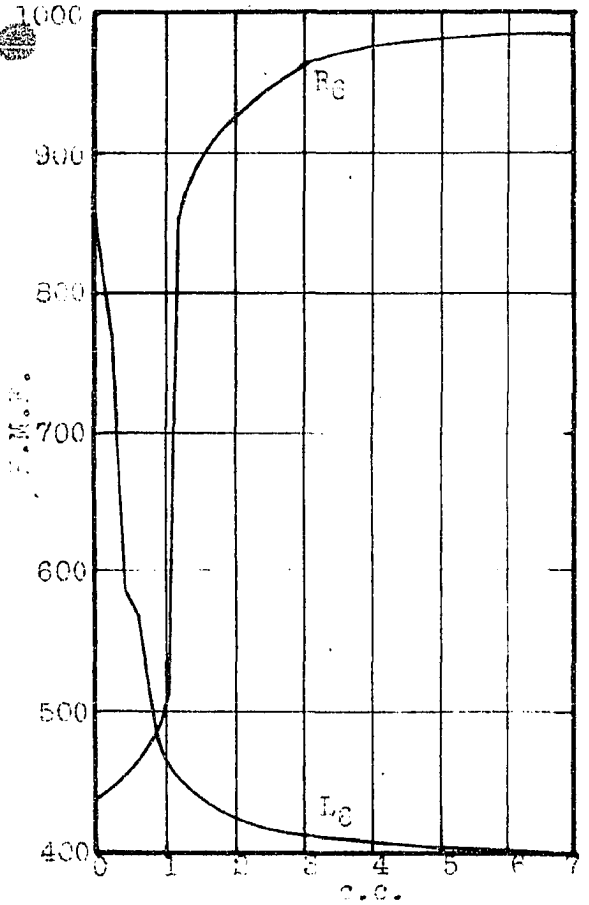


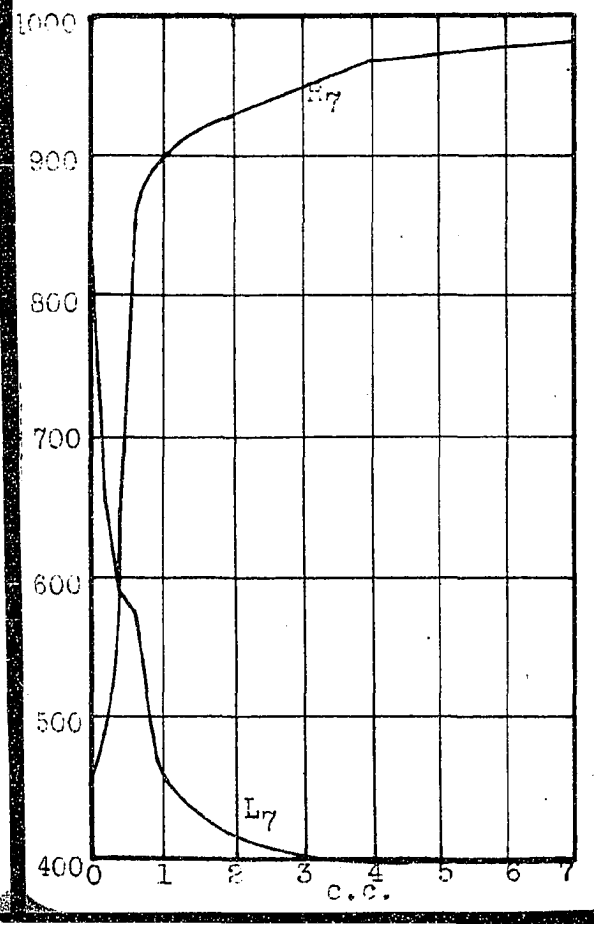


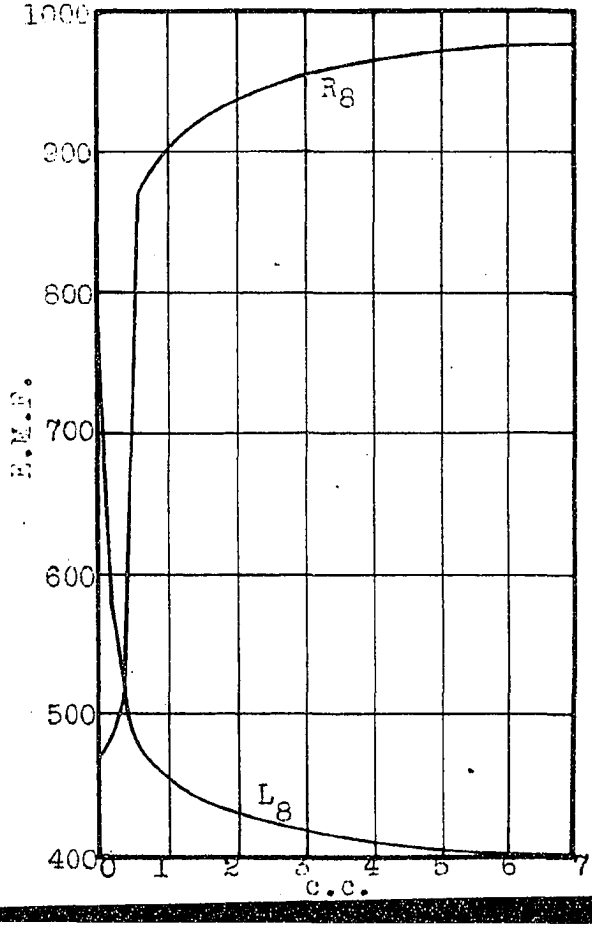


LEAVE
Soil pH 4.0-4.5.

