POTASSIUM NUTRITION OF THE PEACH

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INTRODUCTION

Symptoms of potassium deficiency in leaves of the peach (*Prunus persica*, Sieb.& Zucc.) were not recognized until comparatively recently. Since 1930, such a condition has been reported in orchards in South Carolina, Maryland, Pennsylvania, New York, Indiana, and other areas. Because of the economic value of the peach and the wide distribution of production areas, increasing occurrences of deficiencies of this major element are of concern to the industry.

Severe potassium deficiency in young peach trees was found in 1946 and 1947 in western Maryland. These trees recovered rapidly as a result of potassium fertilizer applications in mid June. Due to the desirability of more accurate information on the diagnosis of potassium deficiencies under field conditions, a controlled greenhouse experiment was designed primarily to gain more accurate information on the following points: (1) to determine the earliest symptom and progression of symptoms associated with potassium deficiency of young peach trees; (2) to determine the levels of potassium associated with such symptoms; and (3) to determine whether or not potassium could be absorbed by potassium deficient trees equally well at different periods during the growing season. Due to the nature of the experiment, other data could also be obtained on the effect of variable potassium nutrition on the growth response of the trees, and on the absorption of calcium, magnesium, phosphorus, and nitrogen.

In order to follow the effects of potassium fertilizer applications as well as the potassium level being maintained by young peach trees which had previously shown potassium deficiency symptoms, plots were laid out in an orchard near Hancock, Maryland. Soil sampling in these plots was also deemed important to gather information on soil conditions that might have been responsible for the previous deficient condition of the trees.

It is well known that certain nutrient elements can be supplied to various plants by means of sprays. In order to determine the possibility of potassium being taken up by peach leaves from sprays, trees in the same orchard in which the fertilizer plots were located were chosen for foliar spray applications, using several sources of potassium.

REVIEW OF LITERATURE

In this review, references will be made mainly to experimental evidence which has been obtained from work with the peach on the following points: (a) the occurrence of potassium deficiency in the field; (b) symptoms of potassium deficiency as obtained in greenhouse nutrient culture experiments; (c) response of peach trees to soil applications of potassium; (d) levels of potassium associated with deficiency symptoms; (e) influence of potassium on growth; (f) seasonal trends of potassium concentration in leaves; (g) effectiveness of mulches in effecting increases in leaf potassium; and (h) the interrelation of potassium with some other elements.

The Occurrence of Potassium Deficiency Under Field Conditions. Prior to the early 1930's, there is no mention, to the author's knowledge, of a known deficiency of potassium in peach trees under field conditions. Rawl, 1936 (31) reported on abnormalities which developed in a fourteen-year-old Elberta orchard in Spartanburg County, South Carolina. The symptoms occurred about two weeks before harvest in 1934 and were described as follows:

> In the early stage of the abnormal condition the leaves first changed to a light, yellowish-green color, later to a very pale yellow, followed by burning or "scorching" of the tips and margins of the leaves. Finally the leaves were considerably curled, showing a bronzing or browning, eventually resulting in a great scarcity of peach buds.

In the light of descriptions of potassium deficiency later reviewed, these symptoms described by Rawl, though not so stated, probably were the result of a deficiency of potassium. The fact that trees which were given applications of nitrogen, phosphorus, potassium, and dolomitic limestone or basic slag showed no symptoms the following year, whereas those receiving only nitrogen did not recover, is still further evidence that a lack of potassium could have been the cause of the trouble.

Probably the first case of abnormal peach foliage that gave a specific response to applications of potassium fertilizer was that reported by Dunbar and Anthony, 1938 (17) in south central Pennsylvania, near the Maryland line. The foliage symptoms were described by these authors:

> The leaves were pale, olive green in color with the edges bordered with red, with only an occasional leaf showing marginal disintegration. Nearly all leaves were crinkled along the midrib and laterally rolled toward the midrib, forming a cylinder in extreme cases with the under surface of the leaf exposed and showing much light red to pink discoloration.

Analyses of these leaves revealed low levels of both potassium and nitrogen, so that the symptoms described probably should not be attributed solely to a lack of potassium.

In the course of a fertilizer experiment with peach trees in the Sandhill area of South Carolina, Scott, 1938 (33) reported definite potassium deficiency symptoms in minus-potassium plots after the trees had borne their second crop. Rolling and yellowing of the foliage as well as a breakdown of the marginal tissue occurred in severe cases. According to Scott: "Potash deficiency develops first at the tips of the shoots and progresses inward toward the trunk...."

Practically the same symptoms which have been described were reported to have occurred in peach trees on the grounds of the United States Horticultural Station at Beltsville, Maryland by Cullinan and Waugh, 1940 (14). In a number of orchards during 1938 and 1939, these authors obtained leaf samples from young peach trees in Michigan, Delaware, and Maryland which showed deficiency symptoms and all contained less than 1 per cent potassium.

