STUDIES ON THE POTASSIUM NUTRITION OF THE APPLE AND PEACH

I. The Effect of Potassium Fertilizer on the Potassium Content of Soil and Tree, Growth and Yield of Tree, and Keeping Quality of Fruit.

II. The Absorption, Distribution and Seasonal Movement of Potassium in Young Apple Trees, and the Effect of Potassium Fertilizer on Potassium and Nitrogen Content and Growth of Tree.

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Part II.

STUDIES ON THE POTASSIUM NUTRITION OF THE APPLE AND PEACH

I. The Effect of Potassium Fertilizer on the Potassium Content of the Soil and Tree, Growth and Yield of Tree, and Keeping Quality of Fruit.

INTRODUCTION

In the spring of 1928 fertilizer experiments were started in apple and peach orchards in different sections of the State of Maryland to determine whether or not the application of potassium fertilizers had any effect upon the firmness and keeping quality of the fruit. The results obtained during the first three years of this study, reported by Weinberger (58) (59), indicated that potassium carrying fertilizers had no significant effects upon the firmness and keeping quality of apples and peaches; also, no increased potassium content could be detected in fruit from the fertilized plots. Nevertheless, it became apparent that a more conclusive answer necessitated the continuance of the study on the same plots to determine if the applied potassium had moved down through the soil, and if so, whether or not it had entered any part of the tree, even though not increasing in the fruit. A further consideration involved the possible slowly cumulative effects of annual potassium applications over a longer period.

Any attempt to solve the above problems naturally required a study of the available potassium in the soil. Twig and fruit samples were essential for their content of total potassium. Injection of potassium-carrying fertilizers into the soil in aqueous solution, to insure proper distribution of the available materials near the roots of the trees was another feature in attacking the problem. Firmness and keeping quality as well as annual growth and yield responses were studied throughout the duration of the experiment with some modifications over the previous work.

LITERATURE REVIEW

Very few workers have studied the replaceable potassium content of orchard soils. Lilleland (30), working on various California soils, reports a definite decrease in the replaceable potassium content as greater depths are reached. McKinnon and Lilleland (36), as well as Wallace and Proebsting (57) found that when potassium fertilizers were applied, large amounts were fixed in the upper few inches of soil. According to Proebsting (43), sixty-five per cent of the potassium added to the soil as fertilizer could be accounted for in the first foot; also there was no leaching beyond the second foot.

The potassium content of apple fruits when fertilized with potash fertilizers was increased according to Hopkins and Gourley (26). Wallace and Proebsting (57) and Wallace (55) stated that the potassium content of the leaves, twigs, and fruit of apple trees in England was increased by potassium fertilizer applications. Proebsting (43), working in California, reported that there was no additional absorption of potassium by apple trees on potassium fertilized plots. He attributed this result to a fixation of potassium in the surface soil. Analyzing the potassium content of different orchard soils, Brown (11) found that the potassium content of the tree tissues was correlated with that of the soil.

McKinnon and Lilleland (36) showed conclusively that the potassium content of the lower levels of the soil could be markedly increased by injecting a solution of potassium fertilizers into the soil. Later Lilleland (31) showed that such a method of application caused the potassium content of prune leaves to be greatly increased.

Many researches on the effect of potash fertilizers on the growth and yield of apples and peaches are to be found in the literature. Nearly all of these works indicated that under the soil conditions of the United States no response could be expected. The following citations are presented as evidence of this statement: Alderman and Crane (2), Ballou (4), Morris (37), Sax (48), Cooper and Wiggans (16), Crane (17), and Larson (28). However, a few workers have obtained a response. Shaw (51) has shown conclusively that potassium, with addition of lime, caused a marked growth response on a sandy loam soil. However, potash fertilizers without lime did not produce increased growth, and still lime alone was not sufficient. Further investigations on the soil conditions present are necessary in order to evaluate the causal factors involved. According to HofMann (25) significant effects of potassium fertilizers upon the growth and yield of apple trees were obtained under cultivation in Virginia. McCue and Detjen (34) in summarizing a seventeen year test of fertilizers for apple trees in Delaware stated that a complete fertilizer was essential for best growth and yield. A yield response of apple trees to potassium applied as wood ashes was reported by Beach (7), while Hedrick (24) a few years later showed only slight differences. Chandler (13) indicated that the differences that Beach and Hedrick obtained were not large enough to be of significance.

That detrimental effects of a cow pea cover-crop on the growth and yield of peaches were corrected by the addition of potassium sulfate was shown by Pickett (41). Ruth (47), continuing this work, determined that the cause for increased fruitfulness was the prevention of formation of shoots less than 1 cm. in length which were unproductive. Auchter and Schrader (3) indicated that under certain conditions potassium in addition to nitrogen and phosphorous, will produce larger, more vigorous trees than nitrogen alone or in combination with phosphorous.

A detrimental effect of potassium on the growth of peach trees was demonstrated by Alderman (1) but his results did not necessarily determine the injury to be a potassium effect as the anion present may have been responsible.

Nearly all work conducted in England showed a beneficial effect of potassium on growth and yield. The investigations of Grubb (23), Dyer and Shrivell (20), and Wallace (55) are good examples.

Investigations on the effect of potassium fertilizers upon the firmness and keeping quality of apples and peaches are few in number. Stuckey (52) showed that potassium fertilizers improved the shipping quality and length of storage life of peaches. The investigations of Overley and Overholser (40) indicated that any effects of potassium fertilizers resulted from an influence upon the size and color of the fruits. The study made by Weinberger (59) did not show any effect of potash fertilizers upon the firmness and keeping quality of apples and peaches. Wallace (56) in England finds that potassium sulfate decreased breakdown in cold storage, while at ordinary temperatures, the reverse was true. However, less decay was found in the potassium deficient fruits.

MATERIALS AND METHODS

Plot Layout

The orchard plots used were identical with those reported by Weinberger excepting that data were used from a Williams apple orchard at Berlin, on a sandy loam soil. Thus four apple and four peach orchards on six soil types were involved. The fertilizer treatments included muriate of potash, sulfate of potash, sulfate of potash-magnesia, kainit (20%), and no potassium fertilizer. All plots received a basic treatment of sodium nitrate, and certain plots received superphosphate. Two rates of application were used. A five pound and ten pound application per tree of muriate of potash or its equivalent for the apples, and a three pound and six pound per tree of muriate of potash or its equivalent for the peaches. The five and three pound amounts will be designated as single amounts and the ten and six pound applications will be designated as double amounts. The plots which received nitrogen, phosphorous, and potassium will be called complete applications and those which received only nitrogen will be designated as checks. The number of trees per plot averaged about fourteen, ranging from ten to sixteen.

The actual plot layout was unsystematic and replications in one location were few and inconsistent. For this reason, in parts of the study, the entire experiment was considered as a population, the only distinction being between apples and peaches. Thus it was possible to have three replications of any treatment of either apples or peaches. In the case of the growth and yield records all plots receiving the single application were combined, likewise the double, complete and check plots, giving four treatments regardless of the nature of the potassium carrier. The analysis in this way depends upon the assumption that if potassium fertilizers were to produce any significant tree responses of any type, similar effects should be produced in the different locations, especially under those conditions where a similar soil type exists.

Method of Obtaining Soil Samples

The soil was extremely dry at the time when the bulk of the samples were dug, thus precluding the use of either a soil auger or a soil sampling tube. However, the samples were satisfactorily obtained by the use of a two-handled post-hole digger. Since samples from three six-inch layers were obtained, it was necessary to dig out around each hole with a spade before the next layer was sampled, in order to prevent contamination among the layers. The samples were dug just within the spread of the branches of the tree, so as to obtain soil which annually had received the fertilizer applications. Four samples from three six-inch layers were obtained from each plot sampled. In general, a double, a single, and a check plot were sampled from each orchard.

Chemical Methods

Replaceable Potassium in the Soil. * The extraction apparatus used is that reported by Shollenberger and Dreibelbis (49). A 100-gram sample of air dry soil was leached with 750 millilditers of normal ammonium acetate solution, adjusted to a pH of 7.07. An aliquot of the filtrate was evaporated to dryness on the steam bath, the ammonia burned off and the remaining salts taken up with 25 milliliters of water, and potassium determined by the sodium cobaltinitrite method of Schueler and Thomas (50). The figures obtained include water-soluble potassium as the samples were not extracted with water before the ammonium acetate leaching.

pH Determinations. The pH of all soil samples was determined by means of the quinhydrone electrode method. A portable Youden potentiometer and galvanometer set was used. A saturated calomel cell served as the reference electrode, while a gold electrode was used in the unknown solution. A KCl agar bridge connected the reference cell and the unknown solution. The dry soil was sifted through a forty mesh sieve, and then approximately twenty-five grams mixed with an equal weight of water. A small

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* The replaceable potassium contents of soil samples obtained in 1931 were determined in the laboratory of R. F. Thomas, of the Department of Soils.

amount of quinhydrone was added, the mixture stirred, and the pH determined with the above apparatus.

Total Potassium in the Plant Tissues. Two-gram samples of the ground, oven-dried material were ashed in an electric muffle furnace at 550 degrees Centigrade. The ash was taken up with hydrochloric acid, and transferred with water to a 100 milliliter volumetric flask, made to volume, and a twenty-five milliliter aliquot taken. Potassium was then determined by means of the sodium cobaltinitrite method of Schueler and Thomas. Since the method used had not been accepted by chemists in general, it seemed advisable to check it with the official platinic chloride method. Through the courtesy of Dr. Lilleland of the University of California, samples of prune leaves on which determinations had been run by the official method, were obtained for analysis. Table 1 gives a comparison of the two methods as evidenced by the potassium content of the prune leaves.

Table 1.- A Comparison of the Total Potassium Content of Prune Leaves as Determined by the Platinic Chloride and Sodium Cobaltinitrite Methods.
(K as per cent dry weight)

Sample No.	Platinic Chloride Method	Sodium Cobaltinitrite Method
1	1.46	1.50
2	1.31	1.29
3	2.31	2.38
4	2.85	2.99

The figures are in rather close agreement considering that different glassware, different solutions, different operators, as well as different chemical methods were employed in obtaining the results.

Moisture. All tree samples were dried at 70 degrees Centrigrade for forty-eight hours in a forced-draft oven, and the loss in weight was called moisture.

Method of Injecting Fertilizer Materials.

The method presented by McKinnon and Lilleland (36) was employed. A fifty gallon barrel spray pump, producing a maximum pressure of 150 pounds was used. Sufficient fertilizer material for two trees was dissolved in fifty gallons of water and twenty-five gallons of solution were injected around each tree to a depth of three feet. The area of injection was approximately that covered by a normal surface application of fertilizer. Figure 1 shows the apparatus in use.

Method of Sampling Fruit for Studies of Keeping Quality.

Two types of samples were picked: (1) a selected sample, which consisted of fruit picked for a given color, size, and maturity, regardless of differences in these respects caused by treatment, (2) a random sample which consisted of all the fruit from several representative trees in

Fig. 1.- Injecting potassium fertilizers into the soil at College Park. 1932.

each plot. In this way, the size, color, and maturity distribution characteristic of each treatment could be determined. The fruit was subsequently separated into various sizes at one-fourth inch intervals, and into various red color classes depending upon the total color range. Figure 2 shows the size and color separations made with peaches.

Pressure Test Methods.

In the case of the apples, the Magness-Taylor (33) pressure tester with a 7/16 inch plunger was used on three uniformly distributed pared surfaces on each fruit. With the peaches, the Blake tester (9) with a 3/16 inch plunger was used, each fruit being tested six times. The skin was not removed. In general, all lots of fruit were tested at picking time and at the close of the storage period which ranged from three days to six months, depending upon the variety, etc.

There were many details connected with the methods employed in this study that were so specific for the given instances that they will, of necessity, be presented with the results obtained.

RESULTS OBTAINED

Replaceable Potassium Content of the Soil.

Soil samples were obtained during July and August, 1931 from all eight orchards by the method already described.

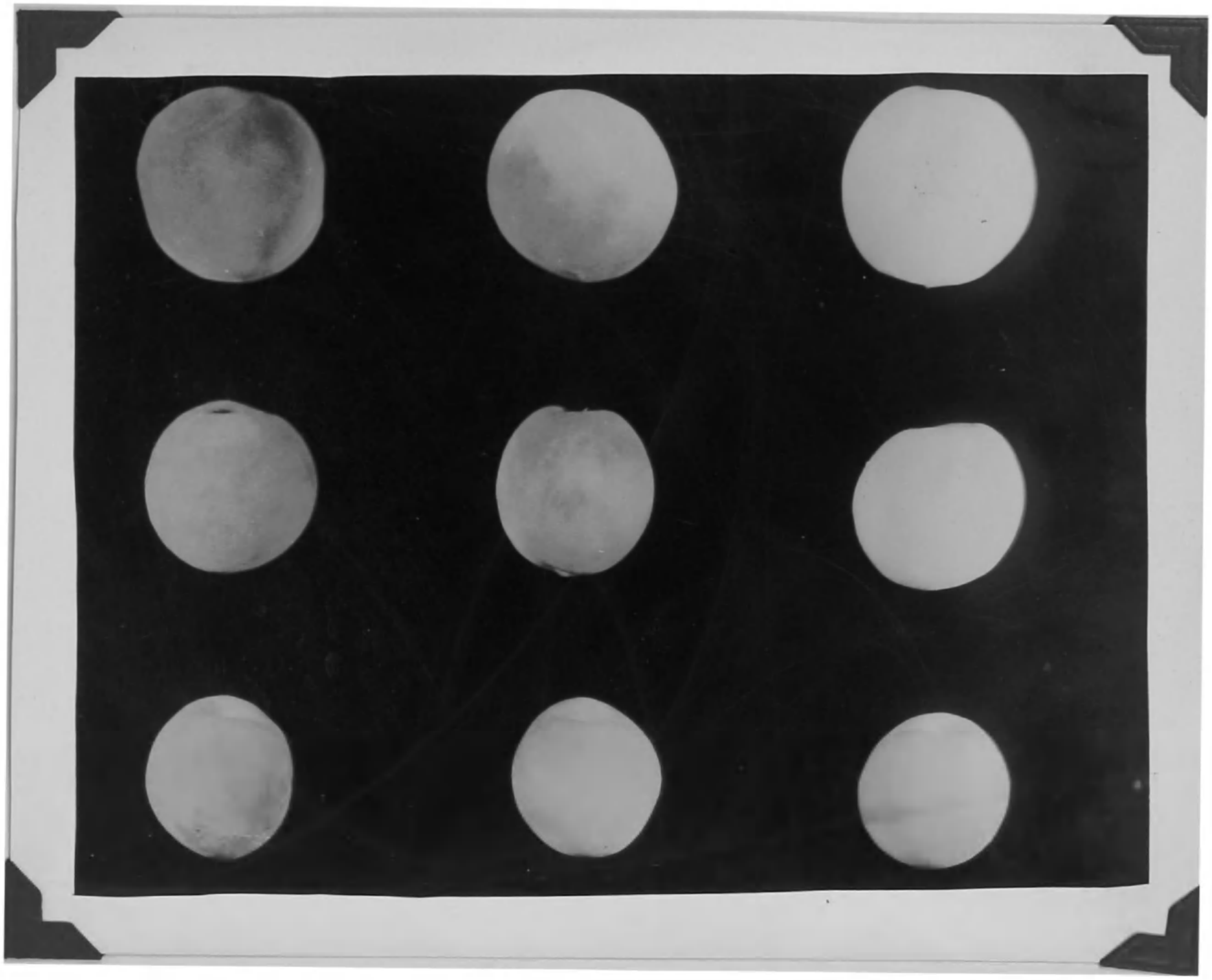


Fig. 2. - Peach fruits separated into three colors and three sizes. Colors - Red color as per cent of total surface - 50-100%; 25-50%; and 0-25%. Sizes - Diameter in inches $2\frac{1}{2}$"-$2\frac{3}{4}$"; $2\frac{1}{4}$"-$2\frac{1}{2}$"; 2"-$2\frac{1}{4}$".

Four annual fertilizer applications had been made before the period of sampling. The last application was made three or four months before the period of sampling. The soil types studied ranged from a clay loam in Western Maryland to a loamy sand on the Eastern Shore.

The complete data for the replaceable potassium content of the orchard soils are presented in Table 1 in the Appendix. The data for the peach soils gave very similar results to those from the apple soils, except that the figures on the treated peach soils ran somewhat lower due to the smaller fertilizer applications. In view of this similarity, only the apple results are presented in detail.

Extreme variations in the replaceable potassium content existed, and in order to determine the factors contributing to this variability, all four soil types were considered together as a population, and the data analyzed by Fisher's Analysis of Variance Method (21). The variance contributed by the four samples within each layer of each treatment was considered to be the best estimate of error, designated as variance within classes in Table 3a.

A condensed summary of the data obtained is presented in Table 2. The analysis of variance and the mean variance and the mean values with their approximate standard errors are presented in Table 3a and b.

Table 2.- Replaceable Potassium Content of the Different Orchard Soils at Different Depths, and Under Various Treatments.

Treatment	Depth	Hagerstown Clay Loam	Penn Gravelly Loam	Sassafras Fine, Sandy Loam	Sassafras Loamy Sand
No Potassium (Check)	0" - 6"	152	70	81	36
	6" -12"	83	36	36	36
	12"-18"	74	39	33	33
5 lbs. KCl per tree for 4 yrs. (Single)	0" - 6"	231	318	308	103
	6" -12"	93	63	100	105
	12"-18"	62	50	38	113
10 lbs. KCl per tree for 4 yrs. (Double)	0" - 6"	823	529	290	105
	6" -12"	336	161	205	78
	12"-18"	202	50	51	71

The effect of soil depth is quite striking. An inspection of Table 3b shows that the top six-inch layer is very significantly differentiated from the two lower layers, averaging all samples, but the difference between the six-inch to twelve-inch and twelve-inch to eighteen-inch layers is not quite great enough to be classed as significant. If, however, we go within the population and separate the treated plots from the untreated and make Fisher's "t" comparison on the two sets, we find that in the case of the treated plots the two layers are significantly different from one another, while on the untreated plots, such is not the case. This differential effect of treatment in the different layers is shown by the significant treatment x depth interaction. Therefore the case exemplifies the fact

Table 3a.- <u>Analysis of Variance of Replaceable Potassium in the Orchard Soils</u>.

Sources	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value
Soil Depth	2	972,695.77	486,347.88	6.5475	1.7637
Treatment	2	954,726.77	477,363.38	6.5377	1.7539
Soil Type	3	488,133.49	162,711.16	5.9977	1.2139
Depth x Treatment	4	451,758.00	112,939.50	5.8131	1.0293
Treatment x Soil Type	6	557,889.50	92,981.58	5.7198	0.9360
Depth x Soil Type	6	372,204.83	62,034.14	5.5174	0.7336
Treatment x Depth x Soil Type	12	336,219.00	28,018.25	5.1199	0.3361
Within Classes	108	1,558,888.40	14,434.15	4.7838	
Total	143	5,692,515.76			

Table 3b.- <u>Mean Values from the Above Analysis With Their Standard Errors</u>.

Soil Types	K in ppm.	Treatment	K in ppm.	Soil Depth	K in ppm.
Hagerstown Clay Loam	237 ± 20	No K	54 ± 17	0"- 6"	260 ± 17
Penn Gravelly Loam	151 ± 20	KCl 5#	134 ± 17	6"-12"	113 ± 17
Sassafras Fine Sandy Loam	122 ± 20	KCl 10#	253 ± 17	12"-18"	68 ± 17
Sassafras Loamy Sand	78 ± 20				
Diff. Necessary for Significance	56.0		48.0		48.0

that when large interactions of a definite causal nature exist, it is sometimes not advisable to apply a generalized standard error to a general mean and make interpretations for the entire population. The several soil types reacted differently in the three soil layers, producing the interaction of depth x soil type. The cause for the differential effect of both treatment and soil type in the various layers is seen in Table 2. The clay loam soil caused a much greater accumulation of potassium in the upper layer, than the loamy sand, while the gravelly loam and fine sandy loam soils occupied an intermediate position.

This difference in movement of potassium through the soil is most logically explained by the colloidal natures of the soils. If we consider the inorganic colloidal content of the soil to be proportional to the clay content, it seems most logical that the fixation of potassium is proportional to the colloid content of the different soils. Of course, qualitative differences in the colloidal materials would also affect the exchange capacity of the soils; and, very probably the silica/sesquioxide ratio of the coastal plain soils is much lower than in the soils of Western Maryland. This probable relationship would tend to support the findings of this study. In addition, colloidal matter is most abundant in the upper six-inch layer, accounting in part for the high potassium content of that layer regardless of soil type. If the proper kind of colloidal materials were present in sufficient amount, one would expect all of the applied potassium to be adsorbed immediately in the upper layer, and remain until hydrogen, or other cations replaced it, temporarily causing it to go into solution.

An important cause of the higher potassium content of the upper layer in the plots where no potassium has been applied is that the plant materials high in potassium content are continually being deposited and decompose in this layer. The potassium liberated contributes to the supply of replaceable potassium. This potassium may have originated from lower layers, and thus constitutes an upward movement of soil potassium through translocation in the plants. Also, the decomposing plant materials add to the organic colloidal material in the upper layer, and, according to McGeorge(35), the organic soil colloids have an exchange capacity considerably in excess of that of the inorganic colloids.

The effect of treatment is very marked in all cases. Figure 2a presents the results graphically.

This chart indicates that the potassium accumulates greatly in the clay loam soil, to a less degree in the gravelly loam, and still less in the fine sandy loam and loamy sand. The statistical significance of these differences is discussed later. The colloidal relationships

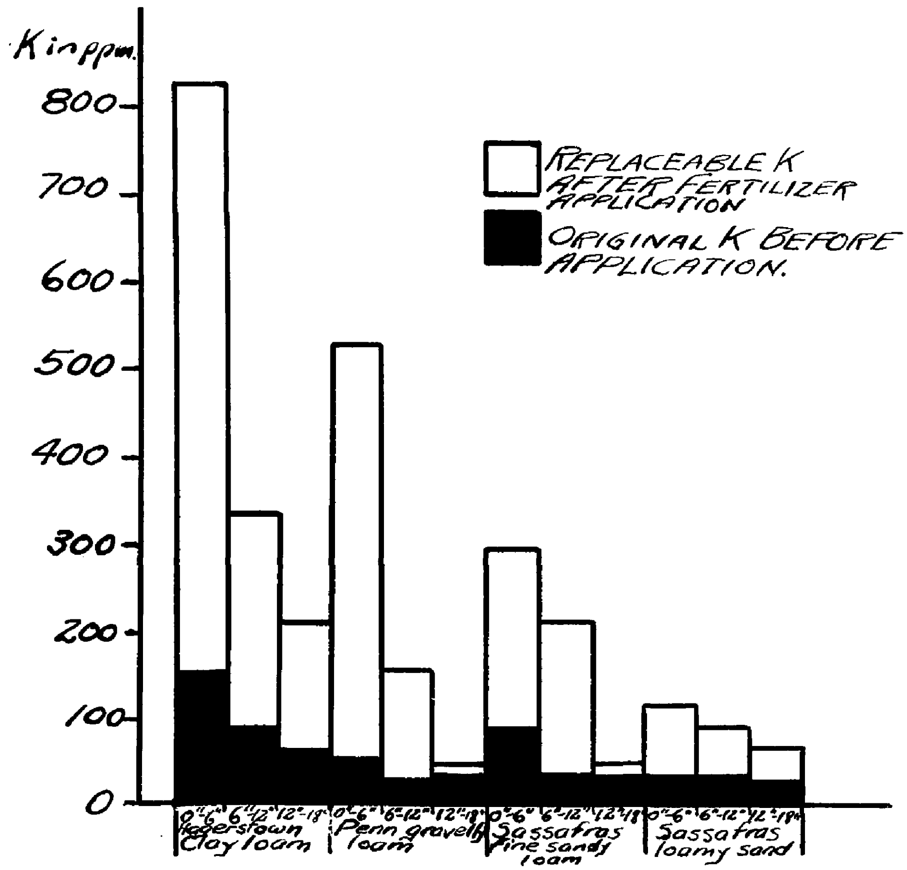


Fig. 2a. - Replaceable potassium content of the different layers of the orchard soils before and after four annual applications of ten pounds of potassium chloride per tree.

discussed above are doubtless responsible for these differences. The interaction of treatment x soil type explains the differences statistically. It is of interest to note that the gravelly loam and fine sandy loam are not far different when no fertilizer has been added, but after the application of ten pounds per tree of K Cl, the gravelly loam contained a greater amount of potassium in the upper six-inch layer, while the fine sandy loam contained more in the lower levels than the former. In general, the double application caused a greater accumulation than the single, although this did not hold true with the loamy sand. This is probably due to either soil heterogeniety or sampling error.

Although a large amount of the applied potassium is absorbed in the upper few inches of soil, it is of interest to note that when the different soil types are considered separately and Fisher's "t" comparison made, the two fertilizer applications had caused all three layers to be significantly higher in replaceable potassium than the corresponding layers of the plots which received no potassium fertilizers. Also, the second and third six-inch layers were significantly higher under the double application than under the single treatment. This indicates that with the soil types included in this study and under the given fertilizer treatments, potassium is moving down through the soil to some extent. Probably the exchange capacity of these soils was lower than that reported by McKinnon and Lilleland (36) where practically no potassium moved down from the surface, even under extremely heavy surface applications of potassium sulfate.

Considering the soil types as a whole, regardless of treatment or layer, the Hagerstown clay loam is significantly higher in replaceable potassium than the remaining types. There is not a significant difference between the Penn gravelly loam and the Sassafras fine sandy loam. The gravelly loam is significantly higher than the loamy sand, while the fine sandy loam is not quite significantly differentiated from the loamy sand, although the probability of such a difference occurring due to chance alone would be only once out of seventeen trials.

In general, it can be said that the soils studied were originally rather low in replaceable potassium. From a comparison of the data by Lilleland (30) and Wallace and Proebsting (57), one would expect to find some signs of deficiency in the trees growing on certain of these soils. As will be shown later, no such signs have been noted. However, as Proebsting (43) points out, plants seem to be capable of utilizing a certain amount of non-replaceable potassium. Also, perhaps the potassium-supplying power of the soil is not necessarily correlated with its replaceable potassium content, particularly with reference to fruit trees which are deep rooted.

A Comparison of Available Potassium Content of the Soil as Determined by the Neubauer Method and Replaceable Potassium Content Method.

The Neubauer method (39) of determining the available potassium of the soil has received rather general acceptance among those who have tested it using annual plants. No work has yet appeared where it is used in analyzing orchard soils. From the nature of the method it seems rather logical that the results obtained would be a rather true index of the potassium-supplying power of the soil. Therefore, it is of interest to measure the association between these results and the replaceable potassium determinations.

Portions of certain samples obtained for the replaceable potassium determinations were sent to the laboratory of S. F. Thornton at Purdue University, where the Neubauer determinations were made. The samples were selected so as to have a comparison from three soil types, three layers and three treatments. The soil types involved were Sassafras loamy sand, Penn gravelly loam and Hagerstown clay loam.

The complete results of the Neubauer determinations are presented in Table 2 in the Appendix. Table 4 gives the summarized values of the replaceable and Neubauer results side by side for purpose of comparison.

Table 4.- The Replaceable and Neubauer Potassium Content of the Different Orchard Soils at Different Depths and Under Various Treatments.

(Expressed as K in ppm.)

	Depth	Sassafras Loamy Sand: Replaceable	Sassafras Loamy Sand: Neubauer	Penn Gravelly Loam: Replaceable	Penn Gravelly Loam: Neubauer	Hagerstown Clay Loam: Replaceable	Hagerstown Clay Loam: Neubauer
10# KCl	0"- 6"	105	89	529	295	823	394
per tree	6"-12"	78	59	161	227	336	262
(Double)	12"-18"	71	72	50	89	202	275
5# KCl	0"- 6"	103	65	318	271	231	221
per tree	6"-12"	105	69	63	100	93	134
(Single)	12"-18"	113	82	50	107	62	111
No	0"- 6"	36	27	70	74	152	163
potassium	6"-12"	36	30	36	73	84	147
(Check)	12"-18"	33	24	39	58	74	165

It is evident that within a soil type the two sets of results are quite closely associated. This point will be brought out later by a comparison of correlation coefficients. But, on an absolute basis, it is interesting to note that on the loamy sand soil the replaceable potassium figures were generally higher than the Neubauer results, while on the heavier soils from the untreated plots, and certain of the lower layers of the treated plots, the Neubauer results exceeded the replaceable ones. A possible explanation of these results is that on the sandy soil, there was a relatively small amount of non-replaceable potassium present and the seedling roots did not penetrate the soil thoroughly enough to permit the absorption of all the replaceable potassium. On the other hand, the heavier soils contained large amounts of mineral potassium (which, according to Proebsting (43) the plants can utilize considerably), which was absorbed by the plants in sufficient amount to cause the Neubauer results to exceed those of the replaceable potassium. However, when these heavier soils were treated with fertilizers, the potassium content was raised sufficiently to prevent the plants from absorbing as much as is fixed in the soil. Doubtless, for a given set of conditions, there is a limit to the amount of potassium which can be absorbed by luxury consumption, even though no toxic effects have been produced.

The coefficients of correlation between the replaceable and Neubauer potassium determinations are presented in Table 5.

Table 5.- Coefficients of Correlation Between the Replaceable and Neubauer Potassium Contents of the Different Soil Layers in the Various Soil Types.

Depth	Sassafras loamy sand	Penn gravelly loam	Hagerstown clay loam
0"- 6"	.858	.830	.706
6"-12"	.871	.963	.738
12"-18"	.776	.640	.858

The correlations were all corrected for the systematic error caused by small numbers. The method employed was that suggested by Fisher (21) subtracting the factor $\frac{r}{2(n' - 1)}$ from the Z value for each coefficient. The significance of the differences between the coefficients of correlation were tested by applying the sum of the reciprocals of n'-3 to the difference between the Z values of any two correlation coefficients. If the difference exceeded twice the sum of the reciprocals, the correlations were considered as having originated from unequally correlated populations. In Table 5 there are no two correlations which are significantly differentiated from each other except those which involve the correlation of .963 obtained from the six-inch to twelve-inch layer of the Penn gravelly loam soil. Since there is no logical reason for this one layer of a given soil to have such a high correlation between the two potassium methods, this difference is accorded a chance origin. In general, the correlations are high. The coefficients of determination range from .41 to .93 indicated that from 41 to 93 per cent of the variability of one method of determination is associated with that of the other. Since there are no general differences among the correlations, little can be said concerning the association of the two methods of determination under different soil conditions. However, the fact that the Neubauer results were generally higher than the replaceable determinations on the heavier soils suggests the probability that Neubauer results might represent more truly the potassium supplying power of a heavier soil than that of a light one. The positive correlation between the two methods is indicative of the fact that either method is efficient in determining relative potassium supplies within a soil type.

pH Determinations.

Although pH determinations were made on all samples, no consistent effects of fertilizer treatment were noted. Lime was applied to certain plots during the first two years of this study, but no difference in pH or replaceable potassium content existed due to the application. The average pH values for the different orchards were as reported in Table 6.

Table 6.- pH Values for Different Orchards and Soil Types. 1931

Soil Type	Variety and Location	pH
Sassafras loamy sand	Stayman, Salisbury	5.75
Sassafras loamy sand	Belle of Georgia, "	6.05
Sassafras fine sandy loam	Elberta, Berlin	6.87
Sassafras fine sandy loam	Williams, "	6.81
Penn gravelly loam	Rome, Frederick	6.83
Upshur gravelly loam	Elberta, Hancock	5.70
Manor loam	Elberta, Mt. Airy	6.69
Hagerstown clay loam	York, Hancock	6.32

The Replaceable Potassium Content After the Injection of Fertilizers.