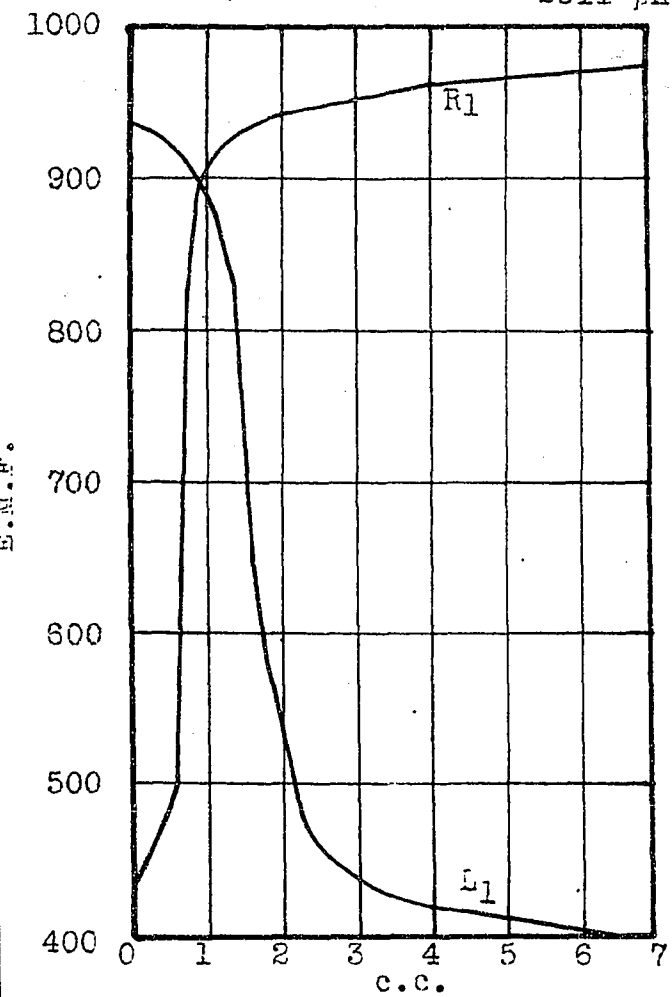


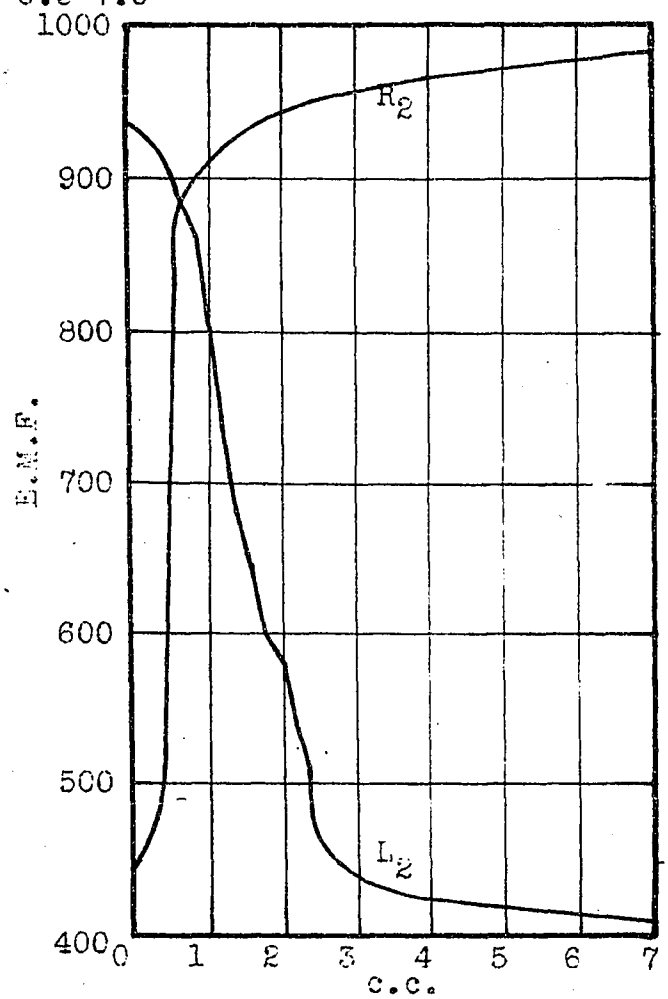