Peach trees exhibiting potassium deficiency symptoms were reported by Boynton, 1944 (6) in a seven-year-old orchard in New York and in a younger orchard in northern Indiana by Baker, 1948 (4).

Symptoms of Potassium Deficiency as Obtained in Greenhouse Nutrient Culture Experiments. Hoagland and Chandler, 1933 (22) described for peach leaves potassium deficiency symptoms induced under artificial conditions, as being lighter in color and mottled with distinct vein patterns. Later in the summer, the leaf tips died, were rolled, and had scattered perforations.

Davidson and Blake, 1937 (15) reported symptoms resulting from a lack of potassium in the nutrient solution as follows:

> Large and small necrotic, straw-colored spots developed on the foliage. In many cases, the leaf margins were scorched severely. Abscission zones usually developed around the necrotic areas and caused them to break loose from the healthy tissue.

Also reporting on symptoms resulting from omitting potassium from peach trees growing in sand culture, Weinberger and Cullinan, 1937 (41) stated:

> The first symptoms produced by a lack of potassium was a puckering of the lamina, caused by relatively greater growth of the intervascular tissue than of the veins.... The most marked symptom of potassium deficiency was the "leaf scorch", developed when cells in the extreme margin of the blades browned and died, and entire serrations lost their chlorophyll. Gradually the necrosis extended inward until entire margins to a depth of one-eighth inch or more fell off in ribbons. Minute brown spots appeared in the intervascular areas, and enlarged, and the dead tissue in the center of the spots shrank and fell out, perforating the blades.

Brown, 1945 (7) also noted on one-year-old Elberta trees in sand culture that a lack of sufficient potassium caused the interveinal areas to have small necrotic lesions which dropped out, leaving a shot-hole appearance.

The typical "leaf scorch" symptoms resulting from potassium deficiency had been reported earlier than any of the above mentioned cases by

Wallace, 1925 (37) in England. Though not obtained in peaches, he did describe "leaf scorch", as a result of omitting potassium from the nutrient solution, in apples, black currants, strawberries, gooseberries and raspberries.

Response of Peach Trees to Soil Applications of Potassium. Rawl, 1936 (31) reported recovery of abnormal peach foliage the season following applications of complete fertilizer. In trees given nitrogen only, the symptoms reappeared the following year. In a later report, Rawl, 1940 (32), reported that with some of the deficient trees which were given nitrogen only, the symptoms continued to reappear until given a complete fertilizer, and recovery was then effected in one season.

Dunbar and Anthony, 1938 (17) observed marked recovery of leaf symptoms during the same season in which potassium applications were made.

Working with two-year-old trees, Cullinan and Waugh, 1940 (14) found it possible to increase potassium concentrations in leaves from soil applications of one-half pound of potassium sulphate per tree. The unfertilized trees had only 0.69 per cent potassium in the leaves, whereas after one season the fertilized trees contained well over 2 per cent potassium in the leaves. Waugh and Cullinan, 1941 (39) reported a marked response resulting from two pounds of potassium sulphate applied to four-year-old trees on June 12. Seven weeks later the potassium concentration in the leaves was three times that of the check and by September 3 was four times as much as the check.

In a seven-year-old orchard showing potassium deficiency symptoms, Boynton, 1944 (6) applied three pounds of 60 per cent muriate of potash per tree in October, and again the following April. Analyses of the leaves sampled on July 25 showed some of the fertilized trees had over 2 per cent potassium in the leaves, whereas the check had slightly above 0.5 per cent.

<u>Levels of Potassium Associated with Deficiency Symptoms</u>. Cullinan, Scott, and Waugh, 1939 (13) in reporting on peach leaves showing potassium deficiency under field conditions, found less than 1 per cent potassium in all instances. The same authors reported that leaves from peach trees in sand culture at five and two parts per million in the nutrient solution had 0.55 and 0.59 per cent potassium, respectively. Trees receiving zero parts per million had 0.46 per cent potassium in the leaves. Trees receiving up to five parts per million showed marked deficiency symptoms on the foliage and the leaves on terminals of trees receiving ten parts per million were rather characteristic of potassium deficient trees, but no severe symptoms of lesions or marginal scorch appeared.

Leaves from orchard trees containing less than one per cent potassium were reported by Cullinan and Waugh, 1940 (14) to be showing deficiency symptoms, whereas the leaves containing from 1 to 1.25 per cent potassium showed no symptoms.

In a report of a survey of 130 peach orchards in California, Lilleland and Brown, 1941 (27) found one nineteen-year-old orchard in which the leaves contained only 0.45 per cent potassium in July, yet the foliage appeared to be healthy. In October, the potassium percentage had fallen to 0.27 per cent and at this time no distinctive scorch or leaf rolling was observed. Most of the orchards, however, showed over 1 per cent potassium in the leaves.