Since the results of the replaceable potassium content of the soils after surface application were not available in the spring of 1932, it seemed advisable to inject some potash fertilizers into the soil to insure an even distribution of fertilizers to a depth of three feet. The procedure has already been described. The amount injected corresponded to a normal surface application. Therefore, since four annual surface applications had already been applied, the amount injected was only 1/4 of the quantity previously applied. In the heavier soils where considerable of the potassium is held from year to year, one would not expect a large percentage increase of replaceable potassium caused by the injection. Also, on these heavier soils one would assume that the top layer would decrease and the lower layers increase as compared to five normal surface applications. Table 7 gives the comparisons. The most revealing fact of this table is that the heavier soils show an increase due to injection of fertilizers, while the lighter soils exhibit a decrease. Therefore, the significance of the differences had to be considered separately. When the comparisons are made by Fisher's "t" method, the chances that the differences did not occur by

Table 7.- The Replaceable Potassium Content of the Soils After Injection and Surface Applications of Potassium Fertilizers (Expressed as K in ppm.) Data obtained Winter, 1932

Heavier Soils (Piedmont)				Lighter Soils (Coastal Plain)			
Soil Type	Depth	Injected	Surface Application	Soil Type	Depth	Injected	Surface Application
Hagerstown Clay Loam	0"- 6"	510	403	Sassafras Loamy Sand	0"- 6"	92	97
	6"-12"	427	232		6"-12"	51	62
	12"-18"	267	190		12"-18"	69	83
Upshur Gravelly Loam	0"- 6"	214	316		0"- 6"	42	90
	6"-12"	210	142		6"-12"	53	41
	12"-18"	95	106		12"-18"	35	39
Manor Loam	0"- 6"	346	335	Sassafras Loamy Sand	0"- 6"	46	87
	6"-12"	139	124		6"-12"	56	97
	12"-18"	96	93		12"-18"	65	94
				Sassafras Fine Sandy Loam	0"- 6"	190	217
					6"-12"	144	144
					12"-18"	115	99

Heavier soils: Mean diff. = + 40.3 ± 8.8

t = 4.3

Lighter soils: Mean diff. = -16.0 ± 2.1

t = 7.5

chance alone are considerable greater than 99 : 1. It is obvious in the case of the heavier soils that considerable sampling error or marked soil heterogeneity must have been present because the two soils compared in each case received identical amounts of potassium. There should be practically no difference in the potassium content computed by totalling all layers, but the lower layers should contain more potassium under injection than under surface applications. The results on the sandy soils are just what one would expect. The potassium salts were injected into the soil, were readily leached, and the replaceable potassium content, with two exceptions, was depressed. Thus, on soils of this type having a low exchange capacity, one would expect to observe signs of a potassium deficiency if any were to appear.

The Entrance of Potassium Into the Tree.

The work of Weinberger on these fertilizer plots had indicated an effect of sulfate of potash-magnesia on the keeping quality of the fruit and color of foliage. The question arises as to whether this was a magnesium effect alone, or whether it resulted through some indirect effect of the presence of magnesium in the soil on the absorption of potassium by the tree.

In order to investigate this problem a group of eight-year-old McIntosh apple trees were selected at

College Park in April, 1932. The trees were paired according to size and location and three treatments applied to groups of six trees, each of which had their corresponding check tree (NP). Thus data were obtained from thirty-six trees. The fertilizer treatments were ten pounds per tree of the following materials: sulfate of potash; Sulfate of potash-magnesia; and magnesium sulfate. All materials were injected around the trees in the manner already described. Each tree received six pounds of superphosphate in solution, and a surface application of 2.5 pounds of sodium nitrate. The soil type was a clay loam.

The replaceable potassium content of the soil before fertilizer applications was 87 ppm. in the upper six inch layer and 50 ppm. in the second and third six-inch layers. After the injection of ten pounds per tree of potassium sulfate, the replaceable potassium content was increased, averaging for all layers, 239 ppm. Twig, leaf, and fruit samples were gathered for chemical analysis at certain dates throughout the season. The twig samples consisted of uniform current season and one year twigs of which the basal ten centimeters were used for analysis. Each twig sample was composed of 50 twigs of a given age from a given treatment. The bark was separated from the wood. The leaf samples consisted of 50 uniform leaves selected from the lower ten centimeters of the current seasons growth. Fifteen fruits at picking time from each treatment constituted the fruit samples. The pulp and seeds were analyzed separately. The complete results of the analyses are presented in Table 3 of the Appendix.

Since the different fractions of the twigs were highly correlated in their potassium content, only the 1931 results are presented in detail. Figure 3 gives a graphical presentation of the potassium content of this fraction throughout the season under the different treatments. Since time did not permit the analysis of individual samples within a treatment, no estimate of the variability within samples is available. Thus interpretations of treatment effects are difficult. However, the concentration of potassium within the bark of the trees receiving ten pounds of potassium sulfate is certainly greater than the check on June 25, and August 20. The sulfate of potash-magnesia treatment caused no appreciable differences in potassium content. The potassium content of the magnesium sulfate treated trees was apparently reduced on both August 20 and November 11. This is a probable result considering that Davis (18) and Colby (14), have found certain absorption relationships among various cations present in the culture medium.

The results of the leaf analyses are shown in Figure 4. From this chart it is evident that the leaves

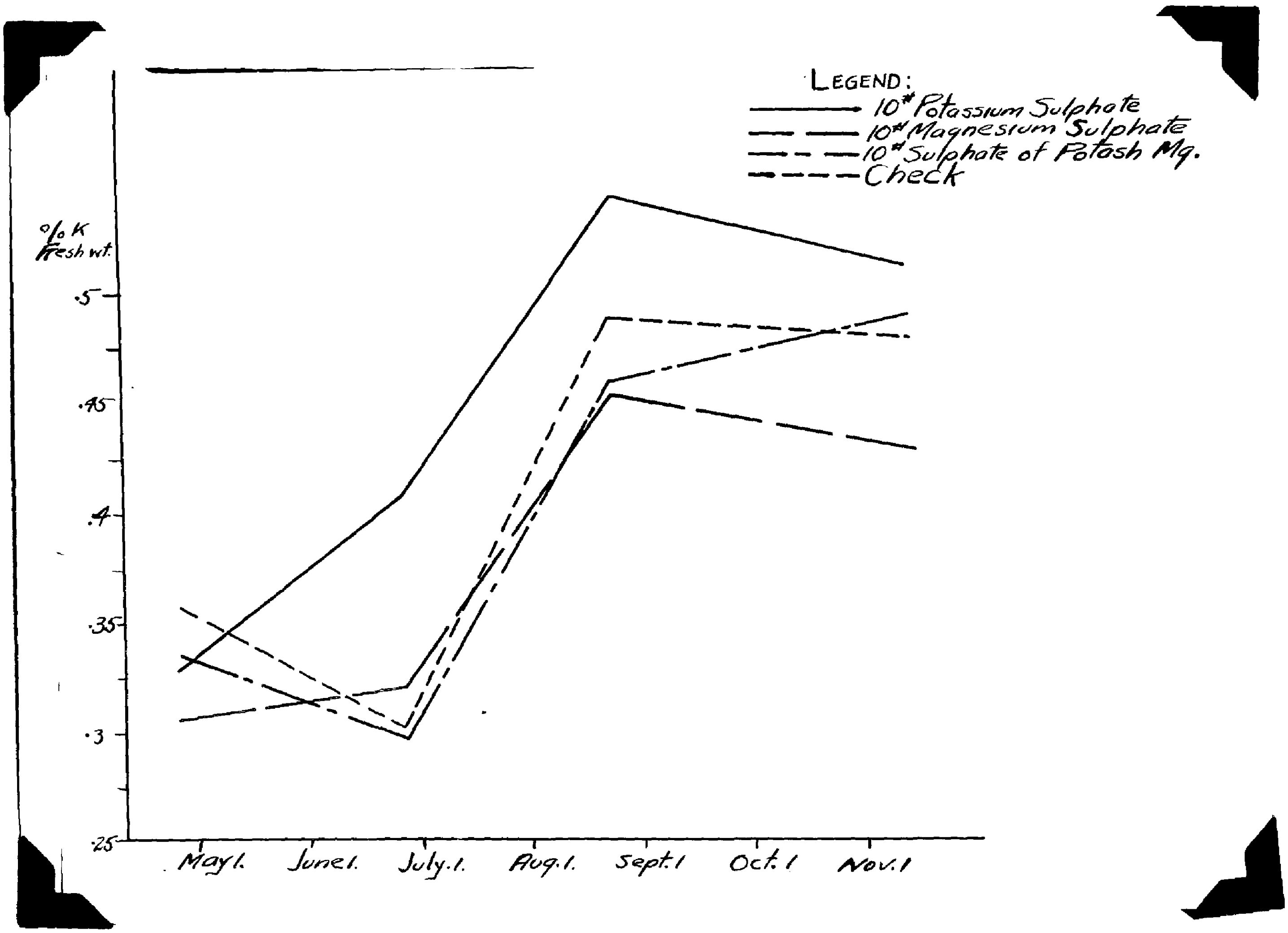


Fig. 3. - Potassium content of the 1931 bark from the McIntosh trees throughout the season, under the injection of various fertilizer materials. (Expressed as per cent of fresh weight.)

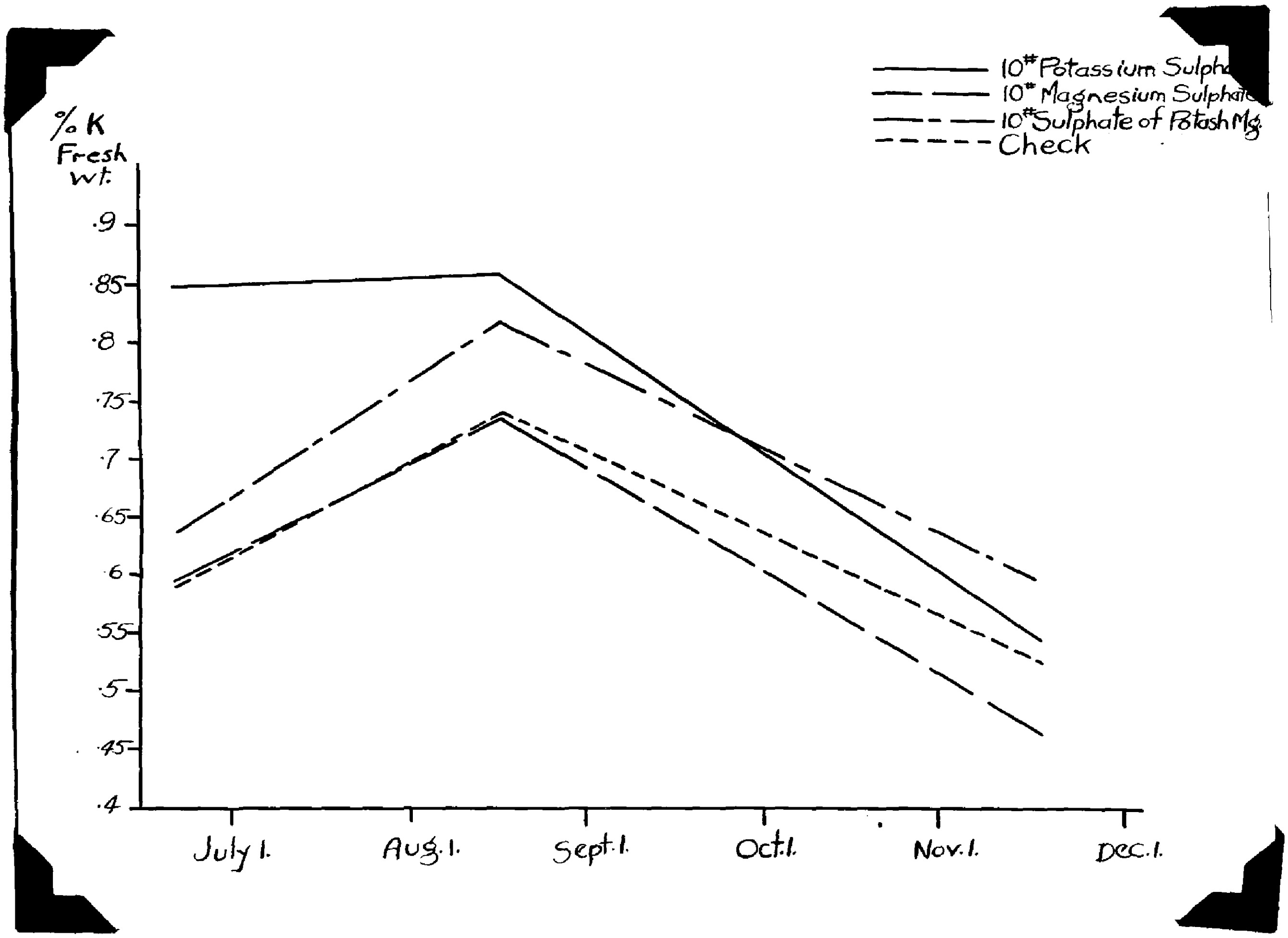


Fig. 4. - Potassium content of the leaves from the McIntosh trees under the injection of various fertilizer materials. (Expressed as per cent of fresh weight.)

from the trees receiving ten pounds of sulfate of potash contain the greatest amount of potassium throughout the season. The sulfate of potash-magnesia produced a concentration of potassium intermediate between the sulfate of potash and check trees. The magnesium sulfate treatment was very comparable to the check up until August 20 and November 11, when the potassium content was depressed. However, the significance of the latter differences could be questioned. The reason for the sulfate of potash-magnesia treatment analyses being lower than the sulfate of potash treatment might arise from two causes, one being that the amount of potassium added to the soilwas less, the other being that the magnesium present might have tended toward a depression of the potassium content of the tissues.

The potassium analyses of the fruit and seeds are presented in Table 8.

Table 8.- The Potassium Content of Fruit Pulp and Seed of McIntosh Apples Under Various Treatments. (K as per cent dry weight.) College Park,1932.

Treatment	Fruit Pulp	Seeds
10# Sulfate of Potash	.960	.600
10# Sulfate of Potash Magnesia	.780	.630
10# Magnesium Sulfate	.790	.680
Check	.787	.712

The sulfate of potash treatment caused a higher potassium content of the fruit pulp. The seed analyses were very uniform, although the actual values arranged themselves in reverse order to that expected.

The trunk circumferences of the trees were measured before and after the study, but no differential growth effects were obtained.

Along with this study it seemed of interest to determine to what extent the potassium content of an apple tree could be increased in a single season by the injection of extremely large amounts of potassium sulfate into the soil. Four eleven-year-old Rome Beauty trees at College Park were selected for this study. To one tree seventy-five pounds of sulfate of potash was injected around the tree to a depth of three feet. Three twenty-five pound applications were made at monthly intervals -- namely April 25, May 25, and June 25. To another tree two injections of fifteen pounds each were made on April 25 and May 25. The two other trees served as checks, receiving no potassium fertilizer. All trees received a basic treatment of sodium nitrate. The replaceable potassium content of the soil before injection averaged 38 ppm., and after injection 414 ppm. for the thirty pound tree, and 751 ppm. for the one receiving seventy-five pounds of potassium sulfate. These soil samples were dug in

November, 1932. The sampling dates, methods of obtaining tree samples, etc. were all very similar to those reported for the McIntosh trees. The complete data are reported in Table 4 of the Appendix. The potassium content for the leaves and 1931 bark and wood is presented graphically in Figure 5. Unfortunately the fruits were picked before samples for chemical analysis could be made. However, samples were obtained in 1933 and the results are reported in Table 11.

The results show emphatically that the concentration of potassium within the tissues of an apple tree can be raised by increasing the potassium content of the soil. However, the extent of this luxury consumption had a limit. The potassium content of the tree receiving only thirty pounds of sulfate of potash was essentially as high as that receiving seventy-five pounds.

No growth differences existed even though the treated trees had much more potassium in their tissues.

Various other potassium relationships, connected with tissue differences were obtained from this study, but since the results are similar to certain ones obtained in part II of this report, they will not receive discussion here.

In the spring of 1931, certain trees in the field plots were injected with potassium fertilizers in

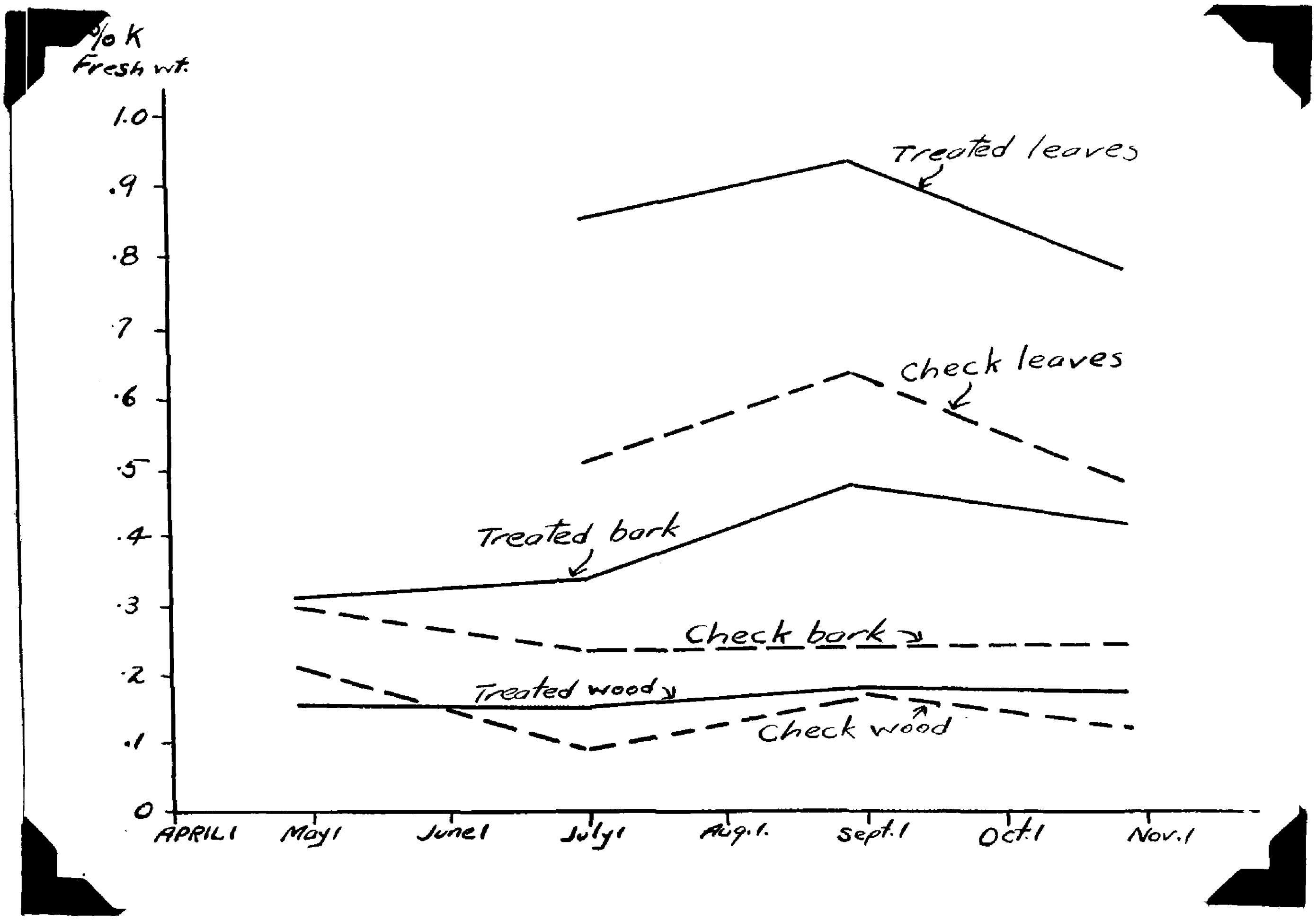


Fig. 5. - Potassium content of the leaves, bark, and wood from the Rome trees at College Park, fertilized with seventy-five pounds of potassium sulfate as compared with the trees which received no potash fertilizers.

equal amounts to those applied on the surface. The potassium content of the bark and wood of trees which had potassium injected around their roots was compared with those which received surface applications. There was not a significant difference between the two types of applications, the mean difference being only .00075 per cent potassium. (Dry weight basis.)

The potassium content of the bark and wood of the treated and untreated plots in the field was compared during the winter of 1932-33. A composite sample of thirty dormant, uniform, current season's twigs were cut at random from treated and untreated rows in certain orchards. The potassium contents expressed as per cent of dry matter are presented in Table 10.

In general, the potassium content of both the bark and wood was increased by the annual application of potassium carrying fertilizers for five years. The four instances where an increase does not result from fertilizer applications can be attributed to sampling error, although it would seem that a composite sample of thirty twigs should largely take care of this error.

During the summer of 1933 certain fruits were preserved for chemical analysis, taken from the treated and untreated fruit samples which were pressure tested. The results of the potassium analyses are presented in Table 11.

Table 10.- The Potassium Content of the Bark and Wood of One Year Twigs of Apple and Peach Trees from Potassium Fertilized Trees as Compared with the Check Trees. 1932

(K as per cent dry matter.)

Variety and Location	Tissue	Receiving Potassium	Check
York Apples, Hancock	Wood	.236	.240
	Bark	.466	.501
Elberta Peaches, Hancock	Wood	.295	.246
	Bark	1.420	.982
Belle of Georgia Peaches, Salisbury	Wood	.192	.206
	Bark	.884	.835
Stayman Apples, Salisbury	Wood	.196	.196
	Bark	.982	.904
Elberta Peaches, Berlin	Wood	.339	.290
	Bark	1.002	.806
Williams Apples, Berlin	Wood	.236	.231
	Bark	.845	.835
	Ave.	.566	.523

Mean difference = + .0434 ± .019

t = 2.28

Table 11.- The Potassium Content of Fruits from Treated and Untreated Potassium Fertilizer Plots. 1933 (K as per cent dry matter.)

Variety and Location	Treated	Check
Elberta Peaches, Mt. Airy	2.277	1.897
Elberta Peaches, Hancock	2.034	1.715
Stayman Apples, Salisbury	.759	.653
Rome Apples, College Park	.941	.592

Mean difference = .302 ± .040

t = 7.5

Although relatively few comparisons were available, the differences are consistent and large. The t value of 7.5 indicates that the chances are infinite that the increased potassium content was due to treatment rather than chance.

The analyses of the trees from the field fertilizer plots presented indicate that the applied potassium has moved into the wood and fruit of the trees. Therefore, any lack of response to potassium fertilizers must be due to the fact that the minimum potassium requirements are satisfied by the soil potassium which is normally present when no fertilizers have been added.

Growth and Yield Results

Having established the fact that the fertilized trees actually contain more potassium, it is interesting to observe the growth and yield responses over the duration of the experiment.

The circumference of all trees was measured each year in millimeters. As no measurements were obtained in the spring of 1928, only five years of growth data are presented. Estimated or actual yields were obtained each season that a crop was present on the trees.

As was stated before, the treatments were combined so as to obtain four quantitatively different treatments. The number of trees making up the different treatments was unequal because of the different number of plots in each treatment, consequently no effect of replication within one area could be determined. However, replication over a wide area was obtained by considering all peach data and all apple data as a population. Also, the effect of averaging many trees in one orchard reduced the variability.

The circumference measurements were treated on the basis of the average trunk increase per tree, per treatment, per year as the smallest unit. The yield data are averaged for each treatment in the different locations. The seasonal effect could not be considered, as yield records were not obtainable every year. In the case of the Elberta peaches at Hancock, no yield data are presented as there were many crop failures due to frost.

The growth and yield data are presented in Tables 5 and 6 in the Appendix. The analysis of variance for the peach growth (circumference) data is presented in Table 12a and the mean values with their standard errors are shown in Table 12b. The same data for the apple trees are presented in Table 13a and b. Insignificant correlations or interactions are included in the remainder variance, which is used as the estimate of error. The treatment x location interaction would always be left in the remainder variance regardless of its size,

Table 12a.- Analysis of Variance of Peach Trunk Circumference Increment Data (Cms.)

Source	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value Found	Z Value Necessary
Season	4	10.6423	2.6606	0.4892	1.2137	.4632
Location	3	33.7626	11.2542	1.2061	1.9306	.5073
Season x Location	12	26.3186	2.1932	0.3919	1.1164	.3255
Remainder	60	13.9653	0.2327	-0.7245		
Total	79	84.6888				

Table 12b.- Mean Values in Cms. of Peach Trunk Circumference Increment Data.

Treatment	Average Cir. Increase in Cms.	Variety and Location	Average Cir. Increase in Cms	Season	Average Cir. Increase in Cms.
Single	2.90 ± .11	Elberta at Mt. Airy	4.07 ± .11	1929	2.73 ± .12
Double	3.01 ± .11	Elberta at Berlin	2.70 ± .11	1930	3.59 ± .12
Complete	3.19 ± .11	Elberta at Hancock	2.35 ± .11	1931	2.66 ± .12
Check	3.24 ± .11	Belle of Georgia at Salisbury	3.22 ± .11	1932	3.41 ± .12
				1933	3.02 ± .12

Table 13a.- Analysis of Variance of Apple Trunk Circumference Increment Data (Cms.)

Sources	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value Found	Z Value Necessary
Season	4	6.1912	1.5478	0.2674	0.9804	.4632
Location	3	3.4672	1.1557	0.0713	0.7843	.5073
Season x Location	12	37.7555	3.1462	0.5726	1.2856	.3255
Remainder	60	14.5108	0.24185	-0.7130		
Total	79	61.9247				

Table 13b.- Mean Values in Cms. of Apple Trunk Circumference Increments.

Treatment	Average Cir. Increase in Cms.	Variety and Location	Average Cir. Increase in Cms.	Season	Average Cir. Increase in Cms.
Single	2.76 ± .14	Williams, Berlin	2.84 ± .14	1929	3.60 ± .15
Double	2.91 ± .14	Stayman, Salisbury	2.87 ± .14	1930	2.55 ± .15
Complete	2.65 ± .14	York, Hancock	2.82 ± .14	1931	2.64 ± .15
Check	2.58 ± .14	Rome, Frederick	2.36 ± .14	1932	2.57 ± .15
				1933	2.29 ± .15

as this is the most logical basis of comparison between treatments.

The fertilizer treatments as a whole did not contribute sufficiently to the total variance of the trunk circumference increments to be classed as significant. However, when individual treatments are considered separately, peach trees receiving no potassium grew significantly more than those receiving only a single amount of potassium. Other potassium treatments did not affect growth, consequently it would seem that the above difference is one resulting from chance, even though such a difference would be expected to result from treatment twenty-one out of twenty-two trials.

The location factor is extremely significant in the case of the peaches and quite so in the case of the apples. The factors contributing to this source of variability are too numerous to receive discussion here, but soil management, soil type, age of tree, variety, etc. are among those involved.

The season factor is quite important, showing that weather influences the trees materially. Probably the amount of rainfall is the most important weather factor, although frost damage and other temperature relationships enter in. The extremely significant interaction of season x location would indicate that the trees on the several soil types responded differently in the various seasons. The differences in soil type, exposure, altitude, etc. would all contribute toward this interaction.

The yield data for the peaches and apples are presented in Tables 14 and 15. The results were treated by Fisher's Analysis of Variance Method but since the location factor was the only significant contribution, the analysis is not tabulated here. The standard errors appended to the means were obtained from the interaction of treatment x location, with the insignificant treatment effect thrown in. The fertilizer treatments did not have a significant effect upon the growth and yield of either peaches or apples.

The location factor was important in its influence upon yield. This is not surprising, considering the many factors which could influence the productivity of the trees in the different orchards.

Firmness and Keeping Quality Studies

In order to lend more weight to the keeping quality results all the selected sample data secured by Weinberger and that secured in this study were averaged together. Thus, it was possible to obtain the average pressure test of about 800 fruits in each of four treatments of both apples and peaches. The pressure test data in Table 16

Table 14.- Yield Data for Peaches, Expressed in Average Bushels per Tree per Year.

Variety and Location	Check	Single	Double	Complete	Location Averages
Elberta, Mount Airy	2.54	2.88	3.41	3.35	3.04 ± .13
Elberta, Berlin	2.35	2.18	2.62	2.40	2.39 ± .13
Belle of Ga. Salisbury	3.21	3.23	3.23	2.99	3.16 ± .13
Treatment Averages	2.70 ± .15	2.76 ± .15	3.08 ± .15	2.91 ± .15	

Table 15.- Yield Data for Apples Expressed in Average Bushels per Tree per Year.

Variety and Location	Check	Single	Double	Complete	Location Averages
York, Hancock	5.47	3.86	5.66	5.22	5.05 ± .28
Rome, Frederick	2.45	3.80	3.42	3.19	3.22 ± .28
Williams, Berlin	2.85	3.43	3.69	3.90	3.47 ± .28
Stayman, Salisbury	5.75	5.06	5.75	5.56	5.53 ± .28
Treatment Averages	4.13 ± .28	4.04 ± .28	4.63 ± .28	4.47 ± .28	

are averages for each treatment in four orchards, obtained over a six year period and combine variety, location, season, and length of storage period. Each factor of variety, location, season, etc. is present an equal number of times, and it is permissible to make comparisons between the means on the basis of a standard error obtained in such a manner as to remove correlations among these factors. The fact cannot be disregarded, however, that the trees are on the same soil each year and place or treatment effects will be pyramided in successive seasons. Soil effects, in part at least, have been compensated for by replication of treatments in the four orchards. However, to be certain that the differences are statistically significant, the standard error obtained from the total variance was used.

Since the individual apples within each orchard and for each season tended to act more or less as a unit, it seemed best to use the total number of locations and seasons occurring within a treatment as the "N" in the denominator of the standard error fraction. This number was fourteen for the apples and sixteen for the peaches.

The standard error of the mean proved to be .347. Two times the standard error of the difference ($2\sqrt{2} \times .347$) is .979. A difference as great as this would probably not occur by chance alone more than once in twenty similar trials. It is true that there is considerable correlation between the original pressure tests and those obtained after the storage period, but since the actual firmness of the fruit at the end of the storage period is important, this association was not removed.

Table 16.- Average Pressure Test in Pounds of Apples from the Various Treatments.

Fertilizer Treatment	Before Storage	At End of Storage
Check	19.818 ± .347	13.638 ± .347
Single	19.321 ± .347	13.164 ± .347
Double	19.428 ± .347	13.784 ± .347
Complete	19.309 ± .347	13.405 ± .347
Difference necessary for significance	.979	.979

Nitrogen was applied equally to all trees.
Check = no potassium or phosphorous.
Single = 5# K Cl per tree.
Double = 10# K Cl per tree.
Complete = 6# superphosphate per tree in addition to N and K.

There were no significant differences between the mean values for the various fertilizer treatments either before or after storage. The maximum difference between check and treated fruit before storage was

.509 pounds and after storage .474 pounds.

The peach data were treated in a similar manner to the apple data. Table 17 gives the average pressure test of 800 peaches in each fertilizer treatment obtained over a five year period. The maximum difference between the check and treated fruit was .346 pounds before storage and .454 pounds after storage. The results, again, were not statistically significant. However, in the case of both the apples and peaches, it is of interest to note that the check fruits were the firmest at picking time, and in the case of the peaches, were softest after the storage period.

Table 17.- Pressure Test in Pounds of Peach Fruits from the Different Fertilizer Plots.

Fertilizer Treatment	Before Storage	At End of Storage
Check	8.616 ± .331	4.135 ± .415
Single	8.270 ± .331	4.144 ± .415
Double	8.439 ± .331	4.589 ± .415
Complete	8.532 ± .331	4.398 ± .415
Difference necessary for significance	.933	1.170

Check = nitrogen only.
Single = 3# K Cl per tree.
Double = 6# K Cl per tree.
Complete = 4# superphosphate in addition to N and K.

As was stated previously, random samples were picked during the last two years of the study. The primary objects in selecting a sample of this type were (1) to obtain an estimate of the association between size and pressure test and between red color and pressure test; (2) to secure a measure of the effect of fertilizer upon the color and size of fruit and thus determine any indirect effects upon firmness and keeping quality.

After the fruit was graded into various sizes and colors, fifteen fruits for each color and size class within each treatment were pressure tested. The data were later analyzed by Fisher's Analysis of Variance Method. This type of data was secured during the 1932 and 1933 seasons, but the samples were too small in 1932 to permit a proper treatment of the data. Since the 1933 data for the apples were without replication, the results of the Stayman Winesap fruit for Salisbury are presented to exemplify the method only. The data presented were secured from twenty-seven bushels of fruit, which, when distributed among three treatments, did not leave sufficient fruits to make more than one color separation and three size classes, and have fifteen fruits in each class. The individual fruits (270 in number) were used as the smallest unit, although only averages are given in subsequent tables.