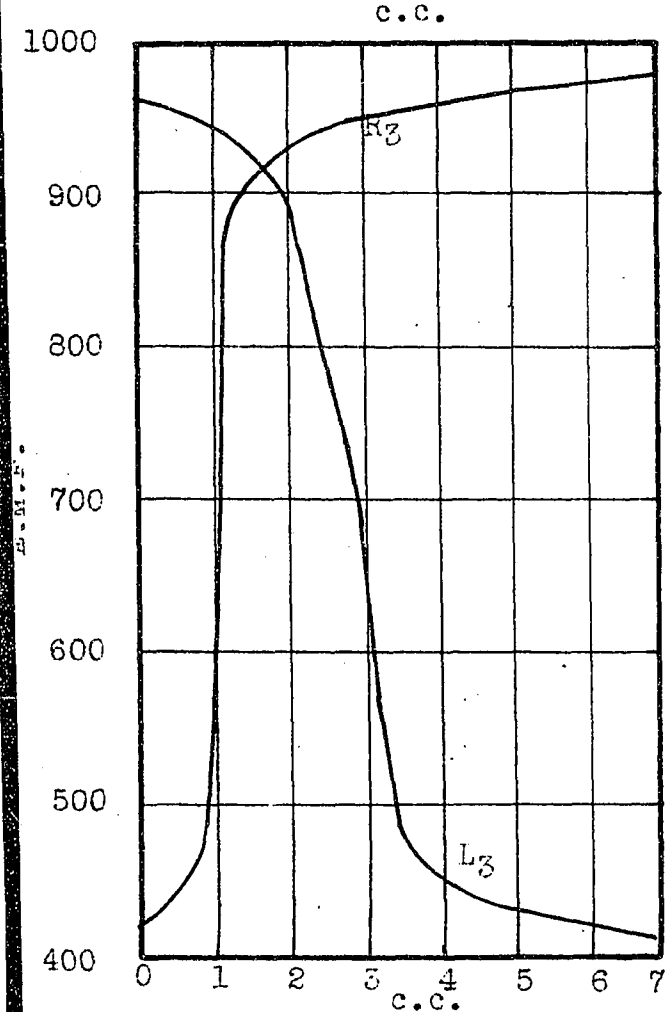


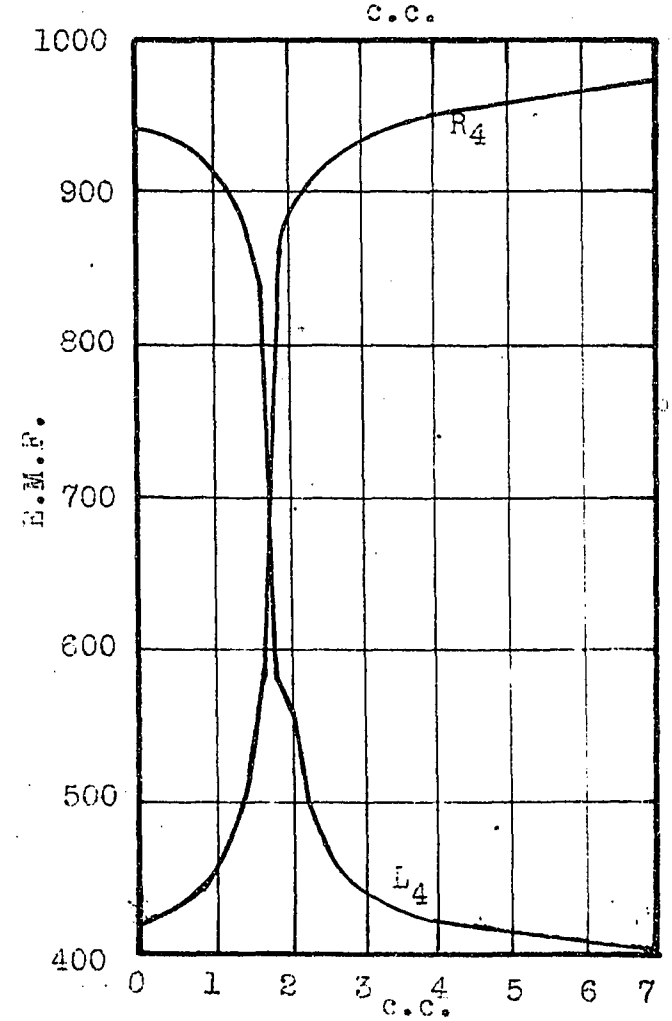


LEAVES.