Baker, 1948 (4) reported the potassium concentration in the leaves from potassium deficient trees growing in loamy fine sand to be as low as 0.26 per cent. Two years later, Baker, 1949 (5) reported that some of the same trees left as checks contained only 0.4 per cent potassium and as in the two previous seasons, showed typical potassium starvation symptoms.

Influence of Potassium on Growth. Hoagland and Chandler, 1933 (22) reported peach trees as making more growth under potassium deficient conditions than the trees receiving complete nutrient solution; the leaves, however, were light in color and mottled.

From studies extending over a period of six years, Chandler, 1934 (10) reported that potassium applied to peach trees in Maryland had no consistent effect on the growth. Weinberger and Cullinan, 1937 (41) in reporting on mineral deficiencies of peach trees in sand culture, stated that trees not receiving potassium in the nutrient solution made almost as much length growth as did the control, but the branches were smaller in diameter. Another experiment with young peach trees in sand culture by Cullinan, Scott, and Waugh, 1939 (13) showed that as much linear growth was made by trees receiving 2 parts per million potassium as by those receiving higher concentrations. The diameter of the laterals and main stem were, however, somewhat smaller in the lower potassium ranges.

Scott, 1939 (33) reported on a field fertilizer experiment with peach trees and stated that trees not given potassium fertilizer applications actually produced more trunk growth than did trees which received a complete fertilizer. Differences in length of shoot growth were not pronounced, but the shoots from trees not supplied with potassium were more slender than those from normally fertilized trees. Slender terminals were also reported in potassium deficient trees by Dunbar and Anthony, 1938 (17) even though growth in length was nearly normal.

In bearing nine-year-old peach trees adequately supplied with potassium, Waugh and Cullinan, 1941 (39) reported greater total growth and a much greater leaf area than in trees given no potassium. Boynton, 1944 (6) reported a striking increase in shoot growth and leaf size in seven-year-old potassium deficient peach trees after potassium fertilizer applications.

Seasonal Trends of Potassium Concentration in Peach Leaves. Lilleland and Brown, 1939 (26) found a decreasing potassium concentration in the leaves of non-bearing orchard trees as the season progressed. However, when placed on a milligram per leaf basis, there was no trend up or down between June 10 and October 1. The same authors, 1941 (27) later reported a seasonal decrease in potassium concentration in leaves from eighteen-year-old as well as ten-year-old trees. Similar results were obtained in nine-year-old trees by Waugh and Cullinan, 1941 (39) and by Baker, 1941 and 1949 (2), (5) in trees growing under field conditions.

Effectiveness of Mulches in Effecting Increases in Leaf Potassium. Baker, 1941 (2) reported an increased potassium in terminal peach leaves when mulched with straw or alfalfa. There were no potassium deficiencies apparent in these trees. In a further report on the effectiveness of mulches on potassium uptake, Baker, 1943 (3) stated that some inorganic mulches such as glass wool and cinders caused practically the same increase in potassium leaf content of apple leaves as did organic mulches.

Mulches were effective in a period of one season in correcting potassium deficiency which appeared in peach trees at the end of their second growing year according to Baker, 1948 (4). In this work the level of potassium in the leaves was found to average 0.26 per cent the fall the mulches were applied, and one year later, the manure mulch had raised the level to 2.58 per cent, the straw mulch to 1.93 per cent, and the soybean hay mulch to 1.83 per cent. The leaves of the check trees one year later had only 0.33 per cent potassium and had again developed deficiency symptoms. Five pounds of potassium chloride were applied to each of several of the mulched trees but appeared unnecessary as mulch alone appeared to correct the deficiency. These conclusions were later confirmed by Baker, 1949 (5) when he reported that check trees showed deficiencies for the third year and leaf potassium was below 1 per cent. Mulches only, brought the potassium range up and kept it up for two years in succession.

Interrelation of Potassium with Other Elements. Hoagland and Chandler, 1933 (22) in working on deficiencies in French prune reported that, "Increased absorption of potassium consequent on fertilization of the soil with this element is accompanied by decreased absorption of calcium or magnesium, or both...." Colby, 1933 (12) showed that a potassium deficiency resulted in reduced nitrate absorption in the French prune. Thomas, 1933 (36) grew Stayman Winesap apple trees in cylinders under applications of nitrogen, phosphorus, and potassium. The entire trees were removed and analyzed after a growth period of six years. The omission of any one element from the complete fertilizer was followed by a decreased absorption of the remaining elements.