Table 18 presents the summarized data secured from pressure testing the fruits. Each figure in the table represents the average of forty-five individual readings from

Table 18.– Pressure Test of Stayman Winesap Apples Under Various Fertilizer Treatments, and Separated into Various Sizes and Colors. Salisbury, 1933

	Fertilizer Treatment	Size and Color						
		3" up 50–100"	3" up 25–50%	$2\frac{3}{4}$" – 3" 50–100%	$2\frac{3}{4}$" – 3" 25–50%	$2\frac{1}{2}$" – $2\frac{3}{4}$" 50–100%	$2\frac{1}{2}$" – $2\frac{3}{4}$" 25–50%	Treatment Averages
Before Storage Oct. 12, 1933	Check	17.54	16.90	17.88	16.83	17.39	17.46	17.33 ± .072
	Single	16.00	16.21	16.04	16.21	16.88	17.21	16.43 ± .072
	Complete	15.64	15.70	16.25	16.25	17.47	17.47	16.46 ± .072
After Storage March 8, 1933	Check	11.97	11.45	12.05	11.33	12.23	12.40	11.91 ± .064
	Single	11.70	10.89	11.78	11.49	12.25	12.03	11.56 ± .064
	Complete	11.81	11.48	11.23	11.33	11.83	11.71	11.69 ± .064

fifteen fruits. The analysis of variance computed on the apple-unit basis for the before storage data is presented in Table 19. All correlated items and all significant interactions are tabulated, while insignificant interactions are included in the remainder variance. The best estimate of error was considered to be the variance among the fifteen apples in each class giving 252 degrees of freedom, plus any insignificant interactions. A similar analysis for the after storage data is presented in Table 20.

The analyses showed that before storage, size and treatment both appreciably influenced the firmness of the fruit, while red color did not have any significant effect. After storage, size, treatment, and red color all proved to be influential, thus indicating a different effect of red color on softening during storage. The effect of treatment, both before and after storage, was that the absence of potassium caused the fruit to be firmer at picking time and to remain firmer throughout the storage period. However, as was pointed out previously, no treatment replications were available, and thus the effect might be one of soil, tree vigor, sampling error, or treatment, or any combination of these influences.

The peach fruits in 1933 were treated very similarly to the apples. The data from three orchards

Table 19.- The Analysis of Variance of the Pressure Test of Stayman Winesap Apples Before Storage

Salisbury 1933

Sources	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value (5%) Found	Necessary
Color	1	0.606	0.606	-.2520	.1255	.6729
Size	2	46.724	23.362	1.5722	1.9497	.5486
Treatment	2	47.252	23.626	1.5801	1.9576	.5486
Size x treatment	4	19.515	4.879	.7923	1.1698	.4319
Remainder	260	122.262	0.470	-.3775		
Total	269	236.359				

Table 20.- The Analysis of Variance of the Pressure Test of Stayman Winesap Apples After Storage

Salisbury 1933

Sources	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value (5%) Found	Necessary
Color	1	6.280	6.280	.9187	1.4252	.6729
Size	2	16.830	8.415	1.0647	1.5712	.5486
Treatment	2	4.190	2.095	.3710	.8775	.5486
Size x treatment	4	5.580	1.395	.1537	.6602	.4319
Color x treatment	2	2.450	1.225	.1495	.6560	.5486
Remainder	258	93.870	0.363	-.5065		
Total	269	129.200				

Table 21.- Average Pressure Test (lbs.) of Peaches in the Two Size and Color Classes Under the Different Fertilizer Treatments. 1933

	Treatment	LR*	LG	SR	SG	Treatment Averages
Before Storage	Check#	8.65	10.06	8.87	10.10	9.42 ± .099
	Single	6.97	9.43	7.75	9.66	8.45 ± .099
	Complete	8.75	10.16	8.90	10.27	9.52 ± .099
After Storage	Check	3.59	4.70	3.84	4.43	4.14 ± .152
	Single	3.42	4.50	3.27	4.59	3.95 ± .152
	Complete	4.22	5.69	3.80	5.79	4.88 ± .152

\# Check = nitrogen only.
Single = 3# K Cl per tree per year.
Complete = 4# superphosphate per tree in addition to N and K.

* L = large fruits R = highly colored fruits
S = small fruits G = poorly colored fruits.

were combined to obtain the advantage of treatment replication. The Belle of Georgia fruits developed brown rot so badly that a test after four days in common storage was impossible, so one degree of freedom for location is lost in the after storage data.

Table 21 gives the average pressure tests of the peaches in the different size and color classes within the treatments before and after storage. Here, as in the case of the apples, tests of fifteen fruits were averaged to give each figure in the table, and the individual fruit was considered as the unit in the analysis of variance computations. Table 22 presents the analysis of variance before storage and Table 23 the same after storage. All interactions are included in the remainder variance. However, certain ones are tabulated to denote their importance. The principal component of the remainder variance is the variance within classes. If replication within a given location were present, probably the most logical basis of comparison between treatments would be made on the basis of the interaction of treatment x replicates.

The statistical analysis of the peach pressure tests before storage showed a significant effect of treatment, size, color, and location upon the firmness of the fruit. The treatment factor was highly significant on the basis of the error variance used here, but, if generalizations for all soil types are to be made, more locations should be studied in view of the large interaction of treatment x location. When the treatment differences were compared on the basis of this interaction they ceased to be significant.

The analysis after storage showed that the size correlation proved to be insignificant, but treatment, color, and location remained important.

Considering the treatments individually, the complete fertilizer and check fruits were firmest at picking time, but only the complete fertilized fruit continued firmer during storage. But, as was pointed out above,

Table 22.- Analysis of Variance of Peach Pressure Tests Before Storage. 1933

Sources	Degrees of Freedom	Sum of Squares	Variance	1/2 $\log_e$	Z Value (5%) Found	Z Value (5%) Necessary
Treatment	2	125.2751	62.6375	2.0715	1.7916	.5486
Size	1	8.9689	8.9689	1.0966	0.8167	.6729
Color	1	360.0163	360.0163	2.9430	2.6631	.6729
Location	2	153.4307	76.7153	2.1665	1.8866	.5486
Remainder	533	934.4365	1.7531	0.2799		
Total	539	1582.1275				
Inter-actions:						
Treatment x color	2	20.6300	10.3150			
Treatment x location	4	46.4482	11.6125			
Treatment x size	2	4.3577	2.1788			
Size x color	1	4.1989	2.1989			

Table 23.- Analysis of Variance of Peach Pressure Tests After Storage. 1933

Sources	Degrees of Freedom.	Sum of Squares.	Variance	1/2 $\log_e$	Z Value Found	Z Value Necessary
Treatment	2	57.8304	28.9452	1.6835	1.1739	.5486
Color	1	143.2392	143.2392	2.4814	1.9718	.6729
Location	1	629.5957	629.5957	3.2250	2.7154	.6729
Remainder	355	984.6988	2.7738	0.5096		
Total	395	1815.4241				
Interactions:						
Treatment x color	2	11.808	5.904			
Treatment x location	2	23.3902	11.6951			
Treatment x size	2	0.3898	0.1949			

these results cannot be generally applied.

The only logical explanation of the differential responses involving treatment in both apples and peaches is that soil differences have produced effects which analyze out as treatment relationships. However, additional studies with more replication might give additional causes for these interactions.

In order to fully evaluate the effects of a fertilizer treatment upon the firmness and keeping quality of fruits, it is necessary to use averages which have been weighted according to the number of fruits of the various colors and sizes within each treatment. From the analysis of variance results presented above, it follows that if a given fertilizer treatment materially affects the color or size of the fruit, the weighted average will represent a more correct estimate of the firmness of the fruit, than a simple average obtained from an equal number of fruit from each size and color class.

Since summer apples might have different color-pressure test relationships than fall or winter varieties, the Williams data also are used in comparing color and size relationships as well as in comparing weighted and simple averages. Table 24 gives the weighted and simple averages for the pressure tests of the fruit from the different fertilizer plots. In the case of peaches and Williams apples, the weighted averages are all higher than

Table 24.- A Comparison of Simple and Weighted Averages of Fruit from the Different Fertilizer Plots. 1933

		Before Storage		After Storage	
	Treatment	Weighted Average	Simple Average	Weighted Average	Simple Average
Peaches (Combined data)	Single	9.92	9.52	5.31	4.88
	Complete	8.82	8.45	4.05	3.94
	Check	10.01	9.42	4.33	4.14
Williams Apples (Berlin)	Double	22.88	22.81	13.47	13.44
	Single	22.60	22.44	13.60	13.43
	Check	22.50	22.28	13.01	12.94
Stayman Apples (Salisbury)	Complete	16.23	16.46	11.54	11.69
	Single	16.18	16.43	11.67	11.56
	Check	17.47	17.33	11.96	11.91

the simple ones. This indicates that small fruits and poorly colored fruits are more numerous than large sized or highly colored fruits. This proved to be true. The Stayman apples contained somewhere near the same number of the two sizes and colors of fruits, although large, red fruits tended to predominate in many cases.

In general the weighted averages are quite highly correlated with the simple ones, although the predominance of small-sized fruit in the check plots of the Stayman apples has caused the weighted averages to be higher than the simple ones, while the fruits receiving a single application of potassium had proportionately more large fruits and the weighted averages were smaller than the simple ones. Although these results are not extensive enough to indicate treatment effects upon color, they do exemplify the fact that weighted averages give a true picture of the actual firmness of a random sample of fruit. Table 25 presents the pressure tests of the different sized and colored fruits. It is of interest to note that in the case of peaches and Williams apples, red fruits are softer than green fruits, while with the Stayman apples the reverse is generally true. These differences hold for the after storage data in spite of the fact that green fruits soften more during storage than red ones. These color responses agree with the findings of Morris (37a) in the case of apples and Blake et al (10) in the

Table 25.- Average Pressure Test of Fruits in the Different Size and Color Classes Before and After Storage.

	Class	Before Storage	After Storage	Decrease in Firmness
Peaches (Combined data)	LR	8.12 ± .114	3.74 ± .176	4.38 ± .209
	LG	9.88 ± .114	4.96 ± .176	4.92 ± .209
	SR	8.51 ± .114	3.64 ± .176	4.87 ± .209
	SG	10.01 ± .114	4.94 ± .176	5.07 ± .209
Williams Apples (Berlin)	LR	21.99 ± .106	12.83 ± .102	9.16 ± .147
	LG	22.43 ± .106	13.21 ± .102	9.22 ± .147
	SR	22.65 ± .106	13.51 ± .102	9.14 ± .147
	SG	22.98 ± .106	13.52 ± .102	9.46 ± .147
Stayman Winesap (Salisbury)	LR	16.39 ± .059	11.82 ± .058	4.57 ± .082
	LG	16.27 ± .059	11.27 ± .058	5.00 ± .082
	SR	17.24 ± .059	12.10 ± .058	5.14 ± .082
	SG	17.38 ± .059	12.04 ± .058	5.34 ± .082

L = large fruits
S = small fruits
R = highly colored fruits
G = poorly colored fruits

case of peaches.

Before storage small fruits test higher than large fruits. After storage this holds true with the apples but in the case of peaches, the reverse is true, since the small fruits have softened so much more in storage.

GENERAL DISCUSSION OF RESULTS

The most striking result obtained in this study is that potassium-carrying fertilizers did not affect the growth or yield of the trees, or the keeping quality of the fruit, in spite of the fact that the available potassium of the soil as well as the potassium content of the tree and fruit were increased. This result is even more surprising when the low potassium content of the Sassafras loamy sand, on which were growing the Belle of Georgia peaches and Stayman Winesap apples, is considered. The replaceable potassium content of the check plots in this soil ranged from 22 to 36 ppm. The Neubauer results ranged from 24 to 30 ppm. The fact that trees in England (Wallace and Proebsting (57)) cannot be grown successfully when the replaceable potassium content in the top soil never gets below 100 ppm., causes one to question the reliability of replaceable potassium determinations in depicting the nutritional status of soils with respect to the potassium nutrition of apple trees. Perhaps tree species, root stocks, temperature, moisture supply, mineral reserve of soil, nitrogen supply, or other replaceable ions may influence the appearance of potassium deficiency symptoms. Kimball (27) suggests leaf scorch is entirely a moisture relationship. Certainly other factors than the replaceable potassium content of the soil are important, or certain trees in this experiment would have exhibited potassium deficiency symptoms.

If the Neubauer method gives a true representation of the potassium supplying power of the soil, it would be valuable to compare the two methods on the soils of England to determine whether or not there is actually less potassium available for plant growth.

If the English figures were not available for comparison, we would interpret our results by saying that a continual supply of potassium, even though very small, is sufficient to supply the needs of fruit trees. The fact that the seedlings employed in the Neubauer test were able to obtain as high as 30 ppm. of potassium from the extremely sandy soils indicates that a continual supply of potassium is available even on the poorest soils. Also, Bartholomew and Janssen (5) point out that plants can reutilize potassium. Thus a limited amount may serve as satisfactorily as a larger amount. Further, if potassium serves as an inorganic catalyst in the plant, increased amounts would only prove beneficial when an increase in the substrate was available. This same principal would apply if potassium activated certain plant enzymes. In other words, when some factor is limiting an increase in potassium could not prove beneficial. This is in accordance with Liebig's "Law of the Minimum" (29). The fact cannot be over stressed that the moisture supply in Maryland was greatly restricted in 1930 and the effect was felt in 1931, and 1932. It is possible that this factor alone was sufficiently limiting to cause a lack of response to potassium fertilizers. Also we know little concerning the availability of other necessary elements in these soils, although it is not probable that any of them besides nitrogen are limiting since other crops grow well on similar soils.

Wallace (35) and Gildehaus (22) have indicated that the nitrogen/potassium ratio of the soil is important in governing the appearance of potassium deficiency symptoms. An adequate supply of nitrogen was given the trees in this study, as indicated by growth and yield of trees, so that the nitrogen/potassium ratio should have been conducive to the occurrence of deficiency symptoms on the check plots, provided that the potassium supply of the soil was anywhere near limiting.

Through the courtesy of Dr. R. P. Thomas of the Department of Soils the average total potassium content of three of the soils used in this study were obtained. The Hagerstown clay loam on which the York apples at Hancock were growing contained about three per cent potassium; the Manor loam on which the Elberta peaches at Mt. Airy were growing contained about 1.85 per cent, while the Sassafras loamy sand on which the Belle of Georgia peaches and Stayman Winesap apples at Salisbury were growing contained about 1.21 per cent. From these figures it is evident that the heavier soils not only contained much more replaceable potassium but also more total potassium. Although the clay loam soil contained over 100 per cent more potassium than the loamy sand, the latter soil contained over 1 per cent, which when continually passing into solution, even in very small amounts, seemed to provide sufficient potassium for optimum growth and yield of the trees.

The fact that the potassium content of the lower layers was significantly increased by fertilizer applications removes the hypothesis that the lack of response to potassium fertilizer was due to the absence of additional potassium in the area of maximum root concentration. In fact the work of Beckenbach and Gourley (8) and others indicate that the feeding roots of a tree are most concentrated in the upper part of the soil, and exhibit a decreasing gradient with increase in depth.

Finding that apple trees do not exhibit potassium deficiency symptoms when many annual plants on similar soil types do could be explained from the standpoint that the older parts of the tree can readily give up part of their potassium supply, and also the roots of an apple tree, under recommended planting distances, can always penetrate new areas of soil. The work of Murphy (38) indicates that when the replaceable potassium content of Oklahoma soils gets below 60 - 70 ppm., a potassium deficiency of annual crops is universally exhibited. This certainly is not generally true of the apple and peach in the United States.

The question now arises -- have we determined the response of fruit trees in Maryland to potassium fertilizers and what future possibilities for study exist? The answer seems to be that small differences in response have appeared which could not be definitely attributed to potassium, especially since the different soils with the same fertilizer applications produced differential responses. However, no large effects, such as occur with nitrogen in Maryland were evident, in spite of greatly increased available potassium in the soil and demonstrated increases in the tree tissues. In order to more fully evaluate these locational differences and to measure more accurately any small differences due to treatment within a soil type, a study involving few potassium treatments with sufficient replication is suggested. If several orchards of one variety could be studied on any one soil type, the interpretation of results would be simplified. This type of plot layout would produce equally efficient results whether analyzing yields, growth, keeping quality, chemical composition or any other measure of response.

As far as the keeping quality results are concerned, a difference of one pound or more at the end of the storage period probably should be present in order to be of much practical value. Any attempt to interpret smaller values would not have commercial importance. Some of the 1933 results, using weighted averages did produce differences as great as one pound, but until some other factors such as soil and variety are evaluated over several seasons, no definite conclusions can be drawn. Another difficulty in interpretation arises in that the increased firmness of fruits fertilized with sulfate of potash-magnesia as noted by Weinberger, was not obvious in the later years of this study.

SUMMARY AND CONCLUSIONS

1. The replaceable potassium content of the orchard soils of Maryland decreased, generally, with an increase in depth, but the change was most marked when comparing the first two six-inch layers.

2. Applications of potassium fertilizers resulted in a considerable fixation of potassium in the upper layers

of all soils. Soils of an extreme sandy nature exhibited this phenomenon to a lesser degree than heavier soils. Apparently the replaceable potassium content of the soils was a function of the colloid content. However, contrary to usual opinion and some results from other sections, a significant increase in the lower layers of all soils was caused by surface fertilizer applications.

3. When no fertilizers were applied, "Neubauer" potassium was higher than replaceable potassium on the heavier soils, and lower on the lighter ones.

4. The Neubauer results were quite closely correlated with the replaceable potassium in all layers of all soil types studied.

5. The injection of ten pounds of potassium sulfate into the soil around eight-year-old McIntosh trees increased the potassium content of their tissues. The injection of magnesium sulfate in like amounts tended to decrease the potassium content.

6. The injection of thirty pounds and seventy-five pounds of potassium sulfate into the soil around eleven-year-old Rome Beauty trees resulted in a marked increase of potassium in the tissues. However, the seventy-five pound application did not materially increase the concentration over that caused by the thirty pound application.

7. Surface applications of potassium-carrying fertilizers for five years increased the potassium content of

the bark, wood, and fruit of apples and peaches.

8. Potassium-carrying fertilizers over a six-year period have not significantly affected the growth or yield of apples or peaches in Maryland. Location of orchard and season proved responsible for considerable variability in growth and yield.

9. The effect of fertilizers upon the firmness and keeping quality of apples and peaches showed certain differences in some seasons, especially under extreme moisture conditions. However, since these differences were largely obliterated when several locations were considered together, no definite conclusions can be drawn.

10. Red color and size were both correlated with firmness and keeping quality in apples and peaches and suggest that weighted averages, involving any treatment differences in size and color should be used in interpreting fertilizer effects.

11. It is suggested that a more refined field plot technique be resorted to if any effects of potassium fertilizers found in this study on keeping quality of fruits as well as growth and yield responses of mature apple and peach trees are to be definitely demonstrated as significant.

II. The Absorption, Distribution, and Seasonal Movement of Potassium in Young Apple Trees and the Effect of Potassium Fertilizer on Potassium and Nitrogen Content and Growth of Tree.

INTRODUCTION

To comprehend more adequately the potassium nutrition of fruit trees in Maryland, knowledge concerning the absorption, distribution, and seasonal movement of potassium was deemed to be a valuable adjunct to the results involved in the first part of this work, and also would aid in the conduct of future investigations. Since young trees were more readily analyzed in entirety than old trees, a study of the absorption, distribution, and seasonal movement of potassium in two year old Stayman apple trees was inaugurated in the spring of 1933 with the following objects in mind.

1. To determine the period and rate of absorption of potassium.

2. To study the relative concentration of potassium in the tree tissues as well as the actual amounts present.

3. To obtain an indication as to any seasonal movements of potassium from one tissue to another.

4. To determine the effect of heavy applications of potassium on the relationships stated above.

5. To study the effect of heavy applications of potassium on the total nitrogen content of the tree tissues and the association of nitrogen with potassium in the tissues throughout the season.

6. To determine any growth responses caused by potassium fertilizer.

LITERATURE REVIEW

The only study of the seasonal movement of potassium in apple trees under field conditions that the writer was able to find was that of Butler Smith and Curry (12) conducted at New Hampshire in 1916. Using seven year old Golden Ball apple trees, they found that there was little movement of potassium until about the period of bloom when there was a translocation from the older branches to the younger twigs. The young roots decreased in their percentage potassium from the dormant period until the time of bloom (May 18). From then until active growth ceased (July 12) the concentration increased markedly, and then fell off again. The concentration in the new growth was a continually decreasing thing throughout the season. The leaves were not included in this study. No absolute amounts were reported.

Richter (45) working in Germany about 1909 studied the potassium content of apple leaves throughout the growing season, and determined that on a percentage basis, the potassium content decreased as the season advanced. On an absolute basis, a maximum was reached at the stage of maximum leaf size. Roberts (46) in 1895, Van Slyke, et. al. (54) in 1905 and Thompson (53) in 1916 all attempted to interpret the fertilizer needs of fruit trees by chemical analysis of the entire tree and a calculation of the total amount of any essential element removed over a definite period. Their work did not lend any additional information as to seasonal movements of potassium, but did give an indication as to where potassium was located in the apple tree. Since Roberts worked with a non-bearing tree, even though it was mature, some of his re-calculated data on the relative proportion of the potassium located in the different parts of the tree, is presented. The analyses showed that 15.0 per cent of the trees potassium was located in the leaves, 7.1 per cent in the current seasons twigs, 9.0 per cent in the one year twigs, 58.3 per cent in the trunk and limbs and 10.5 per cent in the roots.

MATERIALS AND METHODS

Description of Plots.

Out of a group of 400 two year old Stayman apple trees growing in the nursery row, on a Sassafras, sandy loam at College Park, 190 of the most uniform trees were selected. The trees were allowed to remain in their original places. The block of trees consisted of four rows, about four feet apart, the trees being approximately eighteen inches apart in the row.

The block was divided in four plots, all of which received an application of one-fourth pound of ammonium sulfate and one-half pound of superphosphate per tree. Two of the plots received an application of one pound per tree of sulfate of potash. This was considered to be a heavy application of potassium. The materials were applied April 1, 1933.

The rows ran up a slope and the plot boundaries were perpendicular to the rows, so that each plot contained a section of all rows. Since all trees were not used, the numbers of trees in the plots were not equal. However, sufficient numbers were present in each plot to be representative of the treatment. The plots were numbered from 1 to 4, going up the hill, 1 and 3 receiving the potassium.

Growth Records.

Since it was desired to study the effect of the heavy application of potassium upon the growth of the trees, records were taken at weekly intervals during the greater part of the growing season, although occasionally it was necessary for a longer interval between measurements.

By means of a wax pencil a mark was made at a certain point near the base of the tree. The caliper at this point was taken at each measuring date. The accuracy of the measurement extended to .01 centimeters. The longitudinal growth of the terminal shoots of each tree was measured in centimeters.

Sampling Methods

Chemical samples were secured at twelve intervals between April 8, 1933 and January 8, 1934 inclusive. Since the trees had not previously exhibited any potassium deficiency symptoms, the treatment involving only nitrogen and phosphorus was considered to be normal, and since a study under normal conditions was desired, four trees were taken as a composite sample from these plots at each sampling date. The trees designated for chemical sampling were never adjacent. From the plots receiving a heavy application of potassium only a single tree was sampled at each date, with the supposition that if any marked compositional differences existed, they could be detected by the analysis of the one tree.

The entire trees were dug, care being taken to preserve as many roots as possible. However, during the latter part of the season, when the root systems were quite extensive, some of the finer roots were lost. The trees were dug between 7:00 and 8:30 A.M. following a sunny day. They were never dug when it was raining, although in few instances it was rather cloudy. After being dug as rapidly as possible they were carried to the laboratory for subsequent treatment.

Method of Separating Tree Into Its Fractions

After washing and weighing the trees, they were separated into eighteen different fractions. (Fewer fractions were present during the early part of the growing season or when no leaves were present). The following fractions were secured:

Leaves
1933 upper bark
1933 upper wood
1933 lower bark
1933 lower wood
1932 upper bark
1932 upper wood
1932 lower bark
1932 lower wood
1931 upper bark
1932 upper wood
1931 lower bark
1931 lower wood
Large root bark
Large root wood
Small root bark
Small root wood
Rootlets.

The fractions were designated in accordance with the year of their first longitudinal extension. The upper and lower classification designated the upper and lower half of each section. The large roots were those one centimeter or more in diameter; the small roots ranged from one centimeter to two millimeters in diameter, and the remainder of the root system was designated as rootlets. (Figure 7 shows certain separated fractions ready for drying).

Since the time required to fraction five trees

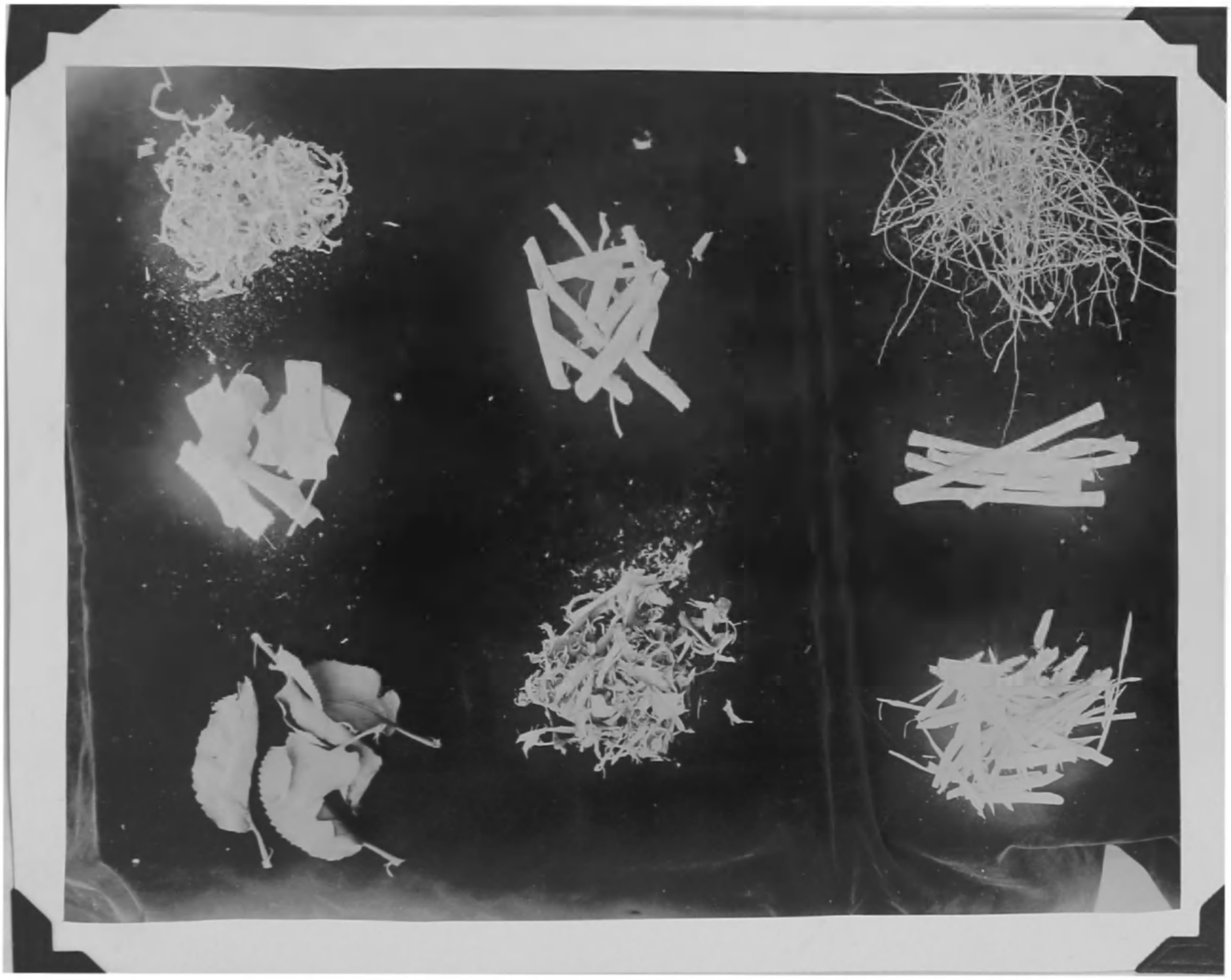


Fig. 7. - Various fractions of the trees prepared for drying.

1931 upper bark — small root wood — Rootlets

1931 upper wood — small root bark — Old wood on 1932 lower

leaves — New wood on 1932 lower

considerable, the bark / wood ratio was obtained from the tree fractioned for moisture determinations. (See under Chemical Methods). Then the weight of the fractions, including bark and wood for all trees, were recorded and the dry weights of the individual fractions were later calculated from the bark/ wood ratio and moisture contents of the one tree.

Smaller samples were taken from the composite sample of the four trees from the no-potassium plots, which were peeled, dried, and ground for chemical analysis as described under part I of this report.

Chemical Methods

Potassium. The total potassium content of the tissues was determined by the same method as described in part I.

Nitrogen. Total nitrogen was determined by the official A.O.A.C. Kjeldahl Gunning Method. No nitrate nitrogen was determined since it is generally considered to be absent from apple trees, except in the roots.

Moisture. At the first three sampling dates, the moisture content of all fractions of trees from both treatments was obtained, but after an inspection of the results, it was observed that the tree sampled first always exhibited the highest moisture content, regardless of treatment. Therefore, at subsequent sampling dates, the one tree from the high potassium plots was immediately cut up for moisture determinations, so as to avoid unnecessary water losses. All moisture calculations were based on this one tree.

The method of determining moisture was the same as given under part I.

RESULTS OBTAINED

Absorption of Potassium by the Trees

Since some variability existed among the trees, it was necessary to smooth out the dry weights of all fractions by means of a three figure moving average. Since a moving average results in a reduction in the number of figures, the first two sampling dates were averaged for the first figure and the dry weight for the last sampling date was left unchanged. Other than these modifications a regular moving average was employed. After the corrected dry weight figures were obtained for each fraction on each sampling date, they were multiplied by their corresponding potassium percentages, which gave the actual grams of potassium present in each fraction. (table 21).

It happened that the four trees of the sample taken from the normally treated plots on October 4th were rather small. Even though their dry weights were corrected by the moving average, the amount of potassium in the trees was still low, indicating a lower concentration than would be expected at this time of the year. The potassium values obtained on October 4th are not plotted on the graphs because the trees were considered as abnormal.

No potassium treated tree was dug on June 25th.

In connection with table 21, a note as to the approximated physiological status of the trees at each sampling date is appended. When comparisons are made between the results of this investigation and that of other similar ones, the use of the tree condition, rather than the calendar dates would seem advisable. However, in this report for the sake of brevity, all references to time of sampling will be made in terms of the actual date. Since the sampling dates were arbitrarily chosen without reference to any expected changes in potassium behavior, any difference between any two dates is only an approximation of actual change which occurred.

Table 21 shows the total grams of potassium in the apple trees at the different sampling dates. Figure 8 presents the same material graphically. The data are given both including and excluding the leaves, so that the potassium content of the tree can be studied without the introduction of the rather large amount of potassium which accumulates in the leaves, and apparently is lost at leaf fall.

Considering the normal treatment (designated by N) it is evident that potassium was absorbed slowly between April 8th and 25th. A portion of the potassium in the woody part of the tree moved into the leaves during this

Table 21. Total Amount of Potassium in Grams Per Tree Under the Two Fertilizer Treatments, Both Including and Excluding the Leaves. 1933

Date Sampled	≁ K*		N		Physiological state of trees.
	≁ leaves	- leaves	≁ leaves	- leaves	
April 8	.9348	.9348	.8669	.8669	Buds beginning to swell. Bark sticking.
April 25	1.0781	.8448	.9945	.7612	Terminal buds bursting. Some leaves ¼" long. Bark still sticking on roots.
May 11	1.5019	10542	1.4908	.9726	Buds fully opened and in some cases very slight terminal growth.
May 29	2.6898	1.5998	2.0502	1.2462	New growth 18-22 cms. in length.
June 13	4.8985	2.4695	2.6993	1.5120	Terminal growth 25-40 cms. Lower part 1933 growth turning brown.
June 25	--	--	3.5938	1.8541	Terminal growth 38-48 cms. Trees still growing rapidly.
July 23	6.0350	2.8332	3.5368	1.9818	Terminal growth 50-70 cms. Trees healthy and vigorous.
Aug. 16	5.8268	3.2275	4.0607	2.3055	Bark sticking on few upper twigs. Growth slowing down.
Sept. 10	6.5827	4.0454	4.2655	2.6027	Leaves falling some. Bark sticking on all parts of tree except trunk and roots.
Oct. 4	6.0751	4.1834	3.1832	2.3303	Many older leaves fallen. Bark sticking on all parts of tree.
Nov. 3	5.2896	4.4887	3.6208	3.1518	Only a few of the younger leaves left. Some of them still green.
Jan. 8	4.3528	4.3528	3.2686	3.2686	Tree entirely dormant.