Soil pH 6.5-7.0

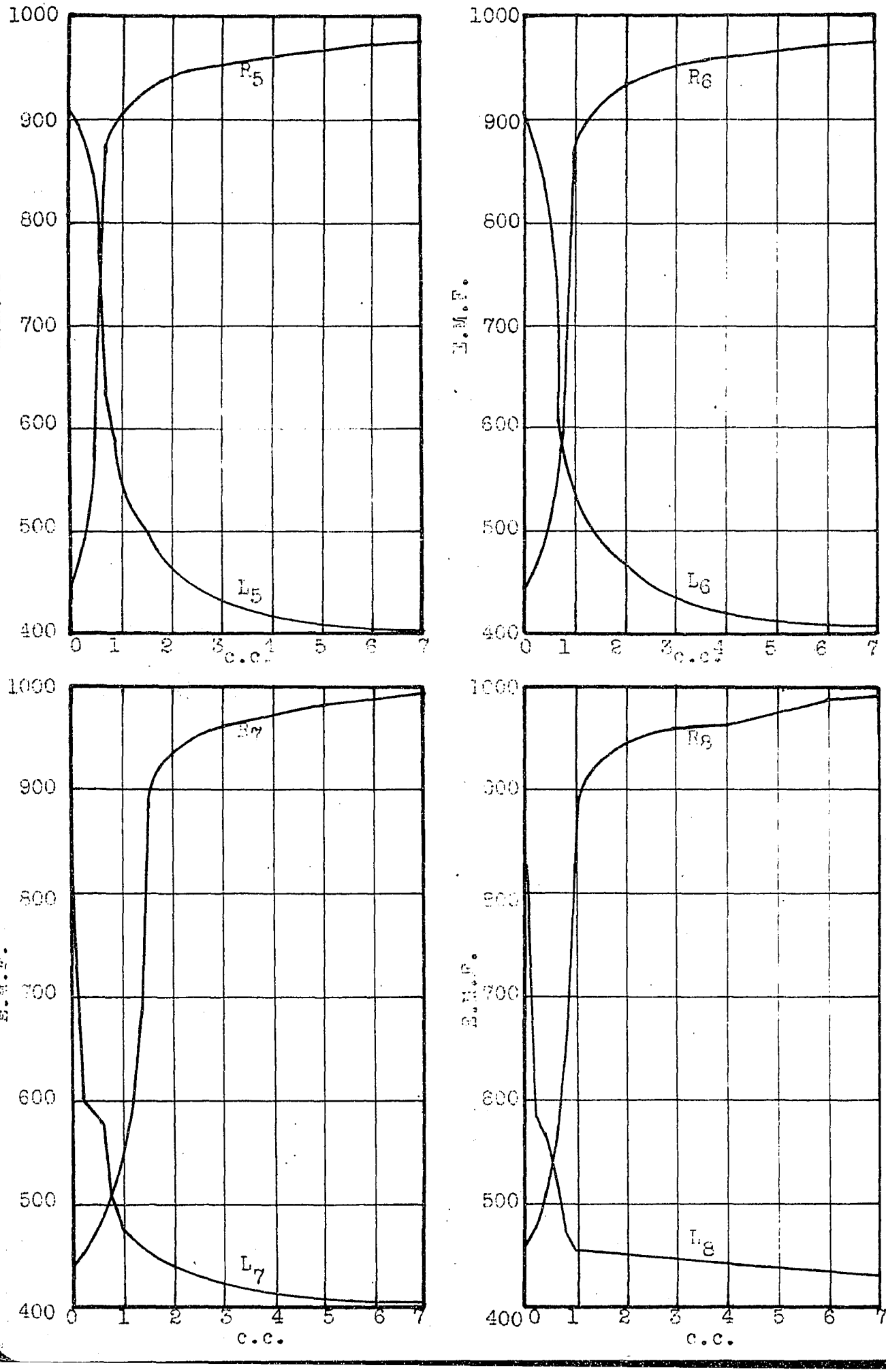




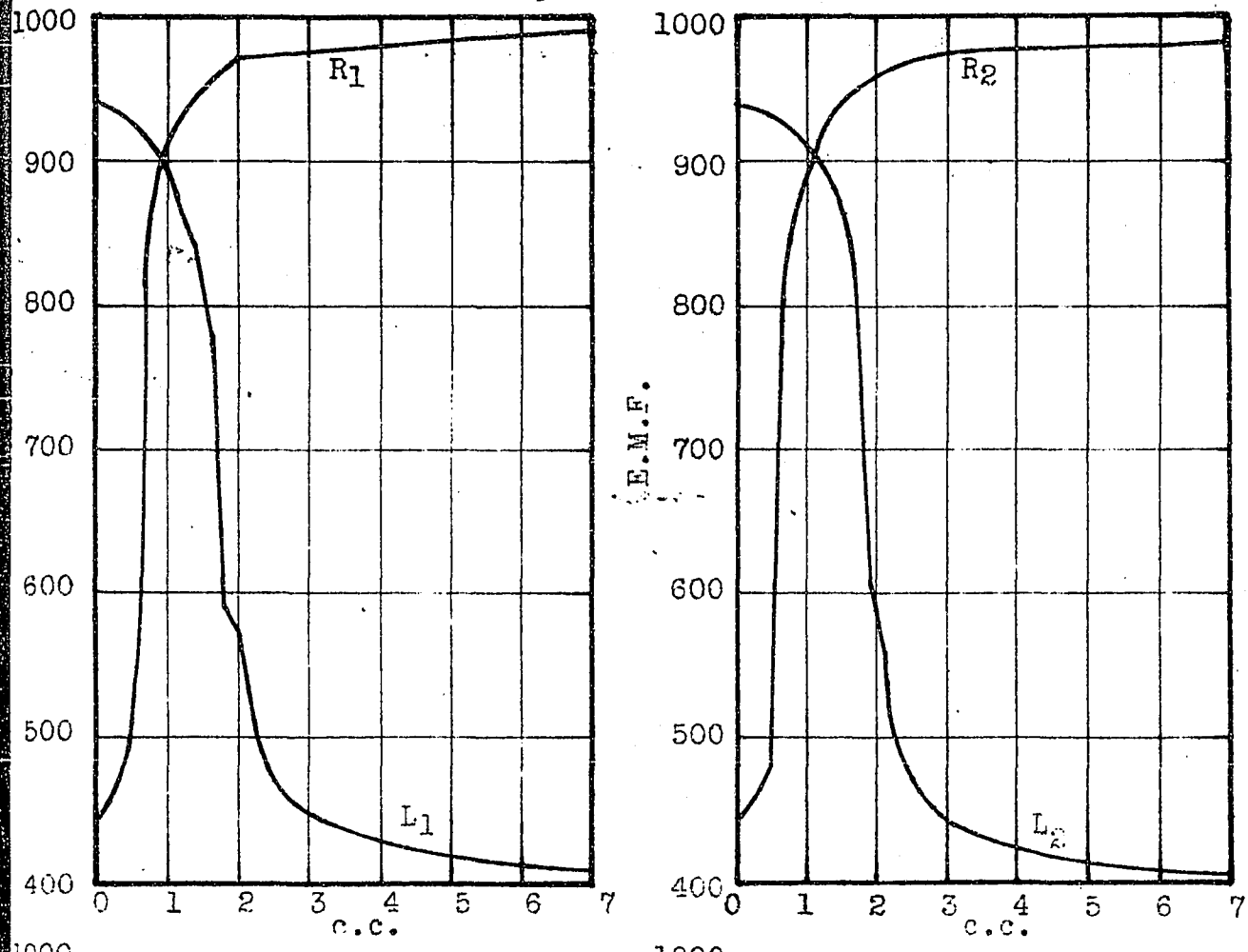