Chandler, 1936 (11) found that a heavy application of potassium resulted in a significant increase in total nitrogen content in Stayman Winesap apple trees. He also stated:

> The relation of potassium to nitrogen seems to be largely a common cause association; that is, nitrogen and potassium both being essential to the life of the cell, more nitrogen and potassium occur where more living cells exist.

Davidson and Blake, 1938 (16) have shown that high calicum and low potassium induced potassium deficiency symptoms in the peach in sand culture. In treatments receiving two parts per million potassium, an increase in calcium concentration from 180 to 410 parts per million caused about 70 per cent reduction of soluble potassium in the stem tips as determined by rapid tests.

No marked difference in nitrogen concentration was found by Cullinan, Scott, and Waugh, 1939 (13) in leaves from young peach trees in sand culture which received 0, 2, 5, 10, 30, and 60 parts per million potassium.

That the concentration of one element might exert some influence as to whether another element was present in concentrations low enough to cause deficiency symptoms was noted by Waugh, Cullinan, and Scott, 1940 (40). In young peach trees growing in sand culture at low levels of either nitrogen or phosphorus, no potassium foliage symptoms were seen, but low potassium trees showed deficiency symptoms at intermediate and adequate levels of nitrogen and adequate level of phosphorus.

Waugh and Cullinan, 1941 (39) reported that potassium applications had no significant effect on nitrogen leaf content in nine-year-old peach trees in the field. The same was found to be true for phosphorus.

PART I

POTASSIUM NUTRITION STUDIES UNDER GREENHOUSE CONDITIONS

MATERIALS AND METHODS

Cultural Treatments. One-year-old budded peach trees of the Shippers Late Red variety were obtained from a commerical nursery and heeled-in for several days before being planted in the greenhouse. From a lot of 200 trees, approximately ninety were selected on the basis of uniformity and vigor. Roots were trimmed back to about three inches and tops removed at fifteen inches above the bud union, as well as all branches from the remaining trunk. Weights of the trees as they were to be planted and the weight of the parts removed were recorded.

On April 10, 1948 the trees were planted in two-gallon glazed crocks filled with 18-mesh white quartz sand. All shoots which came out above the bud union were allowed to develop. Drainage was provided by placing glass wool over the hole in the bottom of the crock. The trees were watered with tap water until nutrient treatments were begun. The trees were divided into nine blocks of nine trees each, the trees being randomized in the blocks and tagged with numbers from one to nine to designate the treatment to be received. The trees within each block were as near the same weight as possible, the original weights as received from the nursery being taken as a measure of uniformity. On this basis the trees in block 1 contained the nine lightest trees, block 2 the next nine, and so on to block 9 which contained the heaviest trees. These blocks were then randomized, the crocks being placed on conventional greenhouse benches. Trees were arranged diagonally in a single row on both sides of the benches, so that all were about two feet apart in and between rows. The extra trees were also potted and set aside and used as replacements for a few trees which did not make a good, early start.

On May 1, the treatments were begun using three different nutrient solutions with potassium as the only variable, other elements being equal in amounts present, except sodium, and with only a very minor variance in sulphur. These were designated as plus-potassium (100 ppm), minus-potassium (0 ppm), and low-potassium (2 ppm). The chemicals used are shown in Table 1. All solutions were also supplied with minor elements in a supplementary solution containing aluminum, bromine, iodine, selenium, lithium, manganese, copper, nickel, and cobalt as used by Hoagland and Snyder, 1934 (23). One milliliter of a 0.5 per cent solution of iron citrate was added per liter of solution.

All trees received nutrient solution three times weekly and were watered with distilled water on other days. Earlier applications consisted of approximately 350 milliliters of solution, but later when the trees began to require more, the amount was increased to 500 milliliters per day.

Some interveinal chlorosis soon occurred and the amount of iron citrate was doubled beginning May 26 and continued thereafter. Toward the latter part of July some of the trees appeared to be lacking in nitrogen, so the amount was doubled for all trees for a week or two and then returned to normal, since the trees appeared to recover within this brief period.

In order to keep the temperature from going too high during the hottest part of the summer, the greenhouse was shaded and the aisles

Table 1. Nutrient Solutions Applied to Peach Trees in the Experiment

Salts Used	Parts Per Million							
	N	P	K	Ca	Mg	S	Cl	Na
	(Plus Potassium)							
NH_4 NO_3	100	-	-	-	-	-	-	-
KH_2 PO_4	-	50	63	-	-	-	-	-
Mg SO_4-$7H_2O$	-	-	-	-	25	33	-	-
Ca Cl_2-$2H_2O$	-	-	-	150	-	-	265	-
K_2 SO_4	-	-	37	-	-	15	-	-
Na_2 SO_4	-	-	-	-	-	26	-	37
TOTAL	100	50	100	150	25	74	265	37
	(Minus Potassium)							
NH_4 NO_3	100	-	-	-	-	-	-	-
Na H