* ≁ K = Treated with one pound potassium sulfate April 1, 1933.

N = No potassium fertilizers added.

All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

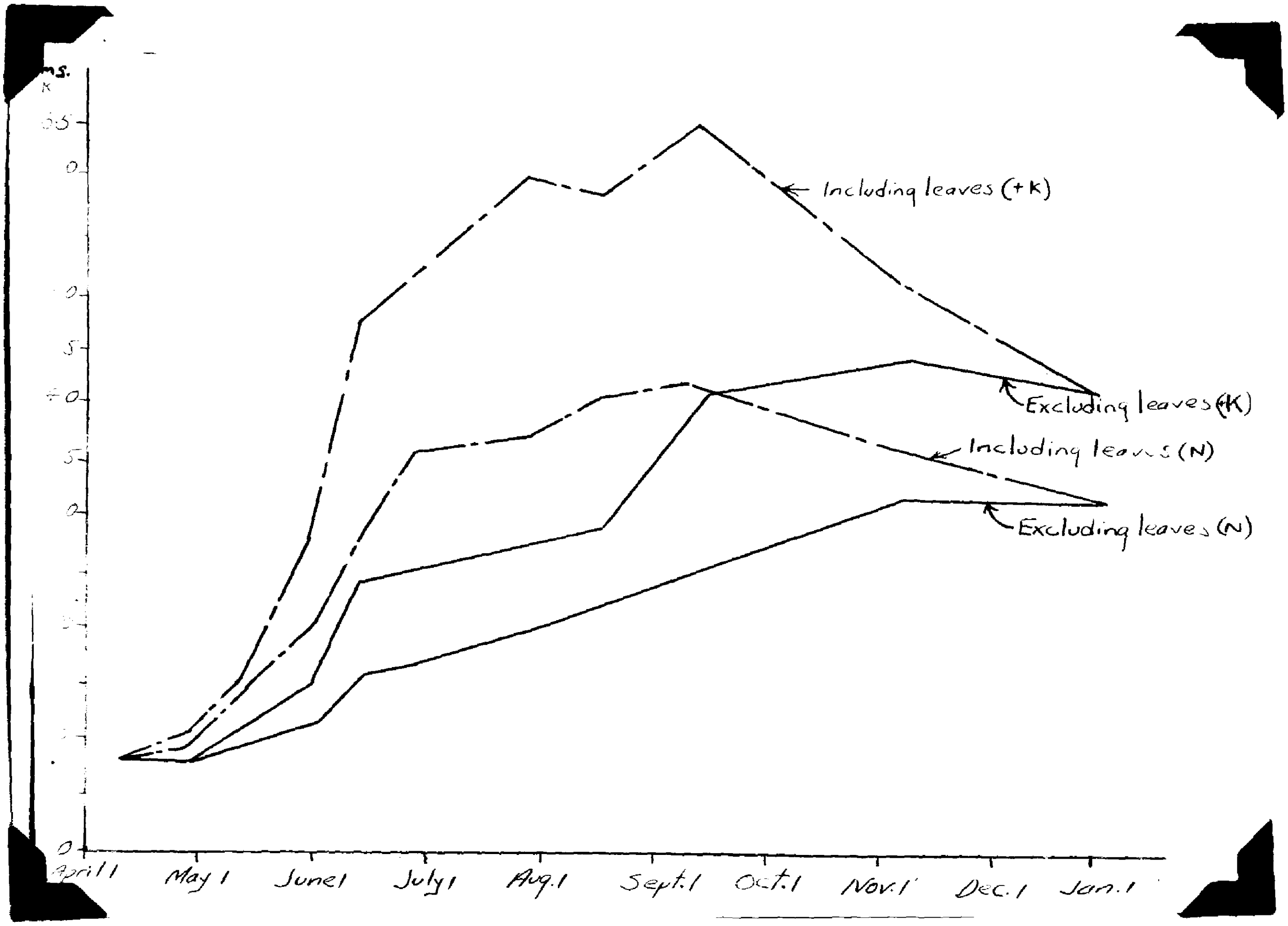


Fig. 8. - Graph showing the total grams of potassium in the trees, both including and excluding the leaves and under high (+K) and low (N) potassium nutrition.

period as indicated by the fact that the potassium content of the tree, minus the leaf content, decreased.

From April 25th to May 11th, the intake of potassium was sufficient to cause an increase in all parts of the tree, and the rate of absorption continued rather uniformly from May 11th to September 10th. Leaf fall was beginning at the latter date, and from then on the potassium content of the tree as a whole decreased. However, considering the tree, excluding leaf potassium, the increase in potassium continued at a uniform rate until November 11th. From then until January 8th, there was little change.

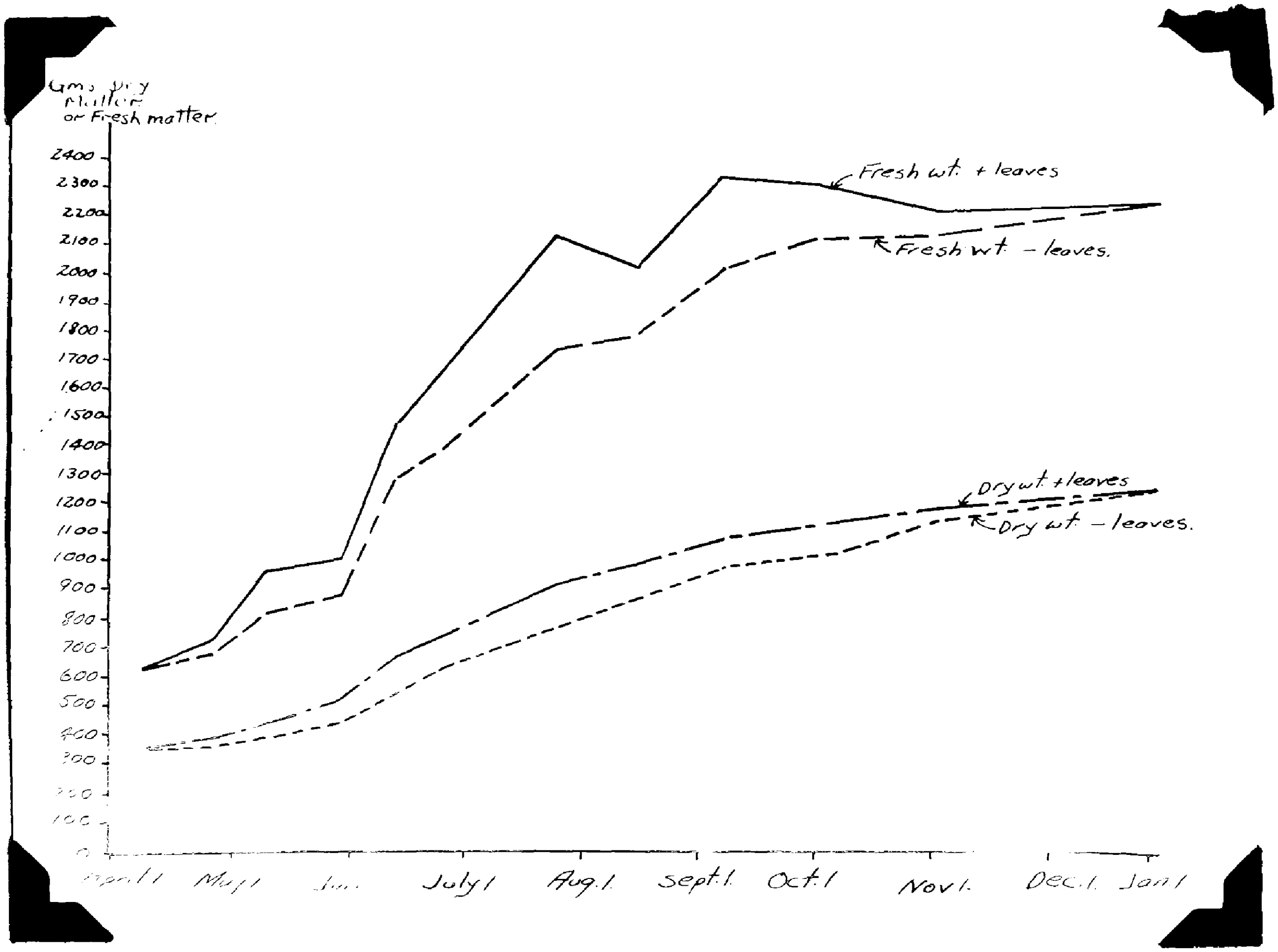
The absorption curve from the potassium fertilized trees (+K) was similar to that for the normal treatment except that considerably more potassium was absorbed over the same period of time. Considering the large differences and the lack of growth response of the trees there can be no doubt that luxury consumption of potassium occurs with the apple. This point will be discussed later.

Seasonal Movement of Potassium Among the Different Tissues and Parts of the Tree

In considering the seasonal movement of potassium among the different tissues, all eighteen fractions could be considered separately. However, to simplify the problem, only the different aged portions of the tree were considered separately. The fact cannot be disregarded that the growth laid down the previous season, and designated here as 1932 growth, has within it new tissue added on by the cambium. This tissue is probably of entirely different composition than that formed the previous year. Therefore, if tissues decrease in potassium with age and young tissues high in potassium are being deposited, the interpretation of the results is somewhat difficult. Some experimental evidence obtained on this point will be presented later. Meanwhile, the data for the potassium content of the tree tissues will be presented disregarding the fact that the 1931 wood, for example, contains new wood added in 1932 and still younger tissue laid down in 1933.

The question arose whether to use the per cent fresh weight or per cent dry weight figures in interpreting the relative potassium concentrations in the different tissues. An inspection of the fresh and dry weight curves for the entire tree presented in fig. 9 indicates that the dry weights present a more stable basis on which to calculate the results. Dry matter accumulated constantly throughout the season. The fact that the fresh weight curve fluctuated somewhat, even though the general trend was the same indicated changes in moisture content at the different periods, rather than any appreciable change in dry matter.

Another problem which arose in connection with the study of the potassium status of the tissues, was the



'Fig. 9. - Total fresh and dry weights of the trees throughout the season, both including and excluding the leaves.

question of how to consider the leaves with the other tissues. They are not a permanent tissue, are extremely vegetative, and contain a large proportion of the tree's potassium. Because of these conflicting features the leaf data are presented separately.

The complete data for the potassium determinations are presented in the appendix in tables 1 to 17. Certain selections and combinations from these tables will be incorporated in the text.

Proportionate Distribution. Table 22 presents the potassium content of the different tree tissues as per cent of the total. These data give an indication as to what tissues contain the bulk of the potassium at the different sampling dates. Fig. 10 presents the results graphically.

The roots started off carrying about 40 per cent of the tree's potassium. By June 13th they had dropped so as to carry only 27 per cent. By October the roots contained about the same portion of the total potassium as they did at the start of the growing season.

During the month of May the 1931 wood lost in its proportionate amount of potassium, and the 1932 growth showed an increase. Butler, et al(12) stated that such an upward movement occurred at the same period. Apparently there is an upward movement of potassium at this period for the purpose of utilization in growth.

Table 22. Potassium in the Different Aged Portions of the Trees Expressed as Per cent of the Total. (Normal treatment.) 1933

Part of tree	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	10.5	16.4	16.8	18.5	17.2	20.9	18.8	16.9	18.0
1932 growth	17.1	18.6	21.9	20.7	18.0	17.1	16.7	13.7	12.7	13.1	13.0	12.8
1931 growth	43.7	38.6	42.7	36.5	38.9	36.5	36.5	34.5	30.7	29.3	30.6	31.1
Roots	39.0	42.7	35.3	32.4	27.3	29.5	28.4	34.6	37.2	38.9	39.2	37.9

Table 23. Total Amount of Potassium in the Different Aged Portions of the Trees under Normal Treatment (K in gms.) 1933

Portion of tree	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	.1306	.2473	.3128	.3654	.3964	.4961	.4388	.5280	.5902
1932 growth	.1498	.1413	.2137	.2571	.2716	.3158	.3312	.3171	.3277	.3048	.4118	.4188
1931 growth	.3792	.2944	.4151	.4553	.5848	.6775	.7235	.7957	.8158	.6812	.9669	1.0171
Roots	.3379	.3255	.3498	.4032	.4083	.5480	.5626	.7963	.9631	.9055	1.2442	1.2425

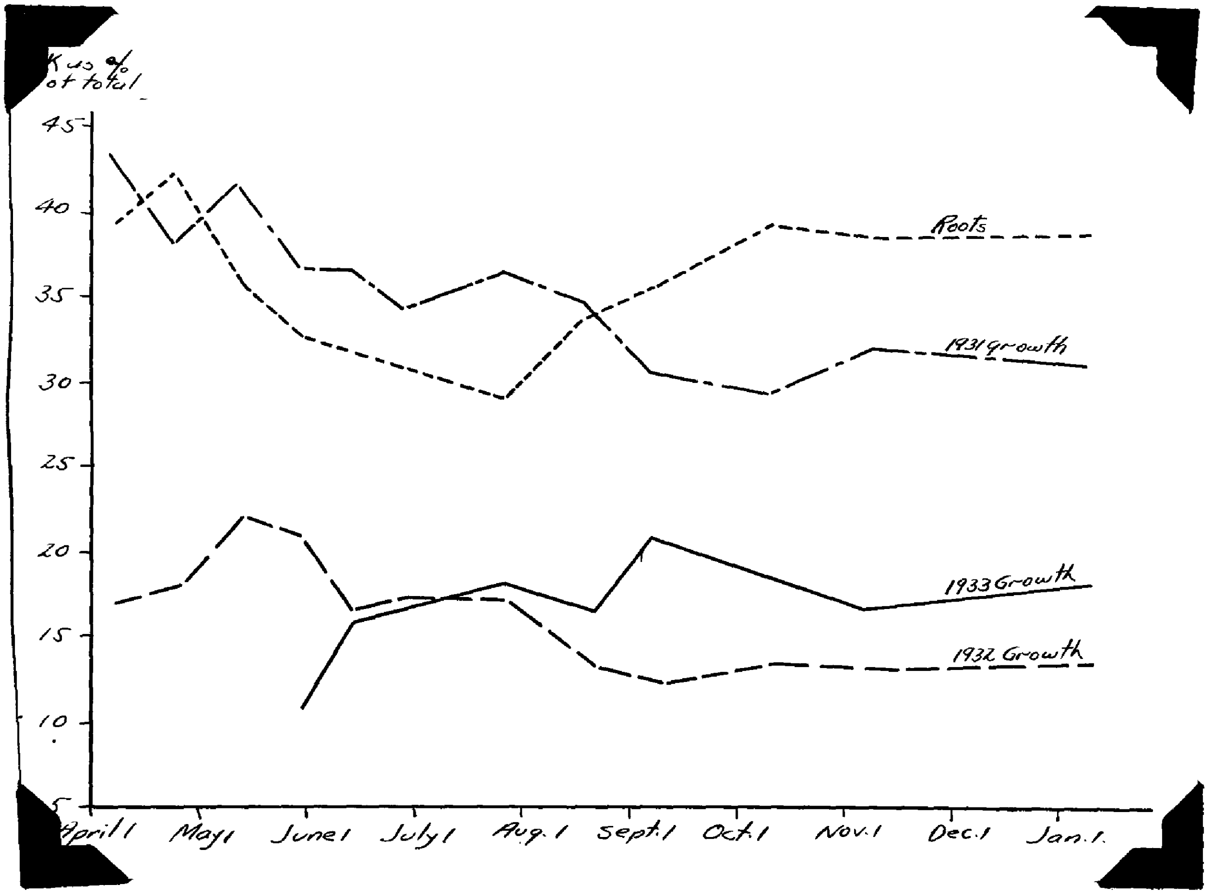


Fig.10. - Potassium content of the different aged portions of the trees throughout the season expressed as per cent of the total.

The 1933 growth continually increased in its proportional amount of potassium. This might be expected since new tissue was being added throughout the season.

The bark of the trees under the normal treatment on June 13th contained 47.5 per cent of the tree's potassium, while the wood contained 52.5 per cent, but under the potassium treatment 57.9 per cent of the potassium was in the bark and only 42.1 per cent in the wood. This would indicate that luxury consumption takes place more readily in the bark than in the wood. Other figures will bring this out more emphatically

<u>Absolute Distribution</u>. Considering the same material expressed in grams per fraction, the actual movement of potassium from one portion to another can be traced. Table 23 gives the figures while fig. 11 presents them graphically. It is immediately evident from the graph that all parts of the tree gained continually in their potassium content. The roots did not increase in potassium during the period of early growth activity at a rate similar to that of other fractions, but from July 23rd on through the season the roots increased greatly in their potassium content. The possibility of attaching some importance to this phenomenon will be considered in the discussion.

The fact that the 1933 growth increased in its potassium content more rapidly than the 1932 growth might be attributed to a greater proportion of meristematic tissue in the 1933 growth. Dowding(19) as well as many

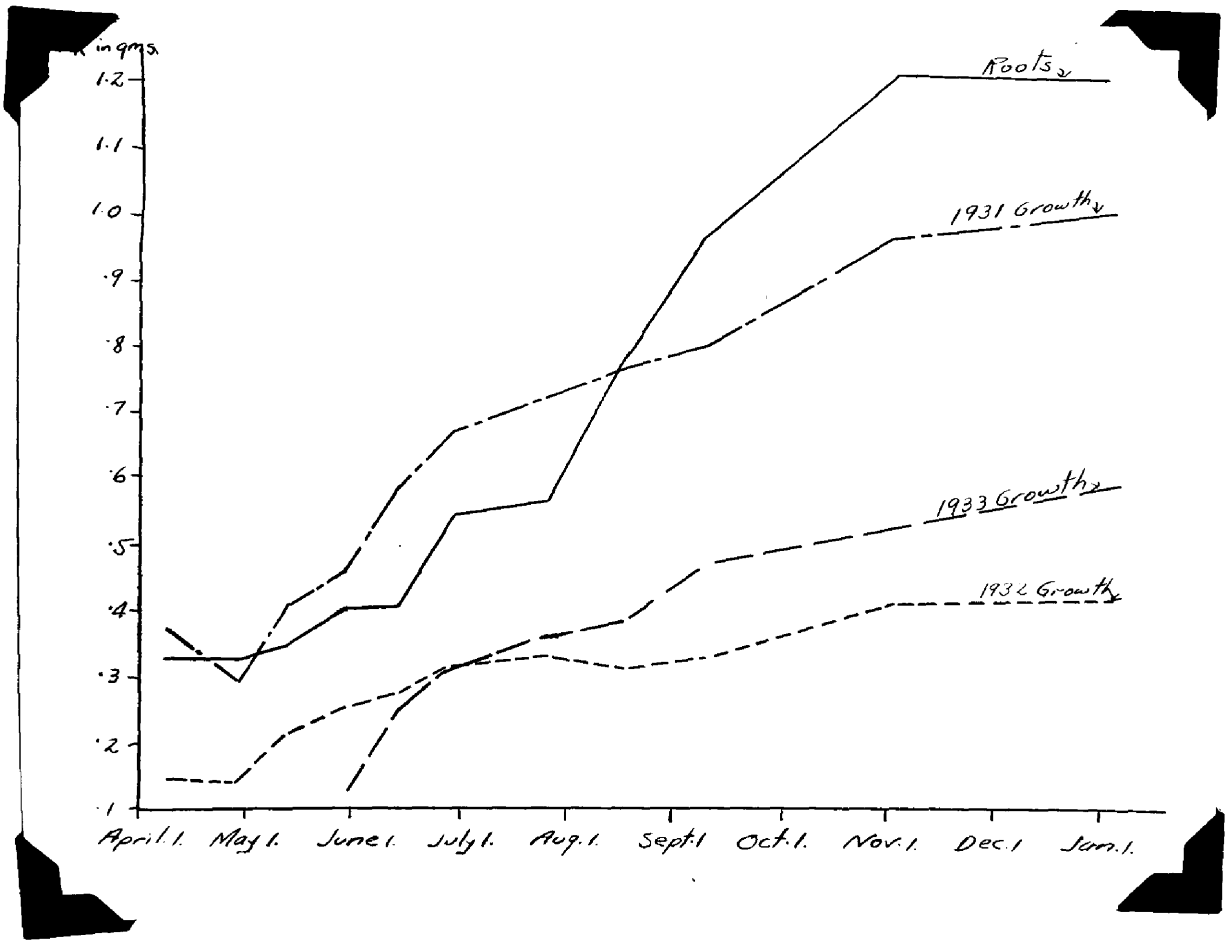


Fig. 11. - Absolute amount of potassium (grams) in the different aged portions of the trees throughout the season.

others has pointed out the high concentration of potassium in the younger tissues.

The total amount of potassium in the 1931 and 1932 growth followed very closely the dry weight as evidenced by comparison of figures 11 and 12. However, the roots and new growth increased in potassium during the latter part of the growing season at a different rate than they accumulated dry matter.

Concentration of Potassium. The amount of potassium in each portion was expressed as per cent of the dry matter. The results are shown in table 25 and are presented graphically in fig. 13. The data indicate that the concentration of potassium in the new growth was very high at start of season compared with other portions of the tree, but decreased suddenly between May 29th and July 23rd. After this period it gradually decreased throughout the growing season. The 1932 growth, after May 29th, showed a gradual decrease throughout the season, while the 1931 wood remained fairly constant, only decreasing slightly.

The roots remained quite constant until the latter part of July when they increased until September 10th, and remained high throughout the remainder of the sampling period.

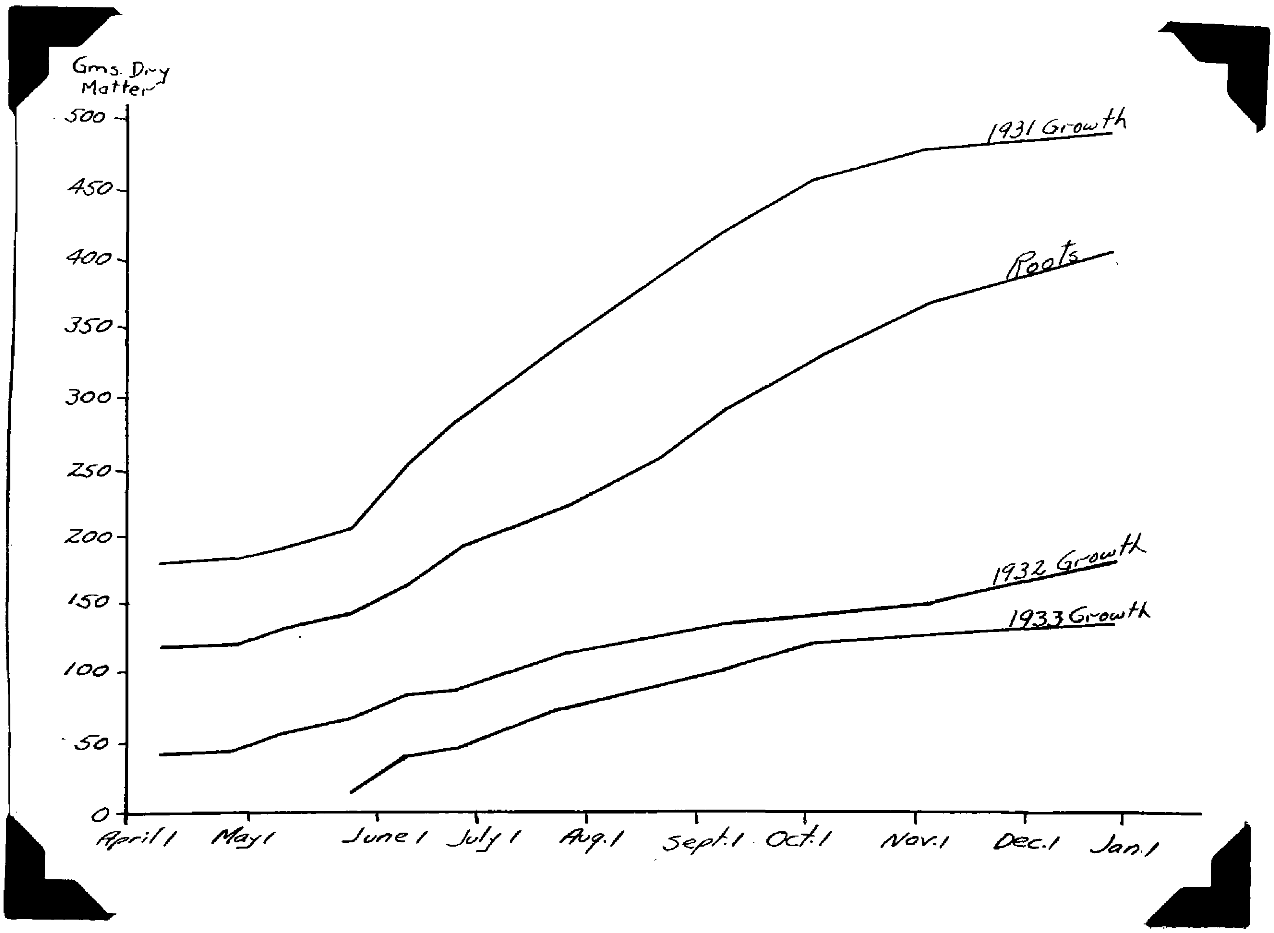


Fig. 12. - Grams of dry matter in the different aged portions of the trees throughout the season.

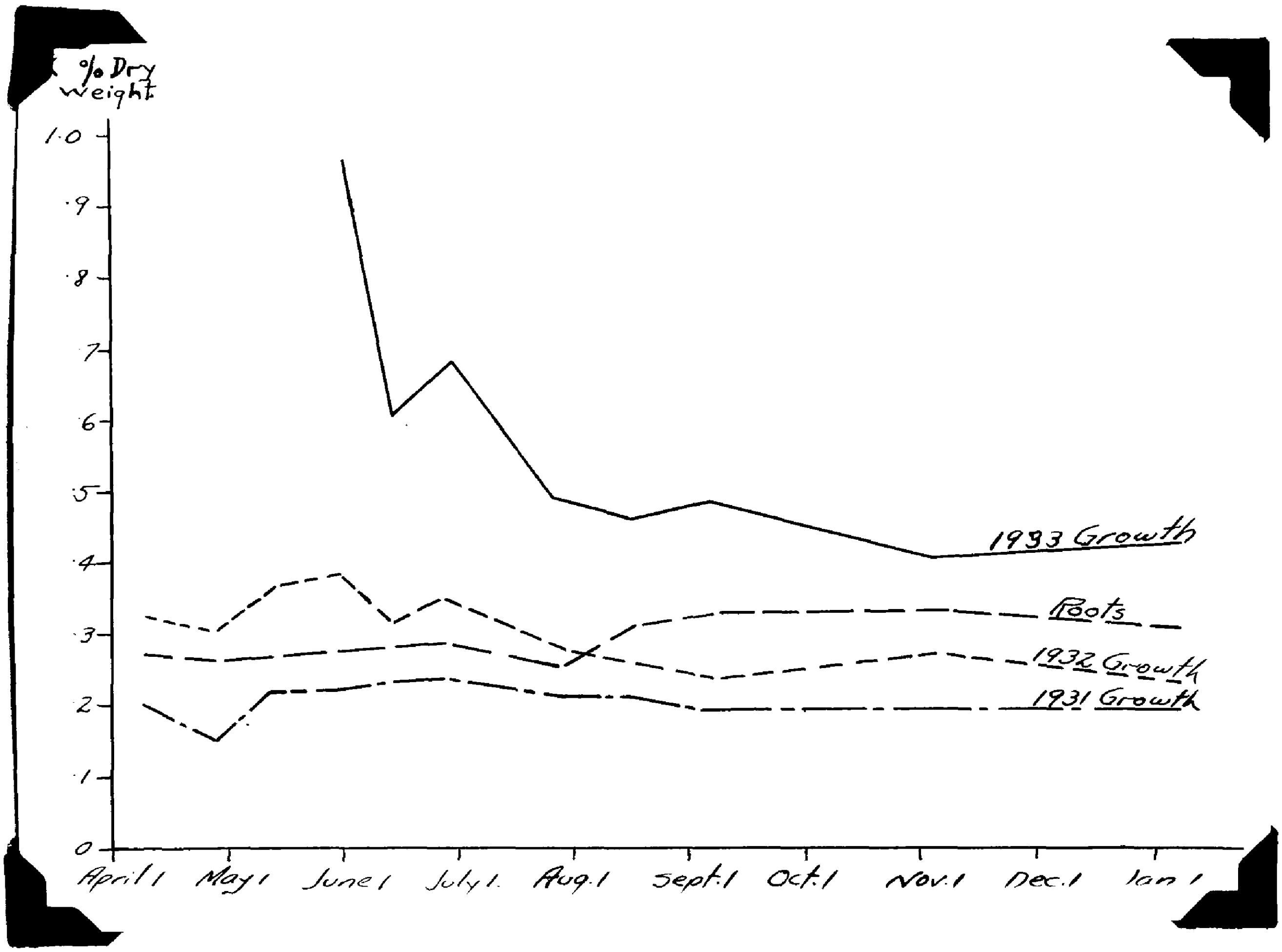


Fig. 13. - Potassium content of the different aged portions of the trees expressed as per cent of the dry matter.

Table 24. Total Dry Weight in Grams of Each Portion of the Apple Trees at the Different Sampling Dates. 1933

Portion of tree	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	13.5	40.7	45.4	74.0	86.2	101.7	122.7	131.2	138.5
1932 growth	46.5	46.8	57.7	67.1	86.4	89.7	118.2	123.3	136.6	139.9	151.5	183.5
1931 growth	184.0	185.0	193.7	209.6	255.0	288.1	349.6	382.5	429.0	462.8	486.1	498.0
Roots	121.8	124.6	132.4	145.7	163.9	193.0	222.5	258.8	296.5	336.8	375.8	410.5

Table 25. Potassium Content of Different Portions of Young Apple Trees Expressed as Per cent Dry Weight.

Portion of tree	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	.967	.608	.689	.494	.460	.488	.358	.403	.426
1932 growth	.322	.302	.370	.383	.314	.352	.280	.257	.240	.218	.273	.228
1931 growth	.206	.159	.214	.217	.229	.235	.207	.208	.190	.147	.199	.204
Roots	.277	.261	.264	.277	.249	.284	.253	.308	.325	.269	.331	.303

It is evident that the percentage composition is an expression of the relation between the absolute increase in potassium and the increase in dry matter. If dry matter and potassium increased proportionately, the percentage composition would remain the same. Therefore, as the graphs bear out, in the roots the increase in potassium was greater than the increase in dry weight, while in the 1933 growths the reverse situation existed.

Distribution of Potassium Between Basal and Apical Portions of Growth. The question now arises -- did both basal and apical portions of the different aged parts of the tree act similarly throughout the season? From the data in the appendix, on a percentage basis the bark and the wood, both upper and lower, of the 1932 and 1931 growth did act very similarly, but in the other tissues differences existed.

The trends for potassium, as per cent dry weight of the upper 1933 wood and lower 1933 bark, as well as those for the large root bark and root wood are presented in fig. 14.

The large increase in the roots after July 23rd was principally caused by increases in the bark rather than in the wood. The root bark and wood seemed to exhibit somewhat of a reciprocal relationship during the early part of the growing season, thus accounting for the constant percentage compositions of the roots as a whole. The causal factors are unknown.