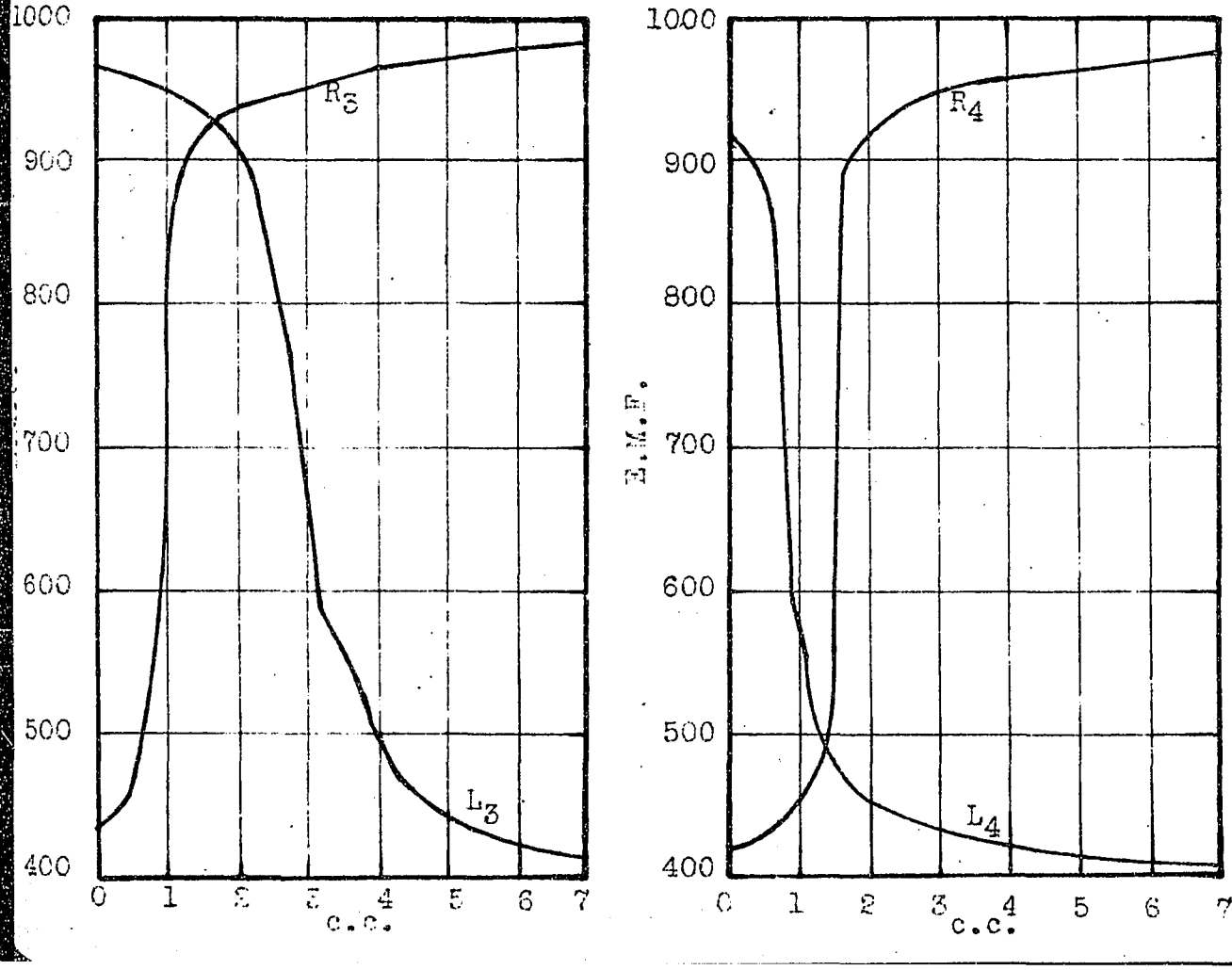


LEAVES.
Soil pH 6.5-7.0.



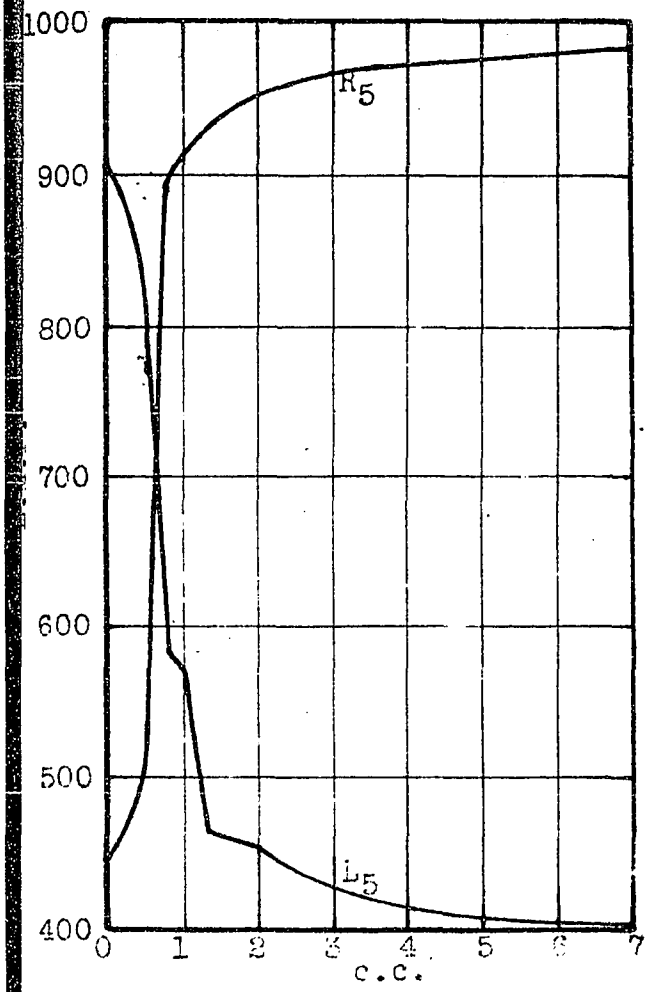
LEAVES.
Soil pH 8.5-9.0

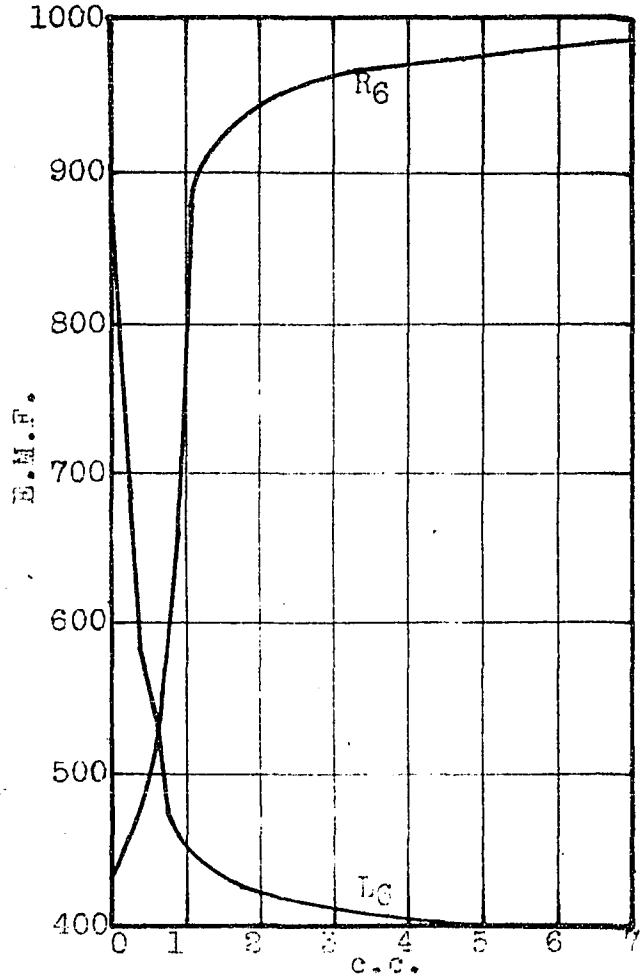