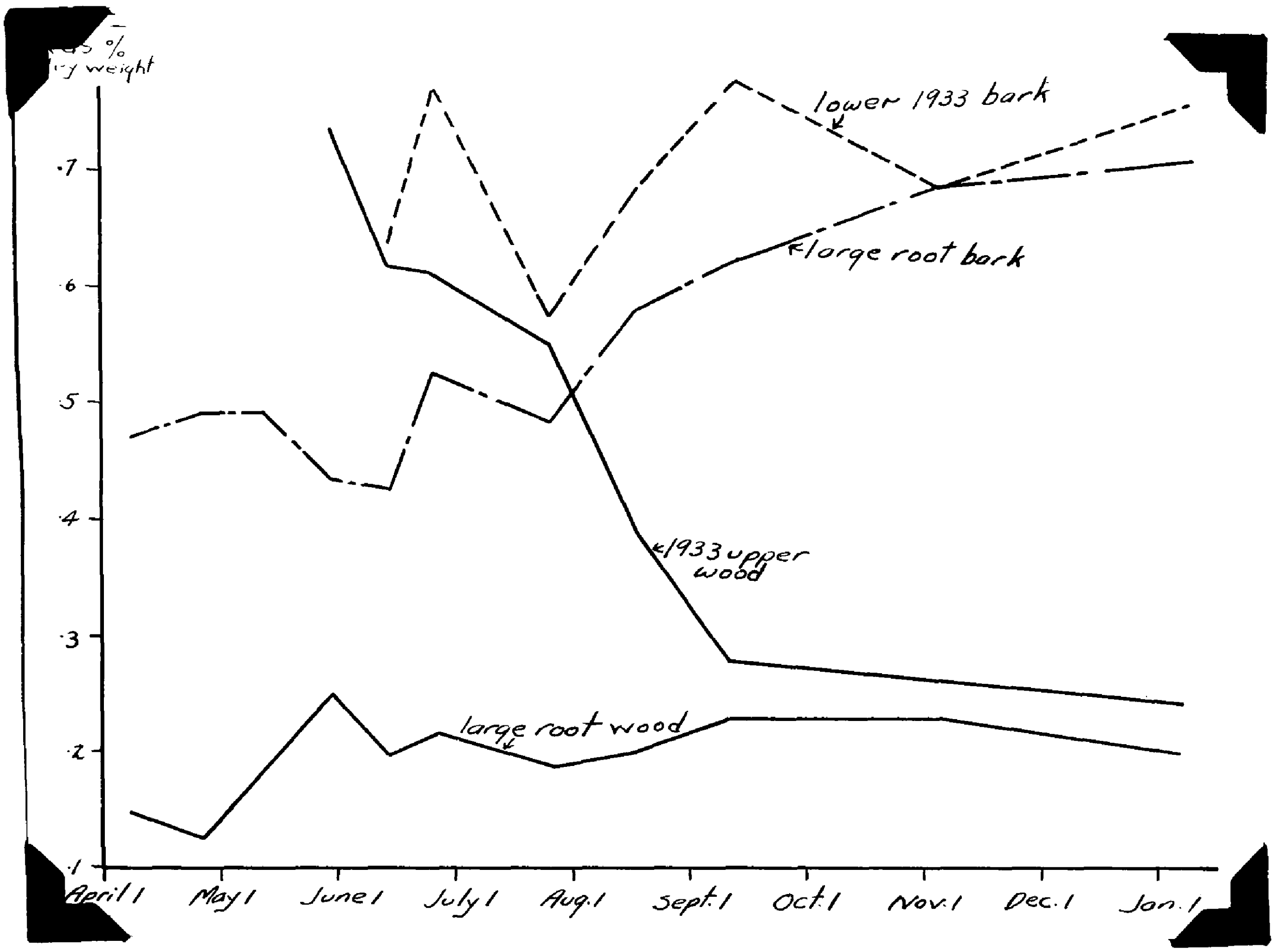


Fig. 14. - Seasonal trends of the potassium content of certain bark and wood fractions expressed as per cent of dry weight.

Some other changes are not presented in fig. 14. The upper 1933 bark decreased only slightly during the season. The 1933 wood, upper and lower, were quite highly correlated. The large roots and small roots acted much alike but the root bark and root wood responded differently. The chart brings out the fact that the decrease in percentage composition of the 1933 growth was largely due to the wood fraction, since the bark did not materially decrease.

On an absolute basis the bark and wood fractions, both upper and lower, maintain similar trends to those of the entire seasons growth, the only differential response being that the bark increases in potassium relatively faster than the wood.

From the data in the appendix it appears that the woody portion of the tree is relatively inactive with respect to potassium. Of course, if potassium were only passing through the conducting elements of the xylem, one should not expect marked seasonal differences. However, the new wood laid down by the cambium should be relatively high in potassium, if the number of living cells in a tissue is correlated with its potassium content. In order to study this point, the new wood laid down by the cambium on the lower 1932 section of the tree was separated at each sampling date and subsequently analyzed for potassium. The curves as per cent of dry matter are plotted in fig. 15.

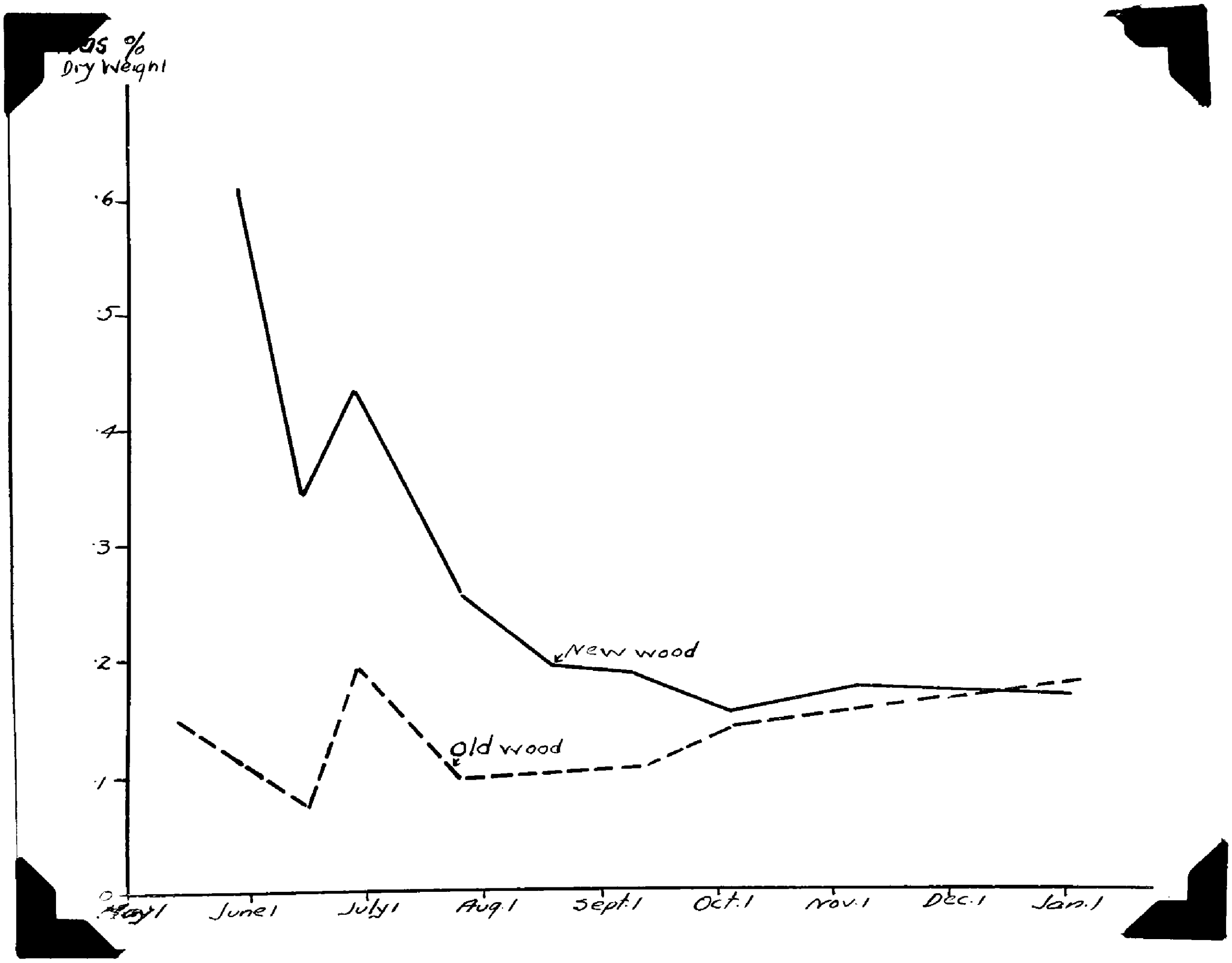


Fig. 15. - Potassium content of the lateral growth added to the lower portions of the 1932 wood, as compared with the old wood which was laid down the previous season.

The curve for the new wood on lower 1932 growth very closely resembles that for the upper 1933 wood. This would tend to indicate that the decrease in concentration of potassium in new wood was quite similar whether it initiated from the cambium or a combination of an apical meristem and the cambium. The old wood laid down the previous year tended to decrease in its potassium concentration during the early part of the growing season, and then increased gradually from the latter part of July on through the season. The number of living cells in this section of the wood were decreasing rather than increasing, yet the potassium content increased during the latter part of the growing season. This would indicate a storage of potassium in this tissue.

Potassium Changes of the Leaves. The leaves, at their maximum weight contained 44 per cent of the trees potassium. The fact that the seat of photosynthetic activity is in the leaves may be a factor in causing this high concentration, since potassium is considered to play a part in carbohydrate metabolism.

Fig. 16 shows the potassium composition of the leaves on a per cent dry weight and absolute amount basis throughout the season.

The curves indicate that on a percentage basis the potassium content of the leaves fell rapidly until June 13th and then suddenly rose and fell again by July 23rd.

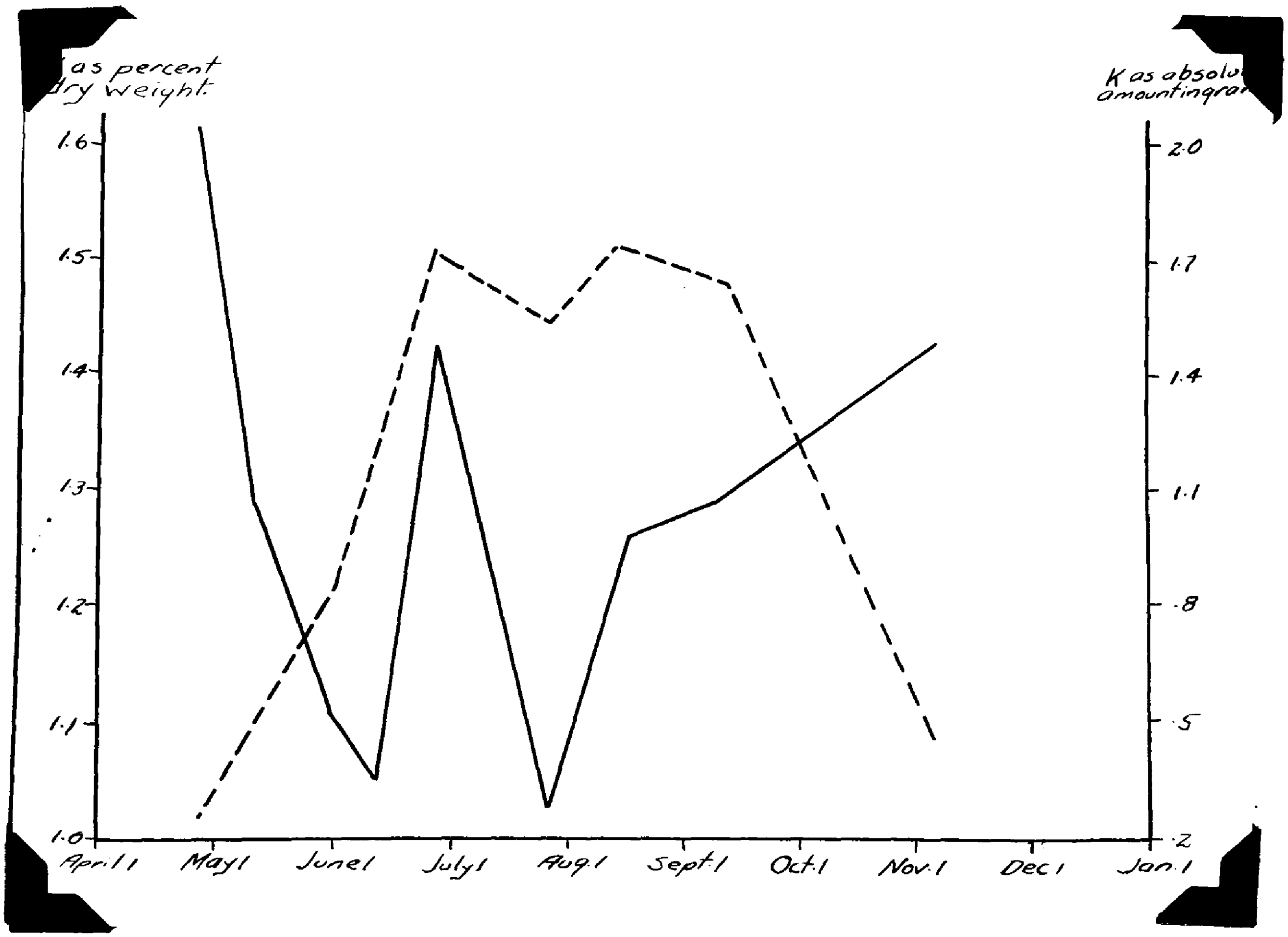


Fig. 16. - Potassium content of the leaves throughout the season, expressed as per cent of dry weight and as absolute amount in grams.

The concentration of potassium increased from this period until leaf fall. The sudden rise between June 13th and June 25th cannot be explained. It is doubtful that sampling error could account for such a large difference. The chemical determination was checked accurately.

On an absolute basis the potassium content increased until June 13th, remained fairly constant until September 10th, and then fell off as leaf fall began. This curve is what one would expect since it conforms quite well to the total dry weight curve of the leaves.

Table 26 -- The Potassium Content of Old and Young Leaves at Three Sampling Dates. 1933.

Date.	Leaves.	K as Per cent Dry Matter.	Gms. K. per 100 Leaves.
July 23	Young	1.539	.529
	Old	1.102	.337
Aug. 16	Young	1.632	.614
	Old	1.320	.459
Sept. 10	Young	1.639	.590
	Old	1.293	.383

Unfortunately the grams of potassium per 100 leaves was not calculated for the first part of the season.

The data in table 26 were obtained from July 23rd to September 10th and indicate that on an absolute basis the potassium content of the leaf was rather constant from July 23rd until September 10th.

To substantiate the fact that young leaves contain more potassium than older ones, on three sampling dates the leaves growing on the upper end of the current season's growth were separated from those growing on the lower portion. The results are reported in table 26.

Relative Potassium Content of the Different Tissues.

Obviously the different tissues vary in their potassium content at the different sampling dates. However, there are certain relationships among the different tissues which hold true generally throughout the season.

Table 27 gives the average potassium content of the different fractions, all sampling dates being averaged. The results are expressed both as per cent dry weight and as absolute amounts of K.

The data are shown graphically in figs. 17 and 18. On a percentage basis the leaves are the richest in their potassium content. As percent of dry matter, there is a decreasing gradient of potassium from the apical end of the tree to the smallest roots. The wood acts similarly until the base of the tree is reached and then the

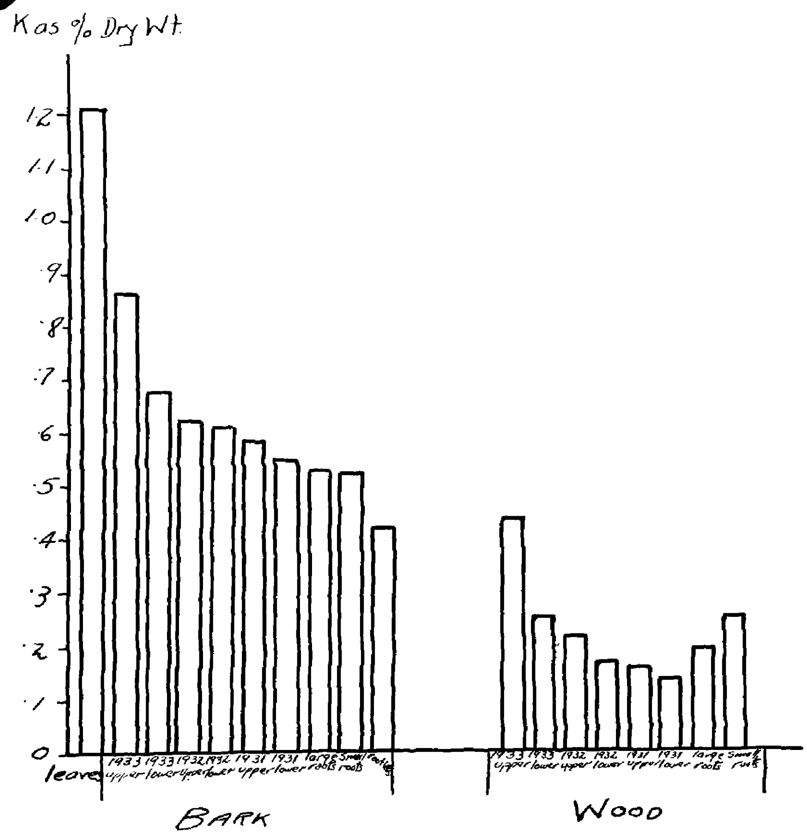


Fig. 17. - Potassium content of the different fractions of the trees expressed as per cent of dry weight. (Averages for entire season.)

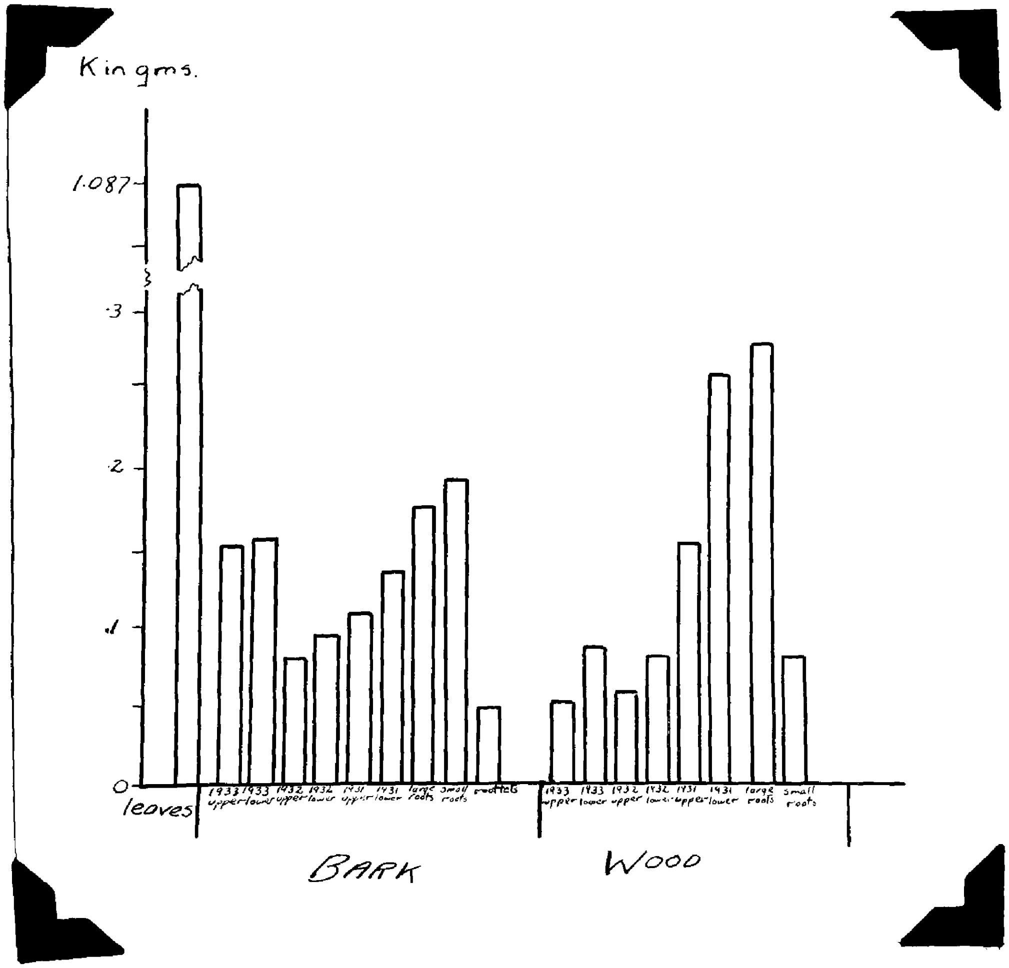


Fig. 18. - Potassium content of the different fractions of the trees expressed as grams per fraction.

Table 27 -- The Potassium Content of the Different Fractions of the Stayman Apple Trees. (Average of All Sampling Dates).

Tissue.	K as Per Cent Dry Weight.	Absolute Amount of K in Grams
Leaves.	1.262	1.078
Upper 1933 bark	.868	.141
Upper 1933 wood	.439	.048
Lower 1933 bark	.681	.145
Lower 1933 wood	.249	.082
Upper 1932 bark	.627	.073
Upper 1932 wood	.219	.057
Lower 1932 bark	.618	.082
Lower 1932 wood	.164	.076
Upper 1931 bark	.590	.109
Upper 1931 wood	.161	.153
Lower 1931 bark	.553	.135
Lower 1931 wood	.137	.261
Large root bark	.534	.173
Large root wood	.194	.271
Small root bark	.522	.195
Small root wood	.243	.072
Rootlets.	.421	.047

large roots have an increased potassium concentration and the small roots are even higher.

Comparing the percentage results with the absolute amounts of potassium in the tissue (fig. 18) the leaves are highest on both bases, and the 1933 bark contains a comparatively high potassium content. From the 1932 bark down to the small root bark, inclusive, there is an increasing gradient of potassium on an absolute basis. Thus the absolute amounts are negatively correlated with the percentage compositions. The wood generally exhibited an increasing amount of potassium from terminal portion to root portion of the tree. The small roots were exceptional and the 1933 lower wood was somewhat higher than the 1932 wood. However, in general, both with the bark and wood, where the concentration of potassium is the greatest, the absolute amounts are the least. This can be most logically explained in that the potassium is highly concentrated in the young, active tissue, while the bulk of the tree is made up of woody, structural material which has a low concentration of potassium. This point has not received proper consideration in the literature, many investigators reporting that the majority of the potassium was located in the bark.

Although there are interactional effects between sampling date and tissue with respect to potassium content, the different tissues showed approximately the same relationships throughout the season.

Effects of Heavy Applications of Potassium Fertilizers on the Potassium Content and Distribution.

Fig. 8 showed that potassium had entered the tree in considerably greater amounts under heavy applications than under normal treatment. Fig. 19 shows the potassium content of the tree tissues on June 13th for both the potassium fertilized and normally treated trees. Note how greatly the leaves have increased in their potassium content, and how much more the bark in-

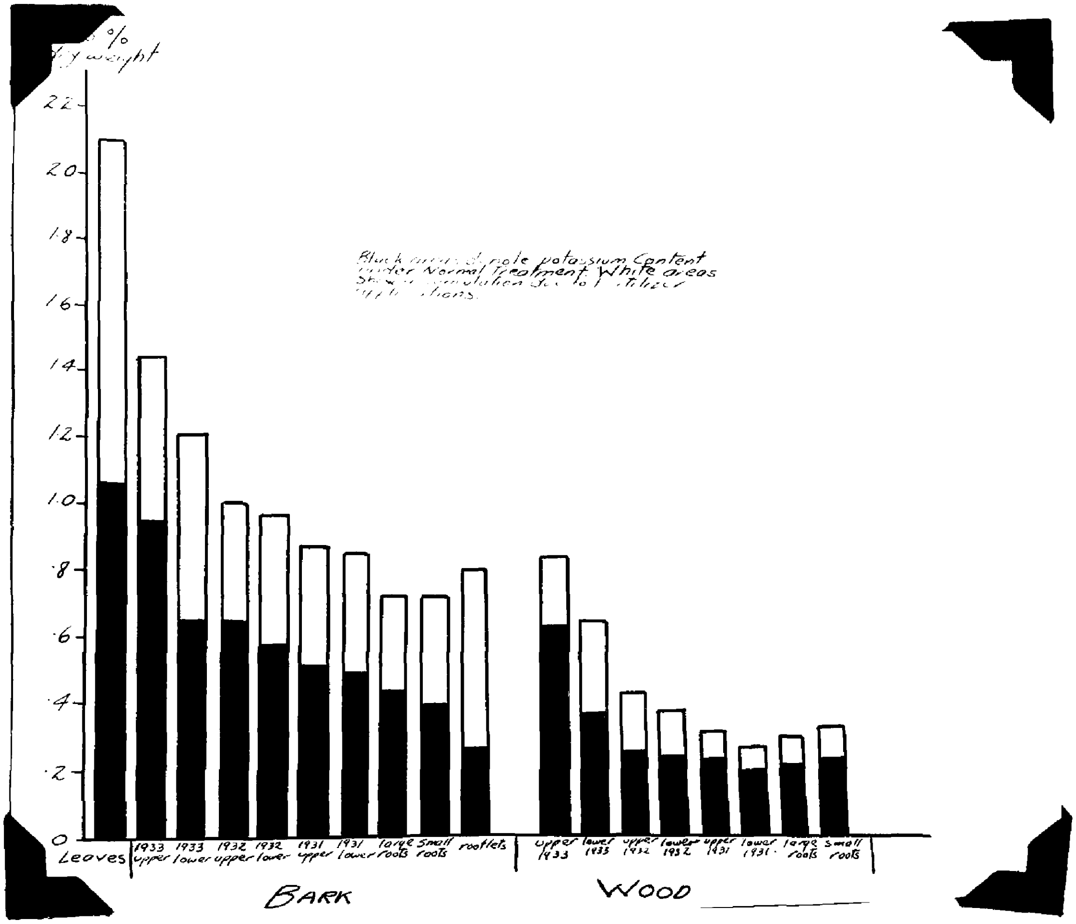


Fig. 19. – Potassium content of the various fractions of the trees on June 13, comparing the potassium treated trees with the normally treated ones. (K as per cent dry weight.)

increases, due to treatment, than the wood.

A similar relationship exists in the case of the absolute amounts (fig. 20), the leaves increasing about 100 per cent due to treatment. The bark increases more than the wood in relation to the amount present in the untreated tissues. The same general tissue relationships exist here as shown in figs. 17 and 18 except that the root bark is relatively low in potassium. It will be recalled that the increased movement of potassium into the roots did not take place until after June 13th.

It apparently required between one and two months for the applied potassium to enter the tree and move up to the leaves and upper twigs. Fig. 21 shows the seasonal trend of the leaves and 1932 upper bark for both treatments. Note that in both cases the treated (+K) and normal (N) curves cross between the May 11th and May 29th sampling dates. From this period on the leaves from the trees treated with potassium fertilizer always maintain a higher concentration of potassium.

All tissues exhibited luxury consumption, but the leaves exhibited it to a greater degree than any other part of the tree. The leaves from the +K treatment abscissed somewhat earlier in the fall indicating that certain toxic or at least detrimental effects occurred from the heavy application of potassium.

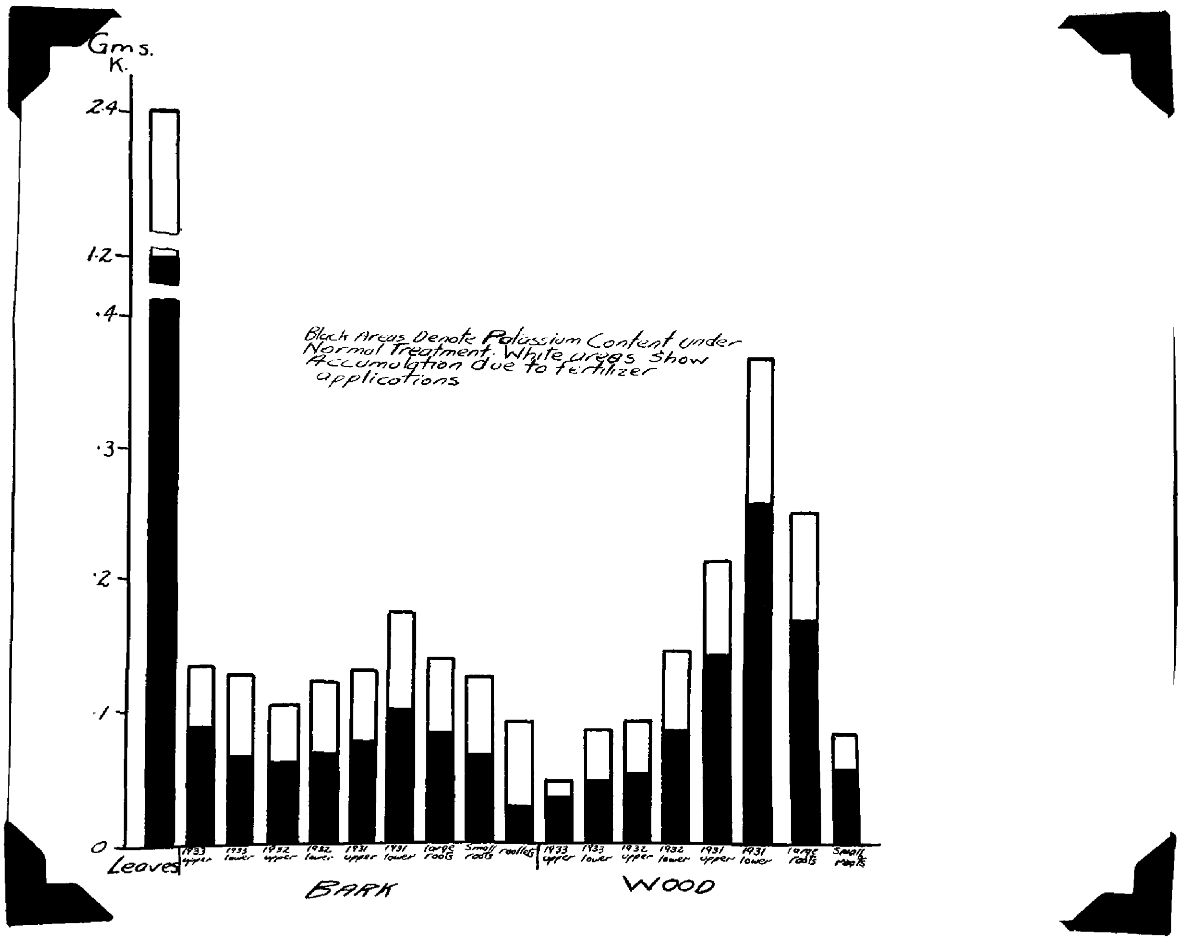


Fig. 20. – Potassium content of the various fractions of the trees on June 13, comparing the potassium treated trees with the normally treated ones. (K as absolute grams per fraction.)

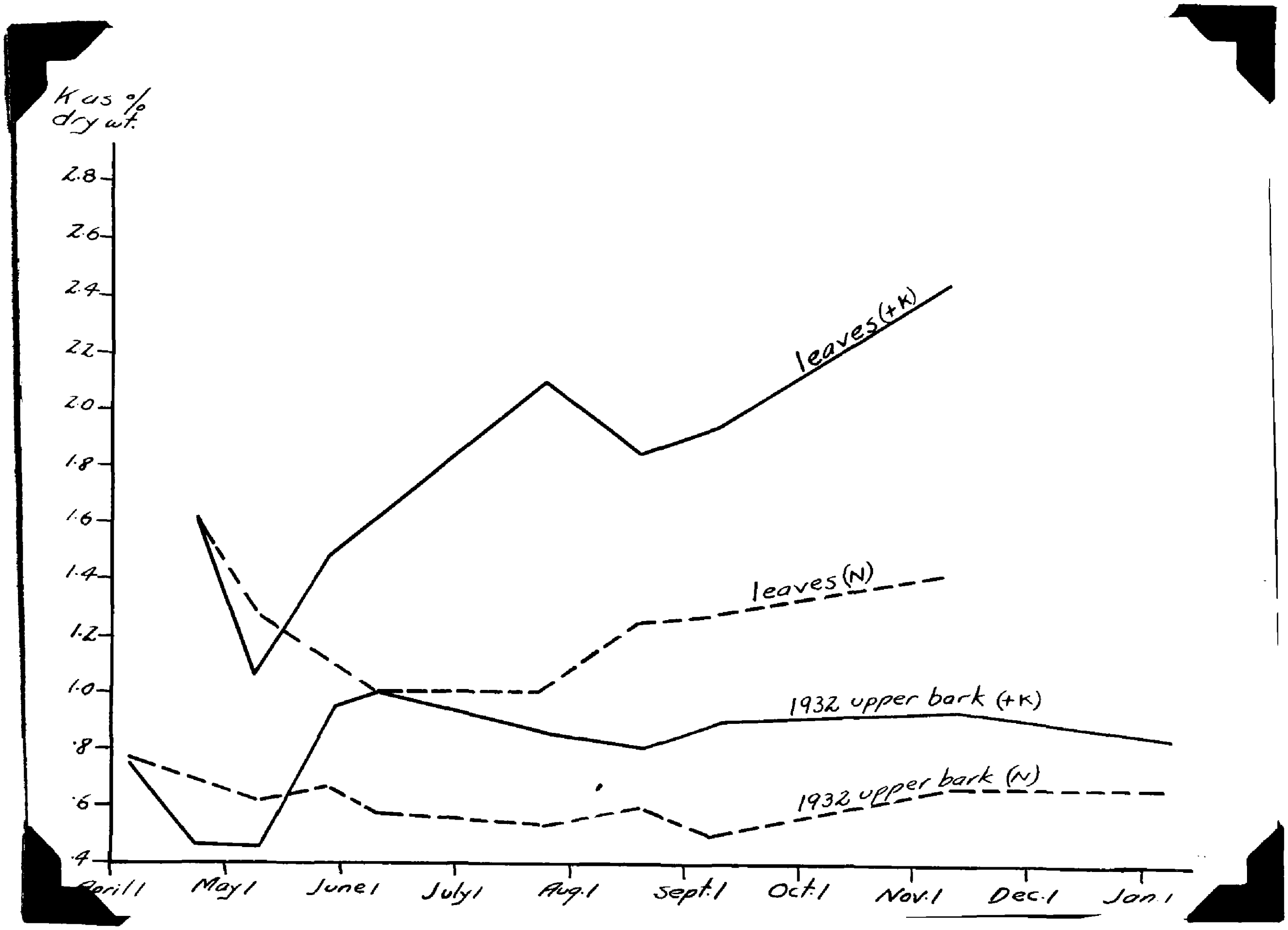


Fig. 21. - Potassium content of the leaves and the 1932 upper bark under the two treatments, showing the period when the increased potassium content of the potassium fertilized trees became noticeable.

Effect of Potassium Applications Upon the Total Nitrogen Content of the Trees.

Table 28 shows the total nitrogen content of the trees under both treatments throughout the season, both including and excluding the leaves. Fisher's "t" comparison made between the nitrogen content of the trees from the two treatments shows that the heavy application of potassium caused the total nitrogen content of the trees to be significantly increased. The material is presented graphically in fig. 22. That the curves for the nitrogen content of the treated and untreated trees move further away from each other as the season advances, also indicates that the difference was due to treatment rather than chance. This agrees with the work of Gildehaus (22) showing that a high concentration of potassium in the culture solution resulted in a higher nitrogen content.

In an effort to determine what tissues are responsible for this phenomenon, the differences for each tissue, averaging all sampling dates, were calculated, and expressed as per cent of the nitrogen content (absolute amount) of the untreated trees. This material is presented in table 29.

Any exact statement concerning the tissues concerned is impossible. However the current season's growth

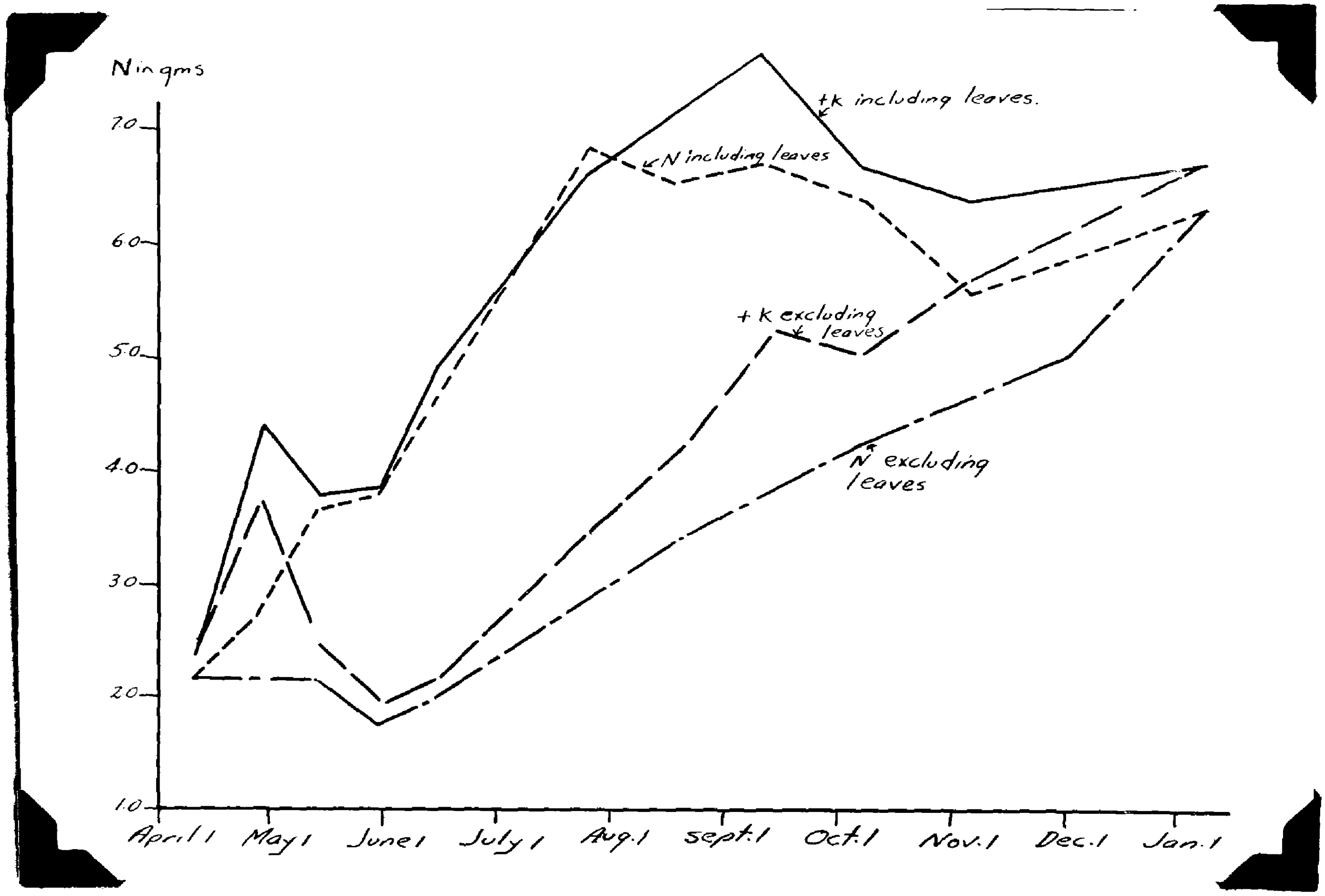


Fig. 22. - Nitrogen absorption curves for the trees, including and excluding the leaves, comparing the potassium fertilized trees with the normally treated ones.

Table 28. Total Amount of Nitrogen per Tree Under the Two Fertilizer Treatments, Both Including and Excluding the Leaves. 1933

Date Sampled	+ K*		N	
	+ leaves	- leaves	+ leaves	- leaves
April 8	2.3384	2.3384	2.1233	2.1233
April 25	4.3412	3.7627	2.7101	2.1315
May 11	3.7784	2.4508	3.6989	2.1489
May 29	3.8362	1.9130	3.8050	1.8281
June 13	4.9359	2.1629	4.6502	2.0046
June 25	--	--	5.0258	2.2919
July 23	6.6399	3.4230	6.8996	3.4856
Aug. 16	7.1106	4.2675	6.5503	3.8200
Sept. 10	7.7134	5.2495	6.7189	4.2601
Oct. 4	6.7449	5.0522	6.4094	4.7159
Nov. 3	6.4028	5.7405	5.6270	5.0390
Jan. 8	6.7755	6.7755	6.3959	6.3959

* + K = Treated with one pound potassium sulfate April 1.

N = Received no potassium fertilizers.

All trees received a basic treatment of $(NH_4)_2SO_4$ and Superphosphate.

Table 29 — A Comparison of the Nitrogen Content of Trees Fertilized With and Without Potassium Sulfate. (Absolute Basis Averages for Entire Season.

Tissue.	Treated Minus Untreated.	Increase or Decrease in Per Cent.
Leaves	-.018	-0.9
Upper 1933 bark	+.062	+35.0
Upper 1933 wood	+.053	+46.9
Lower 1933 bark	+.023	+10.1
Lower 1933 wood	+.180	+109.7
Upper 1932 bark	+.004	+3.4
Upper 1932 wood	-.001	-6.8
Lower 1932 bark	-.005	-4.0
Lower 1932 wood	+.016	+10.4
Upper 1931 bark	-.001	-0.7
Upper 1931 wood	+.021	+8.8
Lower 1931 bark	+.008	+4.1
Lower 1931 wood	+.091	+19.5
Large root bark	+.026	+12.3
Large root wood	+.013	+2.0
Small root bark	+.038	+21.0
Small root wood	+.012	+4.9
Rootlets	-.004	-3.2

showed the greatest difference, with the root bark being next in order of importance. In general, excepting the roots, the wood exhibited greater differences than the bark. There was essentially no difference between the leaf tissues. The importance of this relationship could hardly be conjectured, yet it might designate some relationship between potassium supply and protein synthesis.

<u>Association of Potassium with Nitrogen in the Various Tissues Throughout the Season.</u>

Association of Potassium with Nitrogen in the Various Tissues Throughout the Season.

Nitrogen ènters into many organic compounds in the plant while potassium is believed to be largely in solution as inorganic salts. However both elements are associated with living tissue and it is of interest to compare their behavior in apple trees.

The total absorption curves of potassium and nitrogen have already been presented in figs. 8 and 22 respectively. Comparing the normal treatment in both cases, the curves are similar except for two differences,- one difference being that although nitrogen and potassium moved into the leaves rapidly during the latter part of May, absorption of nitrogen from the soil was much slower at this time. The other difference is that the nitrogen increased from November 3rd to January 8th whereas potassium remained rather constant. This result seems a significant one, although it would require duplication before it could be deemed valid.

Table 30 presents the percentage of the total nitrogen in the tree that exists in each portion throughout the season. The material is presented graphically in fig. 23. The data were quite similar to the corresponding potassium results shown in fig 10) the only exceptions being that a larger proportion of nitrogen resided in the roots than in the 1931 growth at the beginning of the season; also nitrogen seemed to move

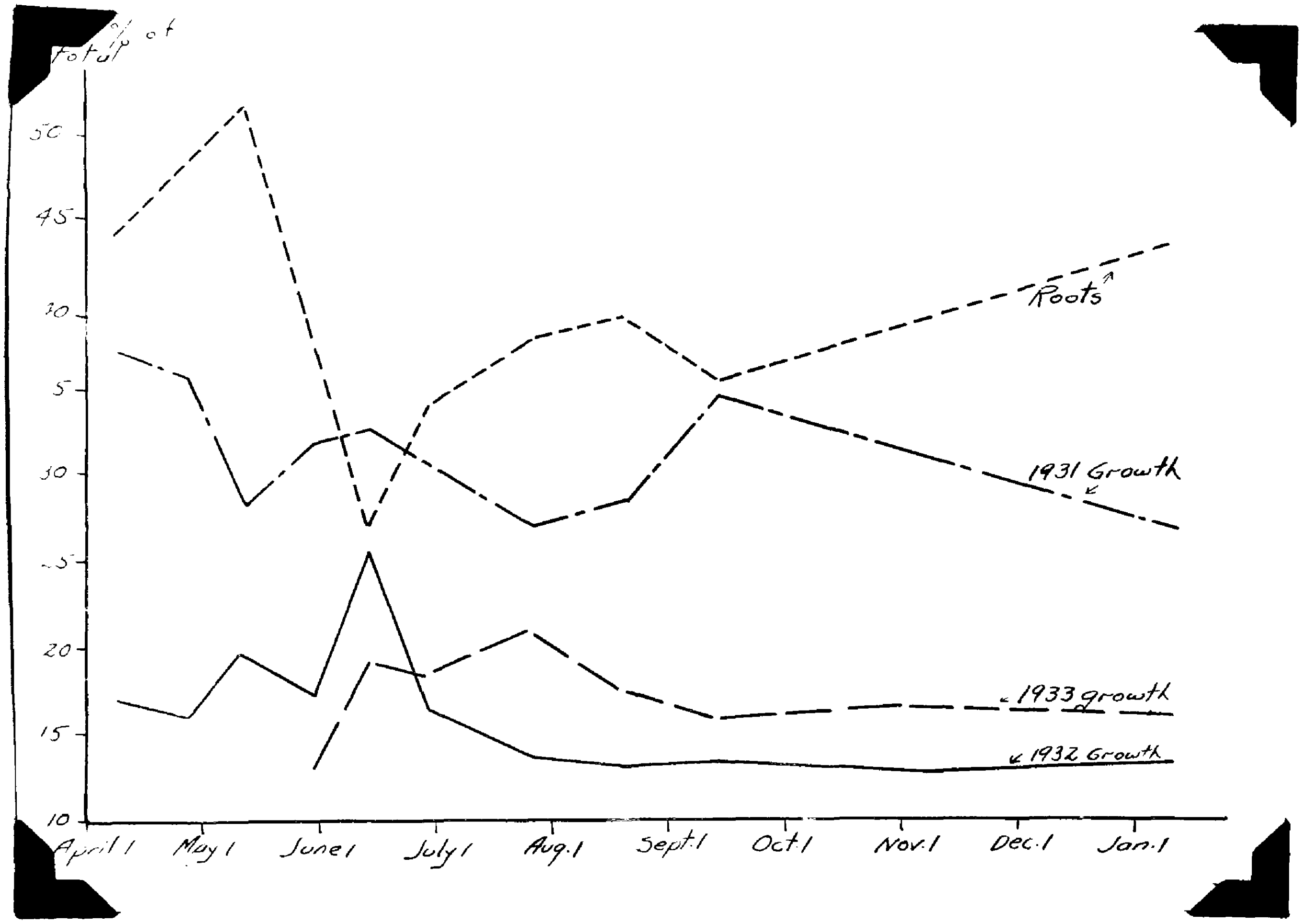


Fig. 23. - Nitrogen content of the different aged portions of the trees throughout the season expressed as per cent of the total.

Table 30. Nitrogen in the Different Portions of the Apple Trees Expressed as Per cent Of the Total.

Tissue	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	12.7	19.1	18.2	20.8	17.3	15.8		16.6	16.2
1932 growth	17.0	16.1	19.9	17.2	20.8	16.3	13.9	13.3	13.4		12.7	13.4
1931 growth	38.0	36.0	28.8	32.3	32.8	31.0	27.2	28.8	35.0		31.0	27.4
Roots	44.9	47.9	51.3	37.8	27.3	34.5	38.1	40.6	35.8		39.7	43.0

Table 31. Amount of Nitrogen Present in the Different Portions of the Apple Trees Throughout the Season. (Gms. K per fraction.) 1931

Tissue	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 growth	--	--	--	.231	.384	.417	.724	.661	.675	.878	.835	1.039
1932 growth	.361	.343	.428	.313	.417	.373	.484	.506	.571	.683	.638	.856
1931 growth	.807	.768	.619	.588	.658	.710	.948	1.101	1.493	--	1.560	1.754
Roots	.953	1.022	1.101	.688	.547	.792	1.331	1.550	1.523	1.990	2.006	2.747

out of the roots and into the upper portion of the tree more rapidly during May. During the latter part of June the roots started increasing in their relative amount of nitrogen, as well as potassium, and continued to increase generally throughout the remainder of the sampling period.

The data calculated on an absolute basis are shown in table 31 and fig. 24. Here the results closely resemble the potassium data, the only conspicuous difference being that there is a low point in the nitrogen content during June and the nitrogen content of the root fraction increases greatly after November 3rd. In the case of potassium, the increase on an absolute basis was rapid in all fractions during June and there was no increase in the roots after Nov. 3rd.

The data on a per cent dry weight basis are shown in table 32, and fig. 25 The curves for nitrogen and potassium again are similar, excepting that the roots decreased greatly in their nitrogen content during May and early June, and increased after November 3rd. Also the concentration of nitrogen in the 1932 growth dropped off during May much more rapidly than did the potassium concentration.

When the same data were calculated for the bark and wood separately, it revealed that the decrease of

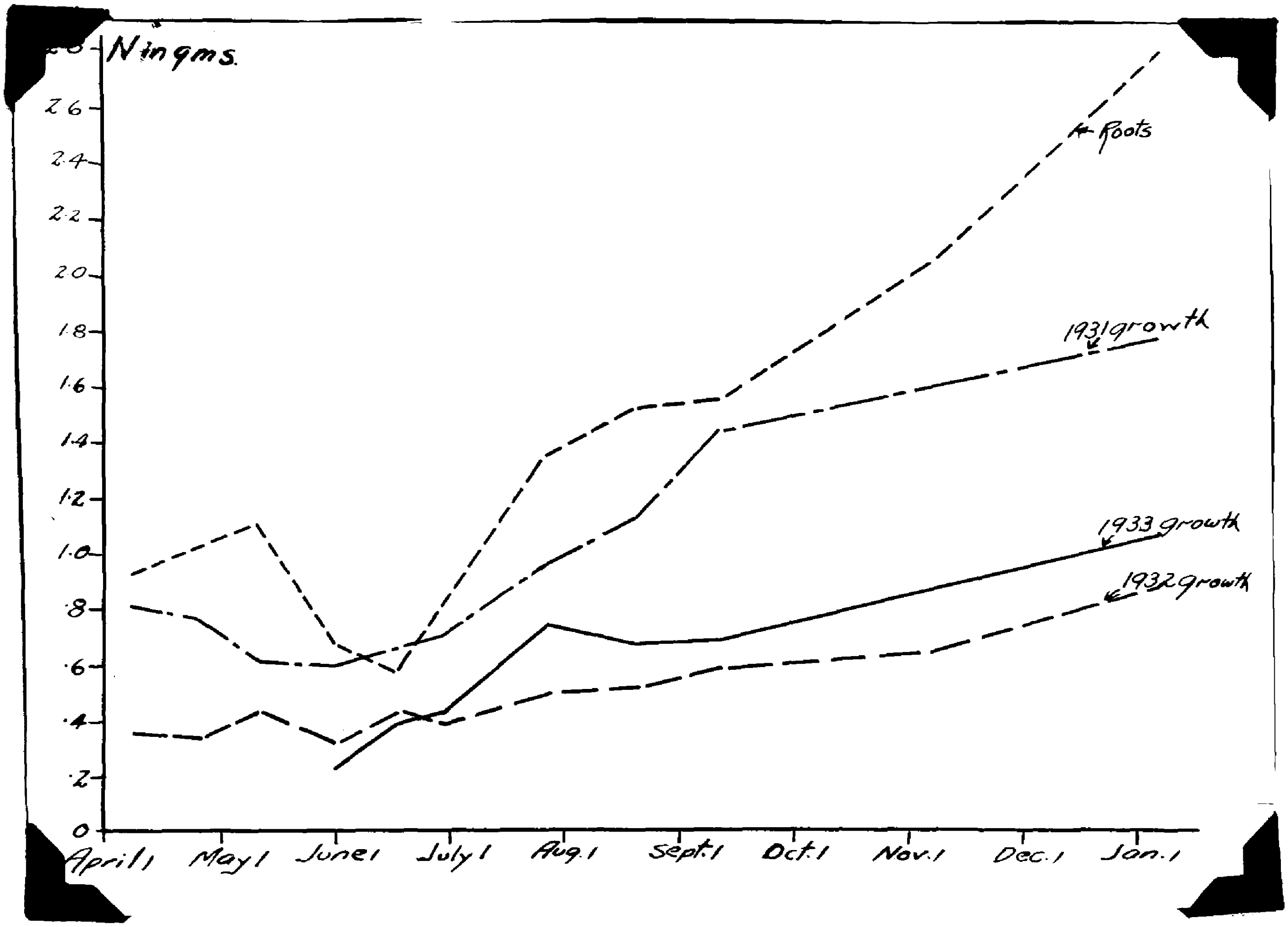


Fig. 24. - Nitrogen content of the different portions of the trees throughout the season expressed as absolute amount in grams per fraction.

Table 32. Nitrogen Determinations on Different Portions of Stayman Apple Trees Expressed as Per cent Dry Weight. 1933

Tissue	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
1933 Growth	--	--	--	1.711	.943	.919	.978	.766	.664	.716	.636	.750
1932 Growth	.776	.733	.742	.466	.483	.416	.409	.410	.418	.488	.421	.466
1931 Growth	.439	.415	.320	.281	.258	.246	.271	.288	.348	--	.321	.352
Roots	.782	.820	.832	.472	.334	.410	.598	.599	.514	.591	.534	.669

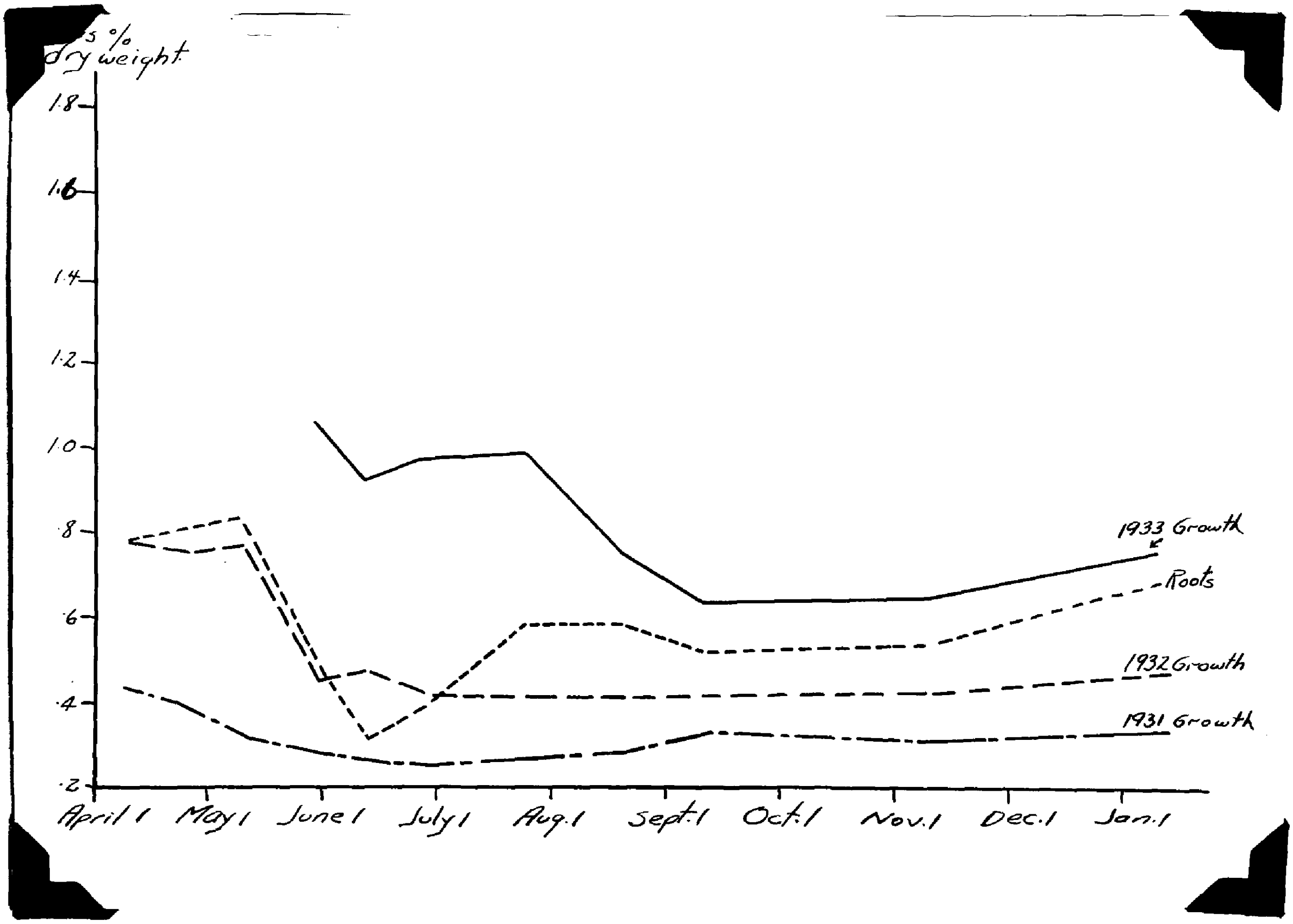


Fig. 25. - Nitrogen content of the different portions of the trees throughout the season expressed as per cent of dry weight.

nitrogen on a percentage basis in the 1933 wood was largely caused by changes in the wood rather than the bark. In the lower portions of the tree the bark and wood were quite highly correlated in their nitrogen changes.

Lincoln and Bennett (32) report that with pear trees the nitrogen content on a per cent fresh weight basis remains quite constant for the entire tree throughout the season. But when the leaves are excluded from the calculation, the percentage composition drops to low values during the middle of the summer. In view of these results, it is interesting to compare similar data with apple trees, and also to see if potassium presents a similar picture.

Table 33 gives the percent fresh weight for the nitrogen and potassium contents of the tree throughout the season. Figs26 and 27 present the material graphically.

In general the principle reported by Lincoln and Bennett holds in the case of nitrogen. However the percentage composition of the tree as a whole increases during the early part of the season and decreases generally from May to November. In other words the increase in nitrogen during April and early May is greater than increase in fresh weight, while during the summer the reverse is true. During the winter, after weight increase has ceased, nitrogen apparently is absorbed to

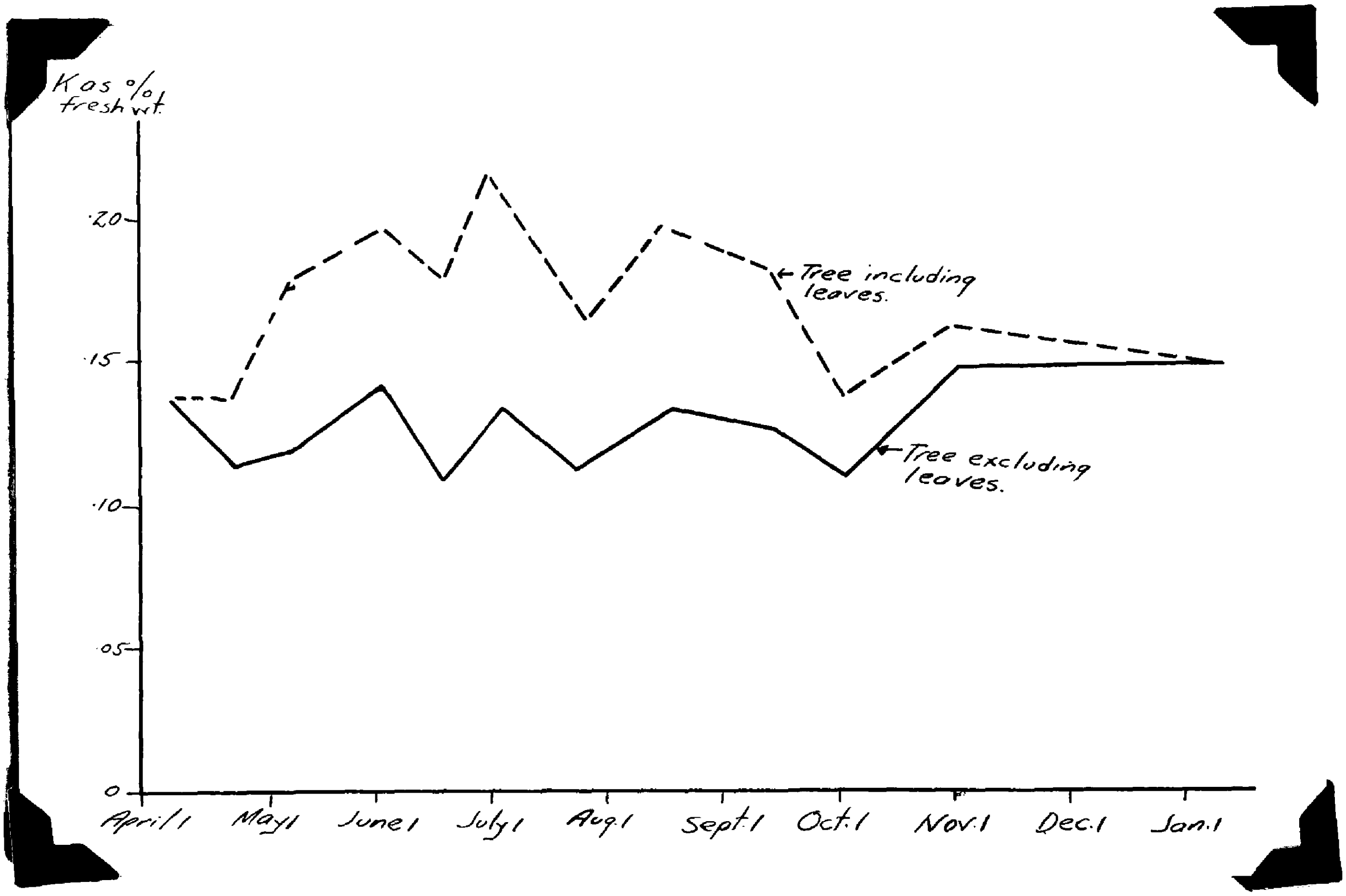


Fig. 26. - **Potassium** content of the tree as a whole throughout the season expressed as per cent of fresh weight, both including and excluding the leaves.

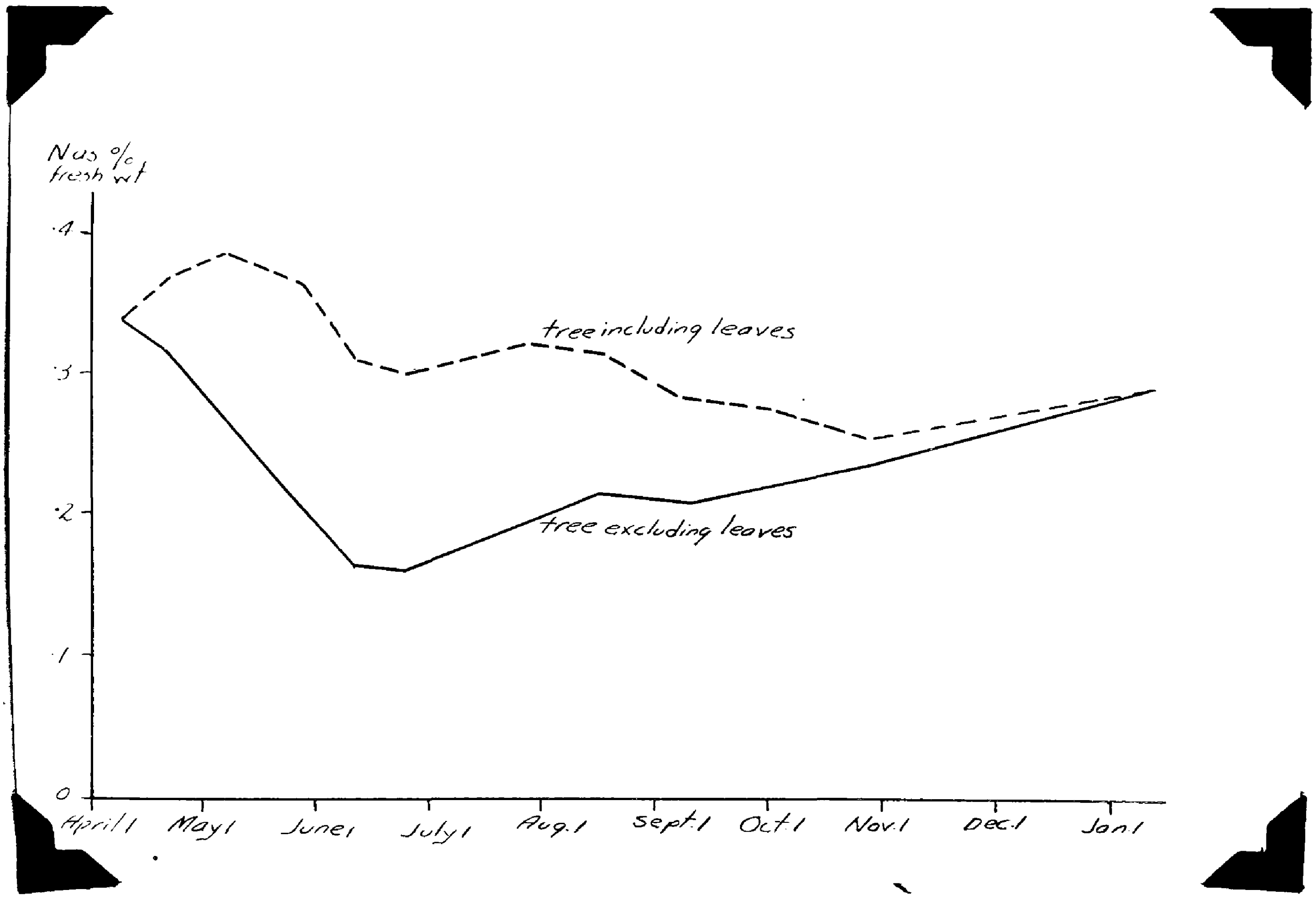


Fig. 27. - Nitrogen content of the tree as a whole throughout the season expressed as per cent of fresh weight, both including and excluding the leaves.