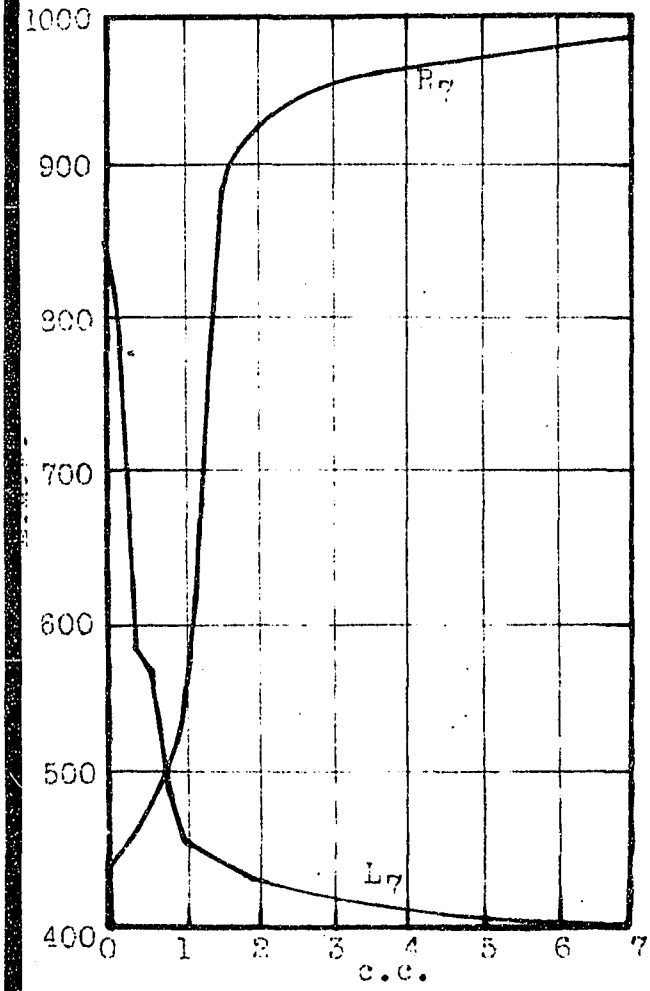


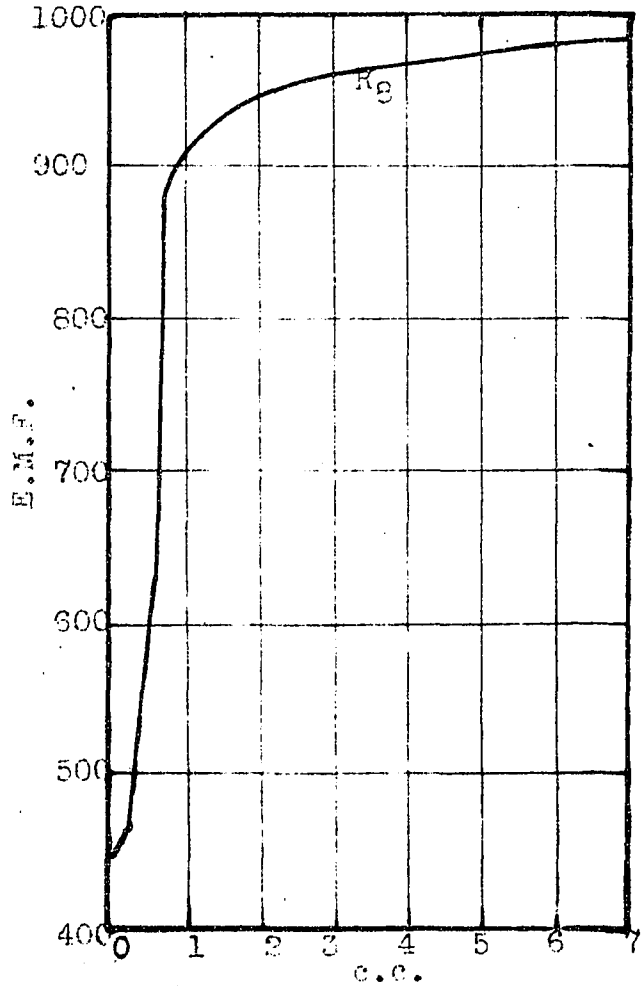
LEAVES.