Table 33.— The Potassium and Nitrogen Contents of the Entire Trees Expressed in Per Cent of Fresh Weight, Both Including and Excluding the Leaves.

Date.	Per Cent K Leaves Included.	Per Cent K Leaves Excluded.	Per Cent N Leaves Included	Per Cent N Leaves Excluded
April 8	.138	.138	.338	.338
April 25	.138	.113	.376	.316
May 11	.156	.120	.387	.266
May 29	.196	.142	.364	.208
June 13	.180	.110	.311	.167
June 25	.216	.134	.302	.166
July 23	.165	.113	.322	.199
Aug. 16	.196	.131	.316	.218
Sept. 10	.182	.128	.286	.210
Oct. 4	.138	.111	.277	.224
Nov. 3	.164	.148	.255	.237
Jan. 8	.148	.148	.290	.290

account for the increased percentage composition.

The potassium percentages did not act similarly, the potassium content of the tree, excluding the leaves, tending to remain somewhat constant throughout the season, while the tree as a whole increased during the summer. In comparison, nitrogen moves into the leaves without being replaced in the tree proper until later in the season, while potassium is replaced sufficiently in the bark and wood to make up for any potassium that moves into the leaves.

Fig. 28 shows the seasonal trend of the leaves throughout the season. The curve slopes generally downward throughout the season denoting that the nitrogen concentration was on the decrease with increase in age of leaf. The increase on October 3rd could be accounted for by the change in proportion of young leaves to old leaves. This trend in nitrogen is entirely different than potassium, since the latter increases rather than decreases during the last few months of the season.

Growth Responses.

Fig. 29 shows the growth curves of the trunks and terminals of the trees. It is evident that potassium fertilizer had no appreciable effect upon the growth of the trees. This conformity of growth under the two treatments is somewhat surprising since the treated trees contained so much more potassium than the untreated ones. However these results support the findings of the work on bearing trees reported in Part I where the potassium content was not so markedly increased.

It is interesting to note that the terminal growth curve corresponds quite well to that conforming to the monomolecular autocatalytic equation. The trunk diameters, however, fitted the equation of a straight

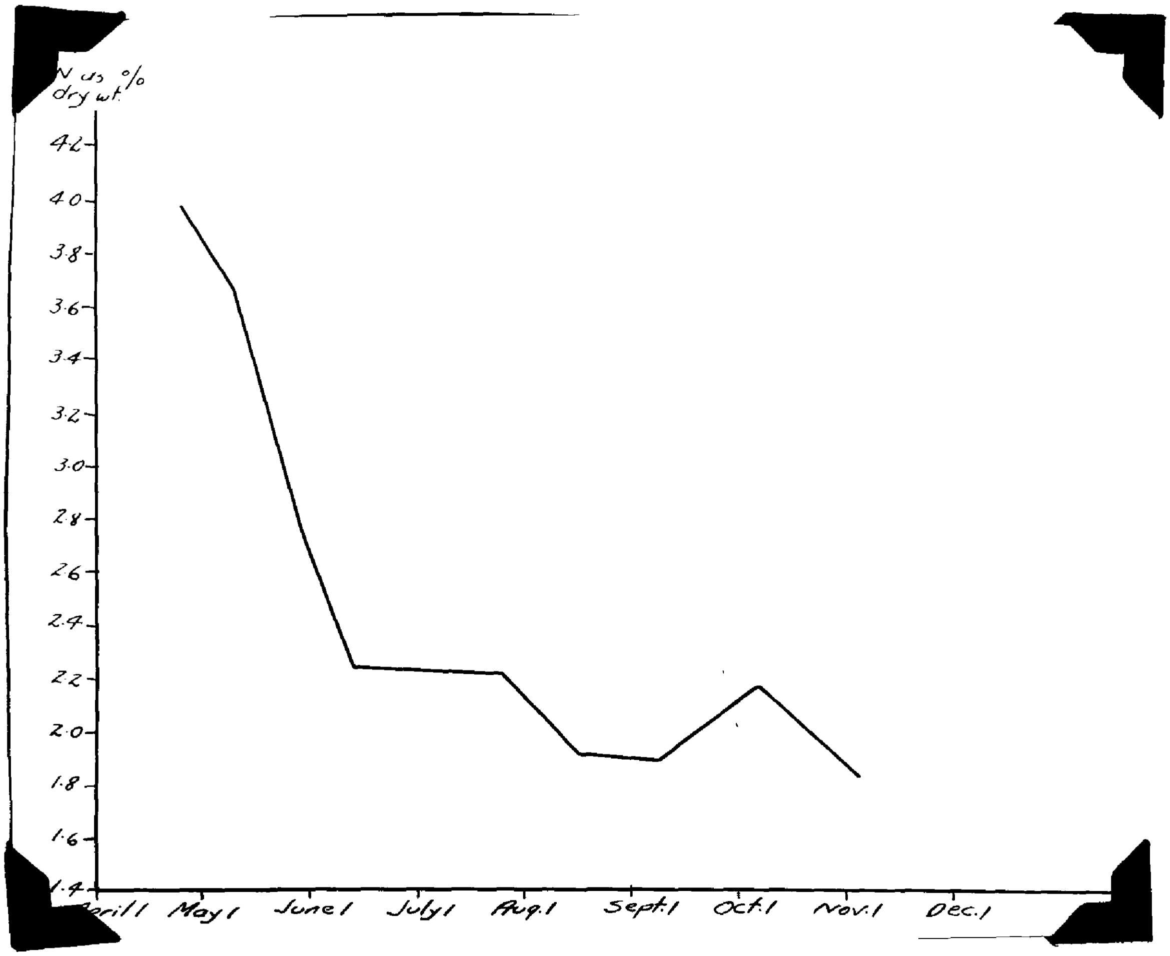


Fig. 28. - Nitrogen content of the leaves throughout the season expressed as per cent of dry weight.

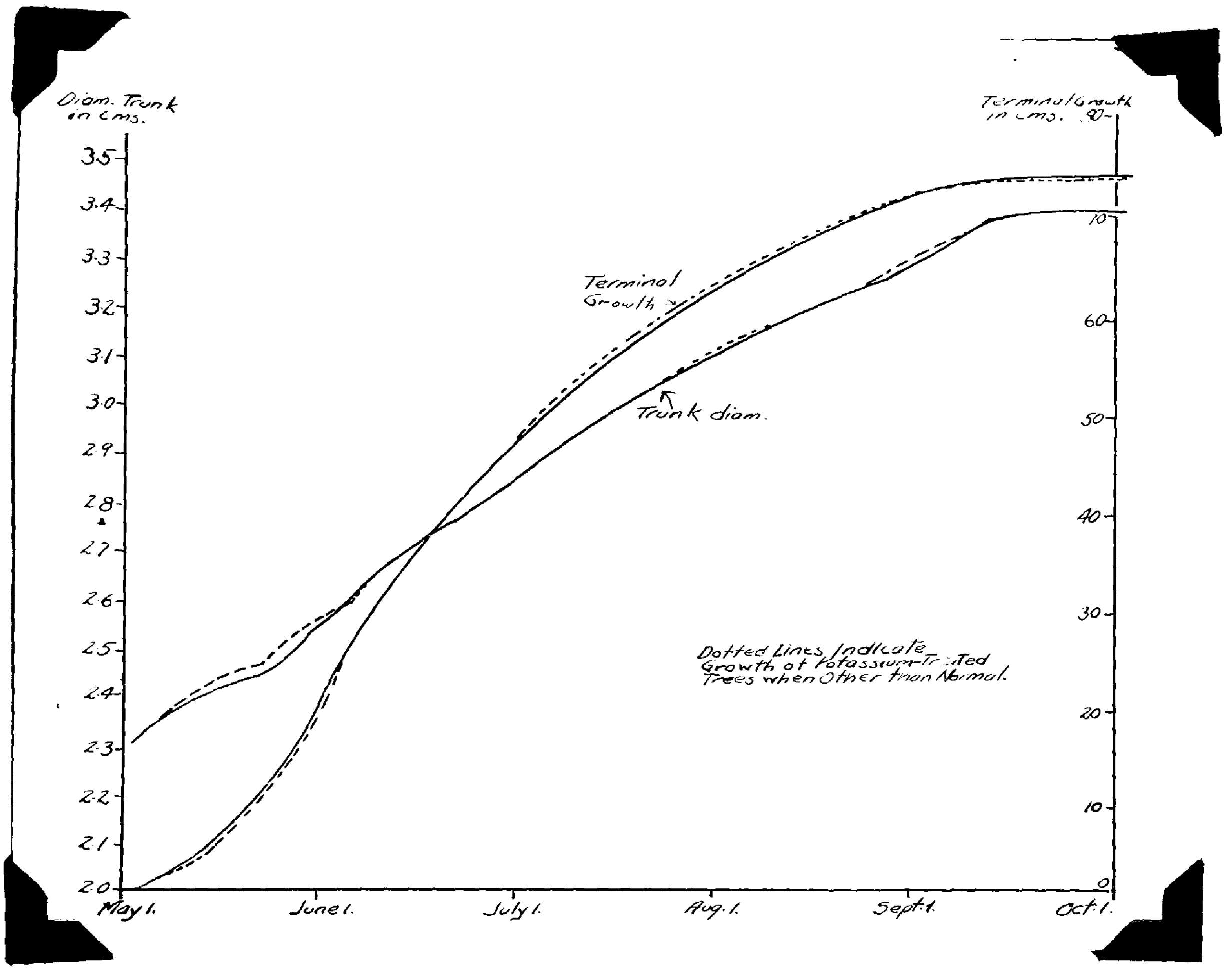


Fig. 29. – Seasonal growth curves of the trees, under the potassium treatment and normal treatment.

line more closely than that of an S-shaped curve. In other words, terminal growth started off at a slow rate, increased to a maximum the latter part of June, and then decreased until it practically ceased about September 1st. There were no definite changes in rate of diameter growth until September 10th, when it essentially ceased.

GENERAL DISCUSSION OF RESULTS

In the light of the findings of this study, the absorption of potassium by apple trees is quite proportional to the accumulation of dry weight. Under the high potassium treatment, potassium was absorbed at a greater proportionate rate than dry weight accumulated. Apparently potassium was absorbed largely during the growing period, although certainly potassium is abundant in the soil solution during the winter. The trees apparently were able to absorb nitrogen after the first part of November indicating that the tree is able to absorb certain nutrients even when its metabolic rate is considered to be rather low.

The rather outstanding tissue relationship in connection with potassium movement was that the roots increased markedly in their potassium content during the latter part of the growing season. A conjecture as to the causal factors involved is problematical, yet if potassium is connected with carbohydrate metabolism, and since Butler, et al (12) reported an increase in starch and sucrose in the roots at this period, there is a possible utilization of additional potassium in the roots at this time, perhaps in a a role of aiding translocation as suggested by some workers. Also the same potassium might function anew in the spring when the stored carbohydrates were broken down and translocated to more active parts of the tree.

This investigation has substantiated the fact, already found with other plants, that potassium is definitely associated with meristematic tissue, is very mobile, and seems to accumulate in certain tissues during the close of the season.

The extremely large proportion of potassium located in the leaves is interesting and may add to the importance of leaf area relationships in fruit tree responses. The fact that the leaves on the trees from the potassium treated plots abscissed earlier in the fall might indicate that any excess potassium is translocated to the leaves for disposal, thus partially accounting for the large luxury consumption in the leaves.

The concentration gradient of both nitrogen and potassium from the apex to the base of the tree is most logically accounted for by the decrease in proportion of living to dead cells. The absolute gradient, in the opposite direction, is largely explained by the fact that the dry weight gradient in the same direction is sufficient to obliterate any concentration differences.

The relation of potassium to nitrogen seems to be largely a common cause association. That is, nitrogen and potassium are both essential for the life of a cell, therefore where more living cells exist, more nitrogen and potassium exist. However, the depletion of nitrogen from the bark and wood of the tree as leaf formation takes place, is very marked, while such a phenomenon hardly exists with potassium. This may be entirely an absorption phenomenon.

The fact that the nitrogen content of the trees was increased by potassium fertilizers was an unexpected relationship. If more growth had been produced by the fertilized trees, possibly it would account for the increased nitrogen content, but no such increased growth took place. The fact that the increased nitrogen was largely in the wood and root bark might suggest a relationship between potassium and the storage of nitrogen. However, any increased supply of nitrogen in a plant, without increased growth, would possibly result in increased reserve nitrogen. Possibly the increased potassium content of the soil had an effect upon the soil microflora, thus causing an increased supply of nitrate nitrogen in the soil.

The increased absorption of nitrogen subsequent to leaf fall is in keeping with the findings of Bauer (6) working with horse chestnut and of Combes (15) working with the beech tree. However, other forest tree species show other periods of nitrogen absorption.

SUMMARY AND CONCLUSIONS

1. The absorption of potassium by young apple trees was quite proportional to dry weight accumulation, started off slowly, maintained a rather rapid rate during the growing season, and slowed down as cessation of growth approached in the fall.

2. Approximately 44 per cent of the potassium in the tree was located in the leaves. At the end of the growing season, when no leaves were present 18 per cent of the potassium was in the current season's growth, 12.8 per cent was in the 1932 growth, 31.1 per cent in the 1931 growth, and 37.9 per cent in the roots. The seasonal trend for these relationships were that the new growth increased, while the 1932 and 1931 tissues decreased in their relative proportions. The roots started off similarly to the way they ended, but had a low period during the time of rapid growth.

3. The absolute amount of potassium in all portions of the tree generally increased throughout the season. This does not apply to the leaves, after leaf abscission began.

4. On a per cent dry weight basis, the potassium content of the current season's growth decreased throughout the season. The roots tended to increase in their potassium concentration

during the last few months of growth. The 1932 growth increased in per cent potassium during May but later decreased. The 1931 growth remained quite constant in its potassium concentration.

4. The new wood added by lateral growth corresponded very similarly to the current season's twig growth with respect to potassium concentration.

5. Young leaves contain much more potassium than old leaves. This difference may be due to either leaching or migration.

6. Generally the concentration of potassium decreases from the apex to the base of the tree, while the actual amount present is in reverse order.

7. The application of potassium to the soil caused an increased intake of potassium by the tree, and an increased concentration in all tissues. The increase was greatest in the leaves, next in the bark, and lowest in the wood.

8. Heavy applications of potassium increased the nitrogen content of the trees.

9. Nitrogen and potassium were rather highly correlated in the trees. The most noticeable differences were that nitrogen was absorbed late in the season while potassium absorption stopped at leaf fall, and the nitrogen content of the tree was depleted considerably during the summer by the movement of nitrogen into the leaves. In

the case of potassium, absorption from the soil was able to maintain a uniform concentration in the wood and bark, and still maintain the content of the leaves.

10. There were no growth differences among the trees which could be attributed to potassium fertilizer influences.

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A P P E N D I X

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Table 1. Replaceable Potassium in Soil
from Fertilizer Plots (expressed as K in ppm.) ##

Treatment per tree per year#	Depth	Apple Variety, Soil Type, and Location															
		York Hagerstown clay loam (Hancock)				Rome Penn gravelly loam (Frederick)				Williams Sassafras fine sandy loam (Berlin)				Stayman Sassafras loamy sand (Salisbury)			
10# K Cl	0"- 6"	268	601	1287	1381	652	855	345	387	271	452	235	204	114	137	65	104
	6"-12"	169	101	767	318	215	208	102	229	96	222	179	320	76	99	58	82
	12"-18"	136	175	302	197	76	61	40	51	36	44	54	71	89	74	49	73
5# K Cl	0"- 6"	389	173	120	293	301	362	336	264	136	423	247	427	81	134	99	95
	6"-12"	104	65	73	129	183	34	40	39	87	132	63	117	86	119	112	105
	12"-18"	93	43	63	49	51	39	49	70	40	35	38	40	108	110	116	120
No K	0"- 6"	168	156	205	80	37	65	63	74	51	53	69	56	52	63	37	28
	6"-12"	93	58	134	49	27	23	19	24	19	30	26	23	51	72	30	16
	12"-18"	80	63	105	48	19	36	25	47	24	21	22	31	39	54	35	15

Treatment per tree per year#	Depth	Peach Variety, Soil Type, and Location															
		Elberta Upshur gravelly loam (Hancock)				Elberta Manor loam (Mount Airy)*				Elberta Sassafras fine sandy loam (Berlin)				Belle of Georgia Sassafras loamy sand (Salisbury)			
6# K Cl	0"- 6"	332	575	380	435	340	230	532	486	70	183	494	309	56	43	87	49
	6"-12"	201	312	435	141	36	30	140	106	140	223	416	244	52	75	109	65
	12"-18"	47	109	98	50	35	29	84	73	128	201	208	185	55	59	83	59
3# K Cl	0"- 6"	243	339	279	310	256	460	365	564	64	135	121	186	24	39	96	70
	6"-12"	111	154	157	210	106	34	65	249	75	131	135	183	34	93	102	64
	12"-18"	40	52	56	57	48	32	36	127	93	136	91	129	32	94	75	54
No K	0"- 6"	84	106	79	93	73	83	41	87	186	79	86	57	17	31	45	21
	6"-12"	37	39	54	56	29	30	24	34	73	38	32	50	20	36	28	38
	12"-18"	47	45	28	66	36	25	30	33	25	58	27	58	24	35	26	41

All plots received a basic application of $NaNO_3$.

* Both treated plots received only 3# KCl.

Sampled in July, 1931, after 4 annual fertilizer applications.

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Table 2. Results of Potassium Determinations by the Neubauer Method on Soil Samples from the Different Apple Fertilizer Plots. 1931 (Expressed as K in ppm.)

		Variety, Soil Type, and Location											
		Stayman Sassafras loamy sand (Salisbury)				Rome Penn gravelly loam (Frederick)				York Hagerstown clay loam (Hancock)			
No potassium (check)	0"- 6"	25	40	--	15	71	52	95	76	152	109	266	125
	6"-12"	25	56	35	5	95	90	49	56	117	110	257	105
	12"-18"	10	40	20	25	29	100	76	25	110	143	276	130
5# KCl per tree (single)	0"- 6"	59	83	56	63	246	266	321	251	372	181	166	164
	6"-12"	59	79	59	78	201	40	84	75	251	45	125	114
	12"-18"	64	93	89	83	100	56	140	130	236	66	90	53
10# KCl per tree (double)	0"- 6"	100	120	76	61	266	342	271	301	346	408	390	432
	6"-12"	76	85	30	45	246	235	151	276	177	193	367	309
	12"-18"	80	85	56	66	105	108	71	71	192	251	346	309

Table 3. Results of Potassium Determinations on Portions of Eight Year Old McIntosh Trees Under Differential Fertilizer Treatment at College Park During 1932

Treatment #	Tissue ## Sampled	April 24			June 25			Aug. 20			Nov. 11		
		Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight
10# K_2SO_4	leaves	--	--	--	39.0	.847	2.173	43.7	.859	1.966	44.8	.542	1.210
	1932 bark	--	--	--	37.2	.476	1.280	43.9	.553	1.260	47.3	.430	.910
	1932 wood	--	--	--	43.5	.237	.533	52.6	.200	.380	55.8	.124	.222
	1931 bark	41.0	.330	.805	41.5	.407	.980	46.0	.542	1.200	48.1	.510	1.060
	1931 wood	55.7	.177	.318	50.0	.221	.441	55.9	.158	.282	57.1	.091	.160
10# $MgSO_4$	leaves	--	--	--	39.0	.597	1.531	43.7	.733	1.677	44.8	.466	1.040
	1932 bark	--	--	--	37.2	.429	1.152	43.9	.509	1.160	47.3	.426	.900
	1932 wood	--	--	--	43.5	.204	.468	52.6	.184	.350	55.8	.109	.195
	1931 bark	41.0	.308	.750	41.5	.320	.772	46.0	.451	.980	48.1	.426	.886
	1931 wood	55.7	.184	.330	50.0	.159	.317	55.9	.132	.237	57.1	.091	.160
10# K_2SO_4	leaves	--	--	--	39.0	.639	1.639	43.7	.819	1.874	44.8	.600	1.340
	1932 bark	--	--	--	37.2	.431	1.158	43.9	.421	.960	47.3	.359	.760
	1932 wood	--	--	--	43.5	.196	.451	52.6	.189	.360	55.8	.103	.185
	1931 bark	41.0	.337	.822	41.5	.299	.720	46.0	.460	1.000	48.1	.488	1.015
	1931 wood	55.7	.175	.315	50.0	.144	.288	55.9	.156	.280	57.1	.097	.170
No treatment	leaves	--	--	--	39.0	.590	1.514	43.7	.735	1.683	44.8	.526	1.173
	1932 bark	--	--	--	37.2	.393	1.056	43.9	.511	1.165	47.3	.489	1.033
	1932 wood	--	--	--	43.5	.207	.476	52.6	.173	.328	55.8	.097	.174
	1931 bark	41.0	.358	.873	41.5	.304	.732	46.0	.486	1.057	48.1	.478	.993
	1931 wood	55.7	.180	.323	50.0	.159	.317	55.9	.156	.279	57.1	.093	.162

\# All trees received a basic treatment of $NaNO_3$.

\## Each determination made on a composite sample from 5 trees.

Table 4. Results of Potassium Determinations on Portions of Eleven Year Old Rome Apple Trees Under Differential Fertilizer Treatment at College Park During 1932.

Treatment #	Tissue Sampled	April 25			June 30			Aug. 26			Oct. 26		
		Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight	Dry matter as % fresh weight	K as % fresh weight	K as % dry weight
75# K_2SO_4	leaves	--	--	--	41.0	.855	2.086	45.0	.945	2.100	45.5	.783	1.740
	1932 bark	--	--	--	41.1	.359	.873	46.1	.498	1.080	45.1	.564	1.250
	1932 wood	--	--	--	47.4	.207	.436	55.9	.199	.357	58.0	.200	.345
	1931 bark	41.4	.305	.736	43.4	.334	.770	47.7	.468	.981	42.5	.412	.970
	1931 wood	56.7	.151	.267	54.4	.147	.270	58.5	.175	.300	61.1	.165	.270
30# K_2SO_4	leaves	--	--	--	41.0	.724	1.766	45.0	.994	2.210	45.5	.837	1.840
	1932 bark	--	--	--	41.1	.399	.970	46.1	.429	.930	45.1	.559	1.240
	1932 wood	--	--	--	47.4	.182	.383	55.9	.115	.205	58.0	.180	.310
	1931 bark	41.4	.383	.925	43.4	.332	.766	47.7	.436	.914	42.5	.442	1.040
	1931 wood	56.7	.151	.267	54.4	.144	.265	58.5	.105	.180	61.1	.137	.224
No Fertilizer	leaves	--	--	--	41.0	.500	1.219	45.0	.629	1.398	45.5	.478	1.050
	1932 bark	--	--	--	41.1	.233	.567	46.1	.254	.551	45.1	.312	.690
	1932 wood	--	--	--	47.4	.142	.300	55.9	.128	.228	58.0	.136	.235
	1931 bark	41.4	.298	.720	43.4	.227	.523	47.7	.237	.497	42.5	.236	.550
	1931 wood	56.7	.201	.355	54.4	.087	.160	58.5	.172	.295	61.1	.117	.192

All trees received a basic application of $NaNO_3$.

All potassium fertilizers were injected into the soil in solution to a depth of 3 feet.

Table 5. Growth Records from Apple Trees in the Potassium Fertilizer Plots. (Annual trunk increment in cms.)

Variety and location	Fertilizer treatment	Season 1929	1930	1931	1932	1933
Williams, Berlin	Check	4.04	2.86	2.69	2.12	2.20
	Single	3.75	2.76	3.01	2.38	2.27
	Double	5.12	3.68	3.92	2.54	2.16
	Complete	2.59	2.29	2.83	1.87	1.82
Stayman, Salisbury	Check	3.30	3.84	1.85	3.42	2.01
	Single	3.46	3.71	1.48	3.18	2.08
	Double	3.08	3.95	1.25	4.28	2.20
	Complete	3.39	3.52	1.91	3.25	1.90
York, Hancock	Check	3.85	2.00	3.97	1.46	3.30
	Single	3.84	1.91	3.11	1.61	2.42
	Double	3.85	2.41	3.24	1.73	2.91
	Complete	3.66	1.72	4.15	2.25	3.03
Rome, Frederick	Check	2.65	1.15	1.07	2.71	1.17
	Single	3.30	1.75	3.35	3.37	2.43
	Double	3.80	1.44	2.02	2.31	1.91
	Complete	3.86	1.80	2.40	2.58	2.32

Table 6. Growth Records from Peach Trees in the Potassium Fertilizer Plots. (Annual trunk increment in cms.)

Variety and location	Fertilizer treatment	Season 1929	1930	1931	1932	1933
Elberta, Mt. Airy	Check	4.81	5.10	2.19	5.55	3.02
	Single	3.85	5.22	2.61	5.57	2.57
	Double	4.10	4.80	2.04	5.43	3.57
	Complete	3.14	4.86	3.49	5.62	3.99
Elberta, Berlin	Check	1.52	3.39	3.01	2.81	3.66
	Single	1.58	2.57	1.93	3.21	2.57
	Double	1.71	3.59	2.19	2.91	2.57
	Complete	2.05	3.81	2.79	3.51	2.64
Elberta, Hancock	Check	1.70	2.97	3.20	3.16	2.05
	Single	1.61	2.86	2.56	2.76	2.28
	Double	1.45	2.30	2.65	2.69	2.31
	Complete	1.77	1.69	2.57	1.43	2.98
Belle of Georgia, Salisbury	Check	3.77	3.82	2.85	2.50	3.81
	Single	3.59	3.45	2.93	1.93	2.33
	Double	3.28	2.99	2.61	2.77	4.26
	Complete	3.75	3.99	3.03	2.75	3.87

Table 7. Dry Weight in Grams (Moving Average) of the Different Fractions of the Young Stayman Apple Trees at the Various Sampling Dates. – 1933.

Tissue	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves		14.5	42.2	73.0	113.4	121.4	151.6	139.3	128.6	77.4	32.2	→→
upper 1933 bark#	–	–	–	8.2	9.5	9.6	15.1	16.0	19.5	22.8	24.4	25.6
upper 1933 wood	–	–	–	5.3	6.1	6.5	10.5	12.7	16.1	20.8	23.0	24.6
lower 1933 bark	–	–	–	–	11.0	12.3	18.9	20.8	23.1	26.0	27.5	30.2
lower 1933 wood	–	–	–	–	14.1	17.0	29.5	36.7	43.0	53.1	56.3	58.1
upper 1932 bark	6.5	6.6	7.8	8.7	10.8	10.9	13.8	14.4	16.0	16.1	15.7	15.8
upper 1932 wood	8.3	8.4	11.9	16.0	23.0	24.9	35.7	36.9	42.8	43.4	48.4	60.3
lower 1932 bark	8.5	8.5	10.1	10.5	12.4	12.4	14.6	16.0	17.1	16.5	16.1	17.9
lower 1932 wood	23.2	23.3	27.9	31.9	40.2	41.5	54.1	56.0	60.7	63.9	71.3	89.5
upper 1931 bark	10.5	10.6	11.5	12.2	14.9	16.4	21.6	20.5	21.9	22.7	22.9	23.5
upper 1931 wood	48.3	48.6	53.3	58.4	73.5	83.8	102.5	113.5	127.9	139.7	151.4	162.7
lower 1931 bark	15.7	16.0	16.3	17.3	20.7	22.9	26.0	28.1	30.9	33.6	34.0	32.9
lower 1931 wood	109.5	109.8	112.6	121.7	145.9	165.0	199.5	220.4	248.3	266.8	277.8	278.9
large root bark*	10.7	11.1	12.9	16.5	20.0	23.9	28.3	37.7	43.0	53.4	54.0	52.4
large root wood	55.6	55.7	59.6	69.3	86.2	109.3	132.9	161.7	187.4	218.8	237.6	249.5
small root bark	18.0	18.1	18.4	18.7	18.6	18.3	17.7	17.7	19.9	21.1	25.8	32.1
small root wood	26.5	26.9	27.7	26.5	26.6	29.9	33.9	32.9	36.5	35.3	48.5	64.3
rootlets	11.0	12.8	13.8	14.7	12.5	11.6	9.7	8.8	9.7	8.2	9.9	12.2

\# The year assigned to each fraction indicates the season during which its first longitudinal growth was made.

* Large roots – 1 cm. or above in diameter.
Small roots – between 1 cm. and 2 mm. in diameter.
Rootlets – 2 mm. or less in diameter.

Table 8.. Dry Weight of Each Fraction
of Young Stayman Apple Trees Expressed as Per cent
of Fresh Weight. 1933.

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	31.4	29.0	47.0	38.4	42.3	38.7	43.9	40.1	37.9	40.5	--
upper 1933 bark#	--	--	--	40.5	41.8	32.4	31.3	35.8	38.3	41.3	44.4	45.2
upper 1933 wood	--	--	--	43.6	41.9	33.3	33.6	41.3	45.2	47.1	55.6	58.8
lower 1933 bark	--	---	--	--	38.7	35.1	35.2	37.5	39.7	42.5	47.3	48.1
lower 1933 wood	--	--	--	--	43.2	42.3	43.5	47.1	51.0	50.1	57.0	58.7
upper 1932 bark	50.0	42.1	36.0	44.3	38.4	35.0	35.7	39.0	42.3	42.5	44.4	45.8
upper 1932 wood	62.4	54.3	45.0	50.3	46.3	44.1	44.2	48.3	50.4	48.7	55.4	54.8
lower 1932 bark	51.8	43.0	36.0	43.5	38.1	36.5	37.3	37.3	41.7	43.9	47.2	45.1
lower 1932 wood	67.3	59.1	52.4	51.2	47.9	48.6	46.8	49.3	50.1	50.5	54.9	55.6
upper 1931 bark	49.3	41.0	37.0	42.6	35.6	35.7	38.0	38.5	37.2	42.2	44.8	45.5
upper 1931 wood	59.0	54.8	49.7	45.0	48.4	46.1	44.0	47.7	47.0	48.3	55.9	57.0
lower 1931 bark	51.0	42.7	39.3	42.7	36.5	37.0	38.8	38.6	39.0	43.7	47.0	45.7
lower 1931 wood	61.1	57.4	54.3	57.1	51.9	49.3	44.0	67.3	51.7	52.4	59.1	57.9
large root bark*	43.3	42.3	36.9	40.7	33.7	33.9	35.6	41.3	42.2	46.9	55.8	42.1
large root wood	55.2	53.2	51.2	51.3	48.8	49.4	52.9	49.3	51.4	56.4	52.9	66.3
small root bark	41.9	49.5	38.4	42.8	33.9	38.7	38.3	39.2	40.3	49.8	41.4	44.0
small root wood	53.8	56.1	49.6	51.6	49.2	51.6	54.1	48.5	49.1	56.6	52.8	55.2
rootlets	51.9	51.5	36.1	57.3	40.6	45.5	42.0	46.3	38.8	48.9	37.5	44.4

The year assigned to each fraction indicates the season during which its first longitudinal growth was made.

* Large roots - 1 cm. or above in diameter.
Small roots - below 1 cm. to 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 9. Fresh Weight in Grams (Moving Average)
of the Different Fractions of the Young Stayman Apple Trees
at the Various Sampling Dates (1933)

Tissue	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	-	46.1	145.3	167.4	295.1	287.1	391.9	317.4	320.8	204.3	79.5	-
upper 1933 bark#	-	-	-	17.5	22.7	29.7	48.3	44.7	50.9	55.0	55.0	56.6
upper 1933 wood	-	-	-	13.1	14.5	19.6	31.2	30.7	35.7	44.2	41.3	41.7
lower 1933 bark	-	-	-	-	28.4	35.1	53.7	55.4	58.2	61.2	58.2	62.8
lower 1933 wood	-	-	-	-	32.7	40.1	67.8	77.7	84.1	105.8	99.0	99.3
upper 1932 bark	13.0	15.7	21.7	19.7	28.2	31.1	38.7	36.9	42.8	37.9	35.4	34.5
upper 1932 wood	13.3	15.4	26.5	31.8	49.6	56.3	80.8	76.2	85.3	88.9	87.4	110.1
lower 1932 bark	16.4	19.8	28.1	24.1	32.6	34.0	39.1	43.0	41.0	37.6	34.1	39.7
lower 1932 wood	34.6	39.4	53.3	62.3	84.0	85.5	115.8	113.0	120.9	126.0	129.4	160.4
upper 1931 bark	21.3	25.9	31.0	28.6	41.9	45.9	57.2	53.3	58.9	53.8	51.1	51.6
upper 1931 wood	81.7	88.2	108.4	130.1	152.2	181.8	232.8	237.4	272.5	289.1	269.7	284.7
lower 1931 bark	30.8	37.6	41.4	40.5	56.7	62.0	66.9	106.0	79.1	76.9	72.3	72.0
lower 1931 wood	178.3	192.7	207.2	212.5	281.6	335.5	454.1	328.4	482.2	506.1	469.8	478.0
large root bark*	24.7	26.3	34.9	40.5	59.1	70.5	79.5	91.2	101.8	114.0	96.7	124.5
large root wood	100.0	105.0	116.6	134.7	176.7	221.7	250.9	327.8	365.6	388.2	447.3	376.1
small root bark	42.8	36.6	48.0	43.7	54.9	47.4	46.3	45.2	49.4	42.3	62.3	72.8
small root wood	49.4	47.9	55.9	51.5	54.1	57.9	62.9	67.8	74.5	62.4	91.8	116.6
rootlets	21.2	24.9	38.2	26.9	30.8	25.5	23.1	19.0	25.0	16.7	26.4	27.5

\# The year assigned to each fraction indicates the season during which its first longitudinal growth was made.

* large roots - 1 cm. or above in diameter.
small roots - between 1 cm. and 2 mm. in diameter.
rootlets - 2 mm. or less in diameter.

Table 10. Results of Potassium Determinations on Young Stayman Apple Trees which Received No Potassium Fertilizer Applications.# (Absolute amount of K in grams in each fraction.) 1933

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	.2333	.5182	.804	1.1873	1.7397	1.555	1.7552	1.6628	.8529	.4690	--
upper 1933 bark*	--	--	--	.0918	.0889	.1130	.1169	.1190	.1773	.1689	.1784	.2125
upper 1933 wood	--	--	--	.0388	.0377	.0397	.0579	.0491	.0440	.0426	.0593	.0585
lower 1933 bark	--	--	--	--	.0697	.0947	.1083	.1421	.1789	.1508	.1878	.2268
lower 1933 wood	--	--	--	--	.0510	.0654	.0814	.0862	.0959	.0765	.1025	.0924
upper 1932 bark	.0498	.0454	.0475	.0590	.0619	.0706	.0718	.0878	.0802	.0892	.1072	.1079
upper 1932 wood	.0151	.0223	.0450	.0470	.0538	.0715	.0675	.0627	.0779	.0690	.0731	.0826
lower 1932 bark	.0576	.0426	.0665	.0742	.0711	.0737	.0815	.0899	.1077	.0789	.1238	.1128
lower 1932 wood	.0273	.0310	.0547	.0769	.0848	.1000	.1104	.0767	.0619	.0677	.1077	.1155
upper 1931 bark	.0763	.0625	.0656	.0791	.0787	.0971	.1123	.1105	.1285	.0999	.1546	.1570
upper 1931 wood	.0710	.0646	.0863	.1121	.1448	.1609	.2009	.1895	.1458	.1690	.2074	.2847
lower 1931 bark	.0972	.0817	.1089	.0901	.1031	.1209	.1310	.1607	.1666	.1482	.1996	.2073
lower 1931 wood	.1347	.0856	.1543	.1740	.2582	.2986	.2793	.3350	.3749	.2641	.4053	.3681
large root bark##	.0504	.0545	.0633	.0713	.0844	.1262	.1367	.2202	.2675	.2675	.3688	.3699
large root wood	.0817	.0684	.1055	.1719	.1689	.2306	.2405	.3185	.4273	.4376	.5298	.4815
small root bark	.1037	.0959	.0469	.0662	.0701	.0829	.0786	.1209	.1329	.0867	.2193	.2099
small root wood	.0416	.0476	.0612	.0519	.0548	.0619	.0614	.1033	.0942	.0805	.0732	.1318
rootlets	.0605	.0591	.0669	.0419	.0301	.0464	.0454	.0334	.0412	.0332	.0540	.0494

\# All trees received a basic application of $(NH_4)_2\ SO_4$ and Superphosphate.

* Year assigned to each fraction indicates season of first terminal growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 11. Results of Potassium Determinations on the Different Fractions of the Young Stayman Apple Trees Treated With One Pound Potassium Sulfate per Tree.# (Absolute amount of K in grams per fraction). 1933

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	.2333	.4477	1.0900	2.4290	3.2018	2.5993	2.5373	1.8917	.8009	--
upper 1933 bark*	--	--	--	.1136	.1367	.1778	.1968	.2457	.3108	.3074	.2670
upper 1933 wood	--	--	--	.0526	.0506	.0784	.0771	.0713	.0936	.0897	.0839
lower 1933 bark	--	--	--	--	.1328	.1854	.2305	.2876	.3492	.3589	.3047
lower 1933 wood	--	--	--	--	.0883	.1092	.1057	.2154	.1450	.1070	.1249
upper 1932 bark	.0479	.0307	.0360	.0820	.1092	.1187	.1158	.1457	.1882	.1490	.1356
upper 1932 wood	.0162	.0123	.0339	.0651	.0927	.1050	.0967	.1083	.1085	.1137	.1327
lower 1932 bark	.0559	.0451	.0506	.0846	.1215	.1256	.0136	.1689	.1790	.2322	.1507
lower 1932 wood	.0318	.0343	.0410	.1091	.1487	.1309	.1187	.1354	.1323	.1540	.1835
upper 1931 bark	.0680	.0572	.0599	.0922	.1304	.1504	.1449	.3922	.2411	.1738	.1845
upper 1931 wood	.0686	.0573	.0997	.1145	.2161	.2398	.2588	.2916	.3325	.3210	.3205
lower 1931 bark	.1002	.0944	.1152	.1173	.1793	.1841	.2192	.2738	.3061	.2502	.2250
lower 1931 wood	.1533	.0867	.1969	.2337	.3633	.3451	.3350	.4147	.3442	.4417	.4435
large root bark##	.0673	.0764	.0646	.0973	.1418	.2649	.4004	.3728	.5345	.6286	.5250
large root wood	.1600	.1092	.1085	.1414	.2474	.2911	.4786	.4460	.4814	.5417	.6063
small root bark	.1474	.1218	.0959	.1395	.1319	.1522	.2267	.2513	.2498	.3684	.3508
small root wood	.0469	.0503	.0626	.0530	.0790	.0868	.1349	.1467	.1098	.1707	.2051
rootlets	.0713	.0691	.0894	.1039	.0998	.0878	.0735	.0780	.0774	.0807	.1091

\# All plots received a basic application of $(NH_4)_2SO_4$ and Superphosphate.
* Year assigned to each fraction indicates season of first terminal growth.
\## Large roots - 1 cm. or above in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 12. Results of Potassium Determinations on the Different Fractions of the Young Stayman Apple Trees which Received no Potassium Fertilizers. # (K as per cent dry weight). 1933

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	1.611	1.288	1.102	1.047	1.433	1.026	1.260	1.293	1.102	1.457	--
upper 1933 bark*	--	--	--	1.120	.936	1.177	.792	.744	.728	.744	.731	.830
upper 1933 wood	--	--	--	.732	.619	.611	.551	.387	.273	.205	.258	.238
lower 1933 bark	--	--	--	--	.634	.770	.573	.683	.774	.580	.683	.751
lower 1933 wood	--	--	--	--	.362	.385	.276	.235	.223	.144	.182	.159
upper 1932 bark	.766	.688	.609	.678	.573	.648	.526	.610	.501	.554	.683	.683
upper 1932 wood	.182	.265	.378	.294	.234	.287	.189	.170	.182	.159	.151	.137
lower 1932 bark	.678	.580	.658	.707	.573	.594	.558	.562	.630	.478	.769	.630
lower 1932 wood	.118	.133	.196	.241	.211	.241	.204	.137	.102	.106	.151	.129
upper 1931 bark	.727	.590	.570	.648	.528	.592	.520	.539	.587	.440	.675	.668
upper 1931 wood	.147	.133	.162	.192	.197	.192	.196	.167	.114	.121	.137	.175
lower 1931 bark	.619	.511	.688	.521	.498	.528	.504	.572	.539	.441	.587	.630
lower 1931 wood	.123	.078	.137	.143	.177	.181	.140	.152	.151	.099	.137	.132
large root bark##	.471	.491	.491	.432	.422	.528	.483	.584	.622	.501	.683	.706
large root wood	.147	.123	.177	.248	.196	.211	.181	.197	.228	.200	.223	.193
small root bark	.576	.530	.255	.354	.377	.453	.444	.683	.668	.411	.850	.654
small root wood	.157	.177	.221	.196	.206	.207	.181	.314	.258	.228	.151	.205
rootlets	.550	.462	.485	.285	.241	.400	.468	.379	.425	.405	.546	.405

\# All trees received a basic application of $(NH_4)_2SO_4$ and Superphosphate.
* Year assigned to each fraction indicates season of first terminal growth.
\## Large roots - 1 cm. or above in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 13. Results of Potassium Determinations on Young Stayman Apple Trees which Received No Potassium Fertilizer Applications.# (K as per cent of fresh weight)

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	--	.356	.480	.402	.606	.397	.553	.518	.418	.590	--
upper 1933 bark*	--	--	--	.526	.391	.301	.248	.266	.281	.307	.325	.375
upper 1933 wood	--	--	--	.296	.259	.203	.185	.160	.123	.097	.143	.140
lower 1933 bark	--	--	--	--	.245	.270	.202	.256	.307	.247	.323	.361
lower 1933 wood	--	--	--	--	.156	.163	.120	.111	.114	.072	.104	.093
upper 1932 bark	.383	.290	.219	.300	.220	.227	.186	.238	.212	.235	.303	.313
upper 1932 wood	.114	.143	.170	.148	.108	.127	.084	.082	.092	.077	.084	.075
lower 1932 bark	.351	.249	.237	.308	.218	.217	.208	.210	.263	.210	.363	.284
lower 1932 wood	.079	.079	.103	.123	.101	.117	.095	.068	.051	.054	.083	.072
upper 1931 bark	.358	.242	.211	.276	.188	.202	.198	.207	.218	.186	.302	.304
upper 1931 wood	.089	.073	.081	.086	.095	.0885	.086	.080	.054	.058	.077	.100
lower 1931 bark	.316	.219	.270	.222	.182	.195	.196	.221	.210	.193	.276	.288
lower 1931 wood	.075	.045	.074	.082	.0920	.089	.061	.102	.078	.052	.081	.077
large root bark##	.204	.208	.181	.176	.142	.179	.172	.241	.262	.235	.381	.297
large root wood	.081	.065	.091	.127	.096	.104	.096	.097	.117	.113	.118	.128
small root bark	.241	.262	.098	.152	.128	.175	.170	.268	.269	.205	.352	.288
small root wood	.084	.099	.110	.101	.101	.107	.098	.152	.127	.129	.080	.113
rootlets	.285	.238	.175	.156	.098	.182	.197	.175	.165	.198	.205	.180

\# All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 14. Results of Potassium Determinations on Young Stayman Apple Trees Fertilized with One Pound Potassium Sulfate per Tree.# 1933 (K as per cent dry weight.)

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	1.611	1.061	1.494	2.142	2.112	1.866	1.973	2.444	2.488	--
upper 1933 bark*	--	--	--	1.385	1.439	1.177	1.230	1.260	1.369	1.260	1.043
upper 1933 wood	--	--	--	.993	.830	.747	.607	.443	.450	.390	.341
lower 1933 bark	--	--	--	--	1.207	.981	1.108	1.245	1.343	1.305	1.009
lower 1933 wood	--	--	--	--	.626	.370	.288	.501	.273	.190	.215
upper 1932 bark	.737	.466	.462	.943	1.011	.860	.804	.911	1.169	.949	.858
upper 1932 wood	.196	.147	.285	.407	.403	.294	.262	.253	.250	.235	.220
lower 1932 bark	.658	.530	.501	.806	.980	.860	.850	.987	1.085	1.442	.842
lower 1932 wood	.137	.147	.147	.342	.370	.242	.212	.223	.207	.216	.205
upper 1931 bark	.648	.540	.521	.756	.875	.696	.707	1.791	1.062	.759	.785
upper 1931 wood	.142	.118	.187	.196	.294	.234	.228	.228	.238	.212	.197
lower 1931 bark	.638	.590	.707	.678	.866	.708	.780	.886	.911	.736	.684
lower 1931 wood	.140	.079	.174	.192	.249	.173	.152	.167	.129	.159	.159
large root bark##	.629	.688	.501	.590	.709	.936	1.062	.867	1.001	1.164	1.002
large root wood	.108	.196	.182	.204	.287	.219	.296	.238	.220	.228	.243
small root bark	.819	.673	.521	.746	.709	.860	1.281	1.263	1.184	1.428	1.093
small root wood	.177	.187	.226	.200	.297	.256	.410	.402	.311	.352	.319
rootlets	.648	.540	.648	.707	.799	.905	.835	.804	.944	.815	.894

*Year assigned to each fraction indicates season of first terminal growth.

Each tree received a basic application of $(NH_4)_2SO_4$ and Superphosphate.

Large roots - 1 cm. and above in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 15. . Amount of Potassium in Each Fraction of the Young Stayman Trees Expressed as Per cent of the Total Data for Trees which Received No Potassium Fertilizer.# (Leaves excluded.) 1933

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
upper 1933 bark *	--	--	--	7.4	5.9	6.1	6.0	5.2	8.9	7.2	5.7	6.5
upper 1933 wood	--	--	--	3.1	2.5	2.1	2.9	2.1	1.7	1.8	1.9	1.8
lower 1933 bark	--	--	--	--	4.6	5.1	5.5	6.2	6.7	6.5	6.0	6.9
lower 1933 wood	--	--	--	--	3.4	3.5	4.1	3.7	3.6	3.3	3.3	2.8
upper 1932 bark	5.7	6.0	4.9	4.7	4.1	3.8	3.6	3.8	3.4	3.8	3.4	3.3
upper 1932 wood	1.7	2.9	4.6	3.8	3.6	3.9	3.4	2.7	3.0	3.0	2.3	2.5
lower 1932 bark	6.6	5.6	6.8	6.0	4.7	4.0	4.1	3.9	4.0	3.4	3.9	3.5
lower 1932 wood	3.1	4.1	5.6	6.2	5.6	5.4	5.6	3.3	2.3	2.9	3.4	3.5
upper 1931 bark	8.8	8.2	6.7	6.3	5.2	5.2	5.7	4.8	4.8	4.3	4.9	4.8
upper 1931 wood	8.2	8.5	8.9	9.0	9.6	8.7	10.1	8.2	5.5	7.3	6.6	8.7
lower 1931 bark	11.2	10.7	11.2	7.2	6.9	6.5	6.6	7.0	6.3	6.4	6.3	6.3
lower 1931 wood	15.5	11.2	15.9	14.0	17.2	16.1	14.1	14.5	14.1	11.3	12.8	11.3
large root bark##	5.8	7.1	6.5	5.7	5.6	6.8	6.9	9.6	10.5	11.5	11.6	11.3
large root wood	9.4	9.0	10.8	13.8	11.2	12.4	12.1	13.8	16.4	18.8	16.8	14.7
small root bark	12.0	12.6	4.8	5.3	4.7	4.5	4.0	5.3	5.1	3.7	6.8	6.4
small root wood	4.8	6.2	6.3	4.2	3.7	3.3	3.1	4.5	3.6	3.5	2.3	4.0
rootlets	7.0	7.8	6.9	3.4	2.0	2.5	2.3	1.4	1.6	1.4	1.7	1.5

\# All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminsl growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 16. Results of Potassium Determinations on the Different Fractions of the Young Stayman Apple Trees, Treated with One Pound Potassium Sulfate per Tree. #
(K as per cent of fresh weight). 1933

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	.506	.308	.651	.823	.817	.819	.791	.926	1.007	--
upper 1933 bark*	--	--	--	.651	.601	.368	.440	.483	.565	.559	.471
upper 1933 wood	--	--	--	.402	.348	.251	.251	.200	.212	.217	.201
lower 1933 bark	--	--	--	--	.467	.345	.416	.494	.571	.617	.485
lower 1933 wood	--	--	--	--	.270	.161	.136	.256	.137	.108	.126
upper 1932 bark	.368	.196	.166	.417	.388	.307	.314	.385	.497	.421	.393
upper 1932 wood	.122	.080	.128	.205	.187	.130	.127	.127	.122	.130	.121
lower 1932 bark	.341	.228	.180	.351	.373	.321	.317	.412	.476	.681	.378
lower 1932 wood	.092	.087	.077	.175	.177	.113	.105	.112	.105	.119	.114
upper 1931 bark	.319	.221	.193	.322	.311	.264	.272	.666	.448	.340	.357
upper 1931 wood	.084	.065	.092	.088	.142	.130	.109	.107	.115	.119	.113
lower 1931 bark	.325	.252	.278	.290	.316	.275	.301	.346	.398	.346	.313
lower 1931 wood	.086	.045	.095	.110	.129	.076	.102	.086	.068	.094	.092
large root bark##	.272	.291	.185	.240	.240	.333	.439	.366	.469	.650	.422
large root wood	.060	.104	.093	.105	.140	.116	.146	.122	.124	.121	.161
small root bark	.344	.333	.200	.319	.240	.329	.502	.509	.590	.591	.481
small root wood	.095	.105	.112	.103	.146	.138	.199	.197	.176	.186	.176
rootlets	.336	.278	.234	.386	.324	.380	.387	.312	.462	.306	.397

All trees received basic treatment of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

Large roots - 1 cm. or above in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 17. Amount of Potassium in Each Fraction of the Young Stayman Apple Trees Expressed as Per cent of the Total. Data is for Trees which Received One Pound of Potassium Sulfate.# (Leaves excluded.) 1933

	April 8	April 25	May 11	May 29	June 13	July 25	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
upper 1933 bark*	--	--	--	7.1	5.5	6.3	3.1	6.1	7.4	6.8	6.1
upper 1933 wood	--	--	--	3.3	2.0	2.8	2.4	1.8	2.2	2.0	1.9
lower 1933 bark	--	--	--	--	5.4	6.5	7.2	7.1	8.3	8.0	7.0
lower 1933 wood	--	--	--	--	3.6	3.9	3.3	5.3	3.5	2.4	2.9
upper 1932 bark	5.1	3.6	3.4	5.1	4.4	4.2	3.7	3.6	4.5	3.3	3.1
upper 1932 wood	1.7	1.5	3.2	4.1	3.8	3.7	3.0	2.7	2.6	2.5	3.0
lower 1932 bark	6.0	5.3	4.8	5.3	4.9	4.4	4.2	4.2	4.3	5.2	3.5
lower 1932 wood	3.4	4.1	3.9	6.8	6.0	4.6	3.7	3.4	3.2	3.4	4.2
upper 1931 bark	7.3	6.8	5.6	5.8	5.3	5.3	4.5	9.7	5.8	3.9	4.3
upper 1931 wood	7.3	6.8	9.4	7.2	8.8	8.5	8.0	7.2	7.9	7.2	7.4
lower 1931 bark	10.7	11.2	10.9	7.3	7.3	6.5	6.8	6.8	7.3	5.6	5.2
lower 1931 wood	16.4	10.3	18.6	14.6	14.7	12.2	10.4	10.3	8.2	9.8	10.1
large root bark##	7.2	9.0	6.1	6.1	5.7	9.4	12.4	9.2	12.8	14.0	12.1
large root wood	6.4	12.9	10.2	8.8	10.0	10.3	14.8	11.0	11.5	12.1	13.9
small root bark	15.8	14.4	9.0	8.7	5.3	5.4	7.0	6.2	6.0	8.2	8.1
small root wood	5.0	6.0	5.9	3.3	3.2	3.0	4.2	3.6	2.6	3.8	4.7
rootlets	7.6	8.2	8.4	6.5	4.0	3.1	2.3	1.9	1.9	1.8	2.5

\# All trees received a basic application of $(NH_4)_2SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 18. Results of Nitrogen Determinations on Young Stayman Apple Trees which Received No Addition of Potassium Fertilizer.# (Absolute amount of N in grams per fraction.) 1933.

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	.579	1.550	1.984	2.645	2.734	3.414	2.730	2.458	1.693	.588	--
upper 1933 bark*	--	--	--	.114	.122	.148	.250	.181	.215	.281	.253	.348
upper 1933 wood	--	--	--	.117	.063	.047	.151	.106	.099	.155	.101	.130
lower 1933 bark	--	--	--	--	.102	.122	.187	.202	.195	.257	.304	.342
lower 1933 wood	--	--	--	--	.097	.100	.136	.172	.166	.185	.177	.217
upper 1932 bark	.097	.095	.106	.056	.095	.095	.103	.128	.122	.151	.147	.171
upper 1932 wood	.045	.054	.135	.064	.093	.081	.111	.101	.135	.176	.164	.195
lower 1932 bark	.122	.113	.103	.090	.107	.096	.116	.109	.136	.144	.154	.171
lower 1932 wood	.098	.081	.084	.103	.123	.101	.154	.168	.177	.212	.173	.319
upper 1931 bark	.115	.119	.105	.097	.111	.151	.203	.130	.181	--	.222	.228
upper 1931 wood	.162	.167	.120	.161	.155	.131	.160	.227	.317	.218	.459	.488
lower 1931 bark	.169	.153	.117	.123	.141	.147	.164	.191	.250	.299	.269	.293
lower 1931 wood	.361	.329	.277	.207	.251	.281	.421	.553	.745	.648	.610	.745
large root bark##	.100	.120	.165	.104	.107	.170	.211	.232	.237	.381	.313	.348
large root wood	.294	.319	.310	.174	.182	.301	.613	.694	.804	1.171	1.075	1.455
small root bark	.221	.205	.209	.151	.100	.122	.209	.132	.160	.148	.163	.296
small root wood	.218	.213	.220	.116	.071	.099	.195	.250	.245	.215	.372	.563
rootlets	.121	.165	.197	.143	.087	.102	.102	.242	.077	.076	.083	.086

All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 19. Results of Nitrogen Determinations on Young Stayman Apple Trees which Received No Potassium Fertilizers.# (N as per cent dry weight.) 1933

	April 8	April 25	May 11	May 29	June 13	June 25	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	3.990	3.673	2.719	2.333	2.252	2.252	1.960	1.912	2.188	1.814	--
upper 1933 bark *	--	--	--	1.389	1.280	1.539	1.652	1.134	1.102	1.231	1.053	1.361
upper 1933 wood	--	--	--	2.200	1.037	.721	1.434	.834	.616	.745	.437	.527
lower 1933 bark	--	--	--	--	.923	.988	.988	.972	.842	.988	1.118	1.134
lower 1933 wood	--	--	--	--	.688	.587	.462	.470	.385	.348	.307	.373
upper 1932 bark	1.486	1.432	1.360	.648	.875	.875	.745	.891	.761	.940	.941	1.085
upper 1932 wood	.539	.647	1.135	.397	.405	.324	.316	.275	.316	.405	.340	.324
lower 1932 bark	1.437	1.330	1.024	.859	.859	.778	.794	.680	.794	.875	.956	.956
lower 1932 wood	.424	.347	.300	.324	.292	.243	.284	.300	.292	.332	.243	.356
upper 1931 bark	1.095	1.118	.909	.794	.745	.923	.940	.632	.826	--	.891	.972
upper 1931 wood	.335	.343	.226	.276	.211	.156	.156	.200	.248	.156	.300	.300
lower 1931 bark	1.079	.957	.719	.713	.680	.664	.632	.680	.810	.891	.794	.891
lower 1931 wood	.330	.300	.246	.170	.172	.170	.211	.251	.300	.243	.219	.267
large root bark ##	.933	1.079	1.278	.632	.535	.713	.745	.616	.551	.713	.583	.664
large root wood	.528	.572	.520	.251	.211	.275	.462	.429	.429	.535	.454	.583
small root bark	1.230	1.134	1.136	.810	.535	.664	1.183	.745	.805	.700	.632	.923
small root wood	.823	.791	.796	.437	.267	.332	.575	.761	.670	.608	.778	.875
rootlets	1.100	1.286	1.429	.972	.697	.875	1.053	2.754	.794	.923	.842	.907

All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 20 Results of Nitrogen Determinations on Young Stayman Apple Trees which Received One Pound of Potassium Sulfate.# (N as per cent dry weight.) 1933.

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	3.990	3.146	2.635	2.446	2.122	2.041	1.916	2.187	2.057	--
upper 1933 bark *	--	--	--	1.182	1.150	1.458	1.280	2.124	1.085	1.199	1.247
upper 1933 wood	--	--	--	2.300	1.199	1.450	1.004	2.041	.656	.518	1.102
lower 1933 bark	--	--	--	--	.923	1.166	.907	1.069	1.037	1.247	1.266
lower 1933 wood	--	--	--	--	.689	.583	.381	.875	.510	.348	.486
upper 1932 bark	1.493	1.373	1.088	.925	1.085	1.037	.907	.859	.907	1.004	.826
upper 1932 wood	.591	.500	.594	.519	.413	.510	.405	.316	.049	.275	.397
lower 1932 bark	1.026	1.156	.976	.925	.794	.680	.891	.965	.860	1.037	.664
lower 1932 wood	.367	.450	.640	.224	.267	.267	.283	.437	.316	.316	.365
upper 1931 bark	1.118	1.031	.966	.751	.778	.648	.842	.761	.810	.859	1.021
upper 1931 wood	.351	.268	.300	.219	.267	.156	.219	.340	.300	.227	.292
lower 1931 bark	1.079	.964	.810	.910	.778	.648	.826	.648	.778	.875	.988
lower 1931 wood	.550	.276	.232	.196	.203	.164	.300	.470	.275	.267	.292
large root bark ##	1.064	1.254	1.064	.432	.664	.680	.700	.821	.702	.700	.860
large root wood	.588	.527	.566	.200	.165	.437	.575	.219	.551	.583	.567
small root bark	1.063	1.368	2.688	.781	.567	.859	.697	.745	.664	.826	1.118
small root wood	.826	.627	.771	.639	.284	.721	.875	.607	.664	.931	.802
rootlets	1.0591	1.416	1.240	.990	1.102	1. 280	1.166	.810	.778	1.004	.907

\# All trees received a basic application of $(NH_4)_2$ SO_4 and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 21. Results of Nitrogen Determinations on the Young Stayman Apple Trees which Received One Pound of Potassium Sulfate. # (N as per cent fresh weight) 1933.

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	1.253	.912	1.239	.933	.821	.896	.480	.829	.833	--
upper 1933 bark*	--	--	--	.479	.481	.456	.458	.813	.448	.532	.564
upper 1933 wood	--	--	--	1.003	.502	.487	.415	.923	.309	.288	.648
lower 1933 bark	--	--	--	--	.357	.409	.340	.424	.441	.590	.609
lower 1933 wood	--	--	--	--	.298	.254	.179	.446	.256	.198	.285
upper 1932 bark	.747	.578	.392	.410	.417	.370	.354	.363	.385	.446	.378
upper 1932 wood	.369	.272	.267	.261	.191	.225	.196	.159	.024	.152	.218
lower 1932 bark	.531	.497	.351	.402	.303	.254	.332	.402	.378	.489	.299
lower 1932 wood	.247	.266	.335	.115	.128	.125	.140	.219	.160	.173	.203
upper 1931 bark	.551	.423	.357	.320	.277	.246	.324	.283	.342	.385	.465
upper 1931 wood	.208	.147	.149	.099	.129	.069	.104	.160	.145	.127	.166
lower 1931 bark	.550	.412	.318	.389	.284	.251	.319	.253	.340	.411	.452
lower 1931 wood	.336	.158	.126	.112	.105	.072	.202	.243	.144	.158	.169
large root bark ##	.461	.530	.393	.176	.224	.242	.289	.346	.329	.391	.362
large root wood	.325	.280	.290	.103	.081	.231	.283	.113	.311	.308	.376
small root bark	.445	.677	.434	.334	.192	.329	.273	.300	.331	.342	.492
small root wood	.444	.352	.382	.330	.140	.391	.424	.298	.376	.492	.443
rootlets	.550	.729	.448	.567	.447	.538	.540	.314	.380	.377	.403

\# All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

\## Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

Table 22. Amount of Nitrogen in Each Fraction of the Young Stayman Apple Trees Treated with One Pound of Potassium Sulfate. # (Absolute amount of N in grams per fraction.) 1933

	April 8	April 25	May 11	May 29	June 13	July 23	Aug. 16	Sept. 10	Oct. 4	Nov. 3	Jan. 8
leaves	--	.579	1.327	1.923	2.773	3.216	2.843	2.463	1.692	.662	--
upper 1933 bark*	--	--	--	.097	.109	.220	.208	.414	.247	.293	.319
upper 1933 wood	--	--	--	.122	.073	.152	.128	.329	.137	.119	.271
lower 1933 bark	--	--	--	--	.102	.220	.189	.247	.270	.343	.382
lower 1933 wood	--	--	--	--	.097	.172	.140	.376	.271	.196	.282
upper 1932 bark	.097	.907	.085	.085	.117	.143	.131	.137	.146	.158	.131
upper 1932 wood	.041	.042	.071	.083	.095	.182	.149	.135	.021	.133	.239
lower 1932 bark	.087	.983	.099	.097	.098	.099	.143	.165	.142	.167	.119
lower 1932 wood	.085	.105	.179	.071	.107	.144	.158	.265	.202	.225	.327
upper 1931 bark	.117	.109	.111	.092	.116	.140	.173	.167	.184	.197	.240
upper 1931 wood	.170	.130	.160	.128	.196	.160	.249	.435	.419	.344	.475
lower 1931 bark	.169	.154	.132	.157	.161	.169	.232	.200	.261	.298	.325
lower 1931 wood	.602	.303	.261	.239	.296	.327	.661	1.167	.734	.742	.814
large root bark##	.114	.139	.137	.071	.133	.192	.264	.353	.375	.378	.451
large root wood	.327	.294	.337	.210	.142	.580	.930	.410	1.206	1.385	1.415
small root bark	.191	.248	.495	.146	.106	.152	.123	.148	.140	.213	.359
small root wood	.219	.169	.214	.169	.076	.244	.288	.222	.234	.452	.516
rootlets	.117	.181	.171	.146	.138	.124	.103	.079	.064	.099	.111

All trees received a basic application of $(NH_4)_2 SO_4$ and Superphosphate.

* The year assigned to each fraction indicates the season of first terminal growth.

Large roots - 1 cm. and up in diameter.
Small roots - between 1 cm. and 2 mm. in diameter.
Rootlets - below 2 mm. in diameter.

(APPROVED) H. L. Schrader

(DATED) May 12 1934