Soil pH 8.5-9.0

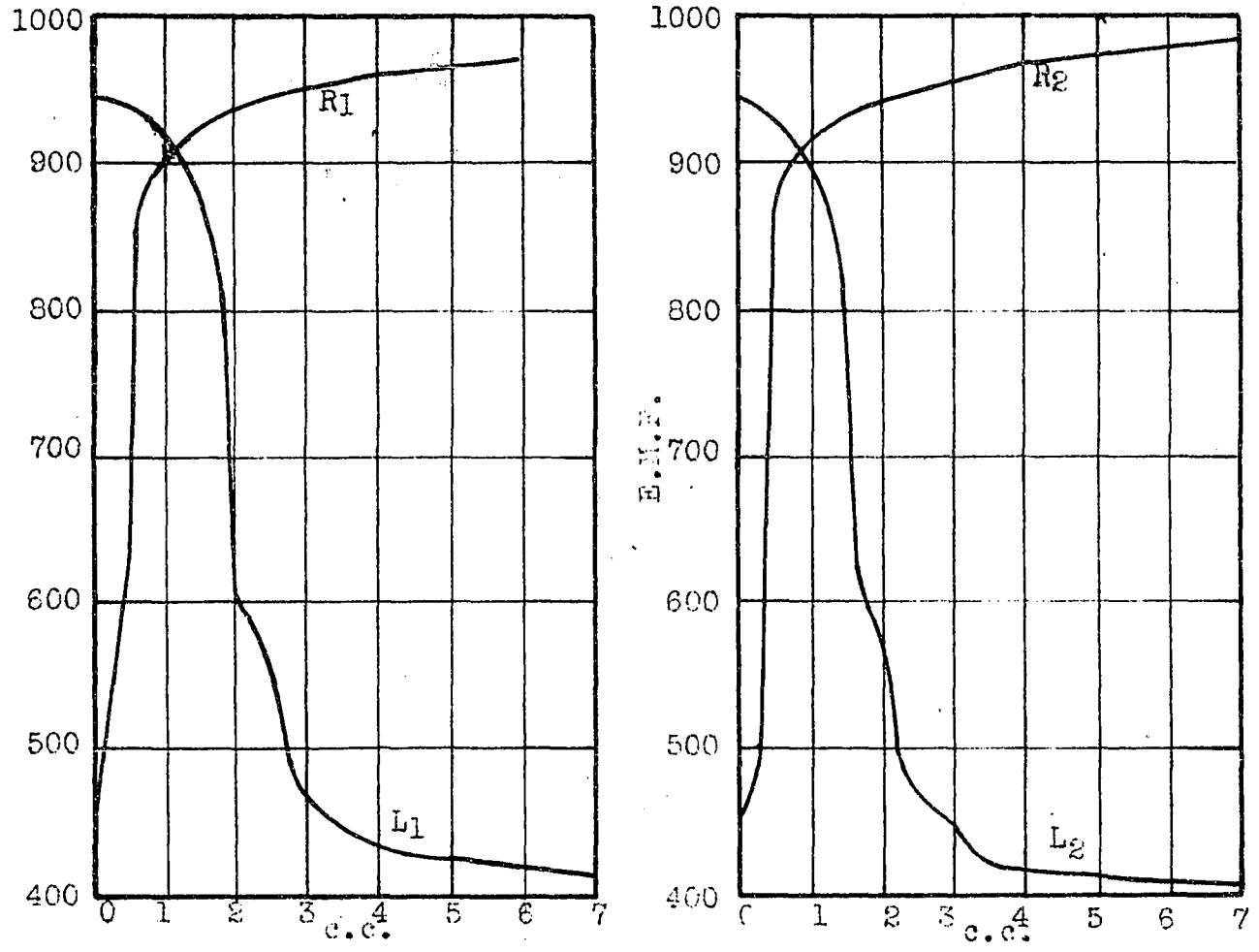


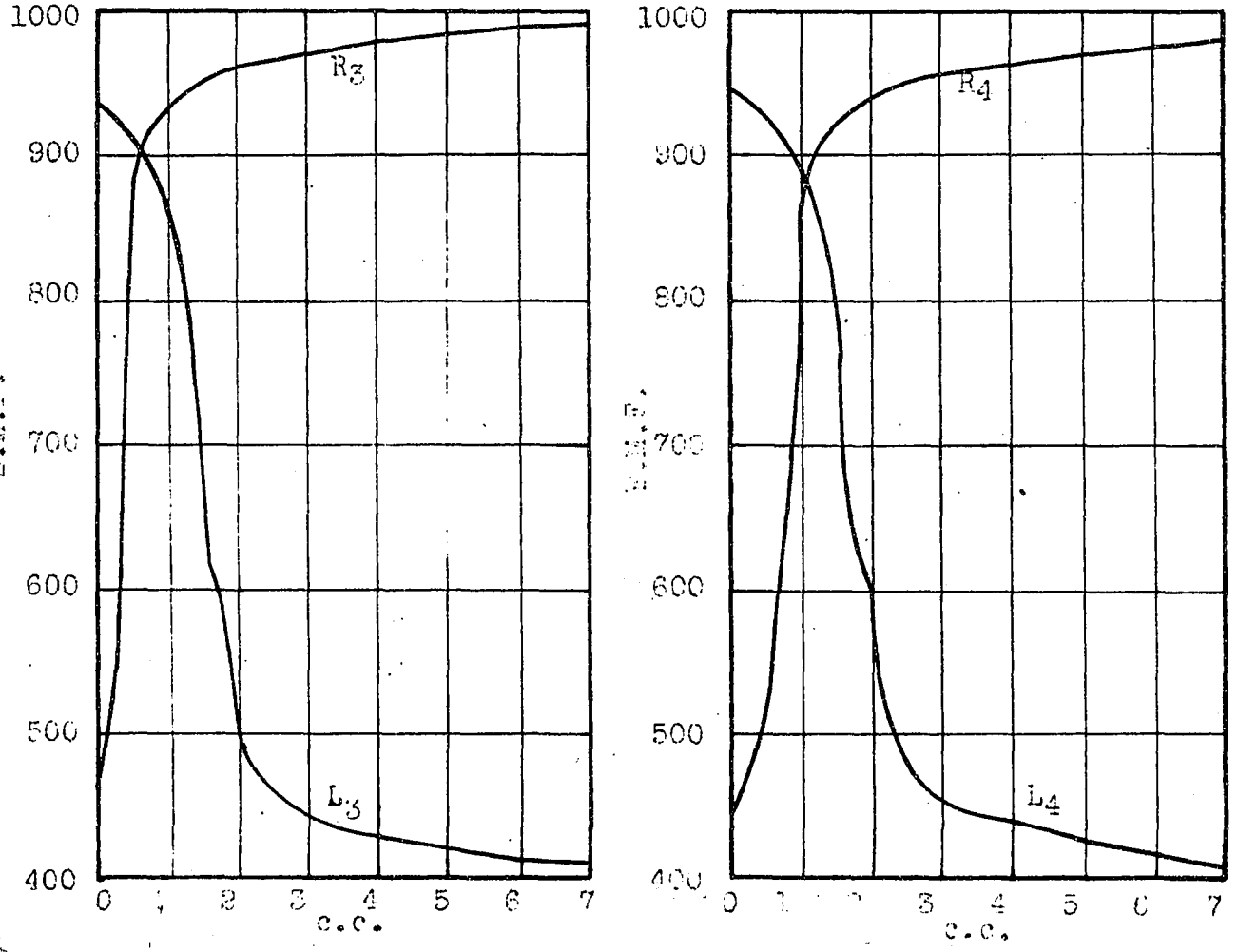






RIPE FRUIT.
Soil pH 6.5-7.0





RIPE FRUIT.
Soil pH 6.5-7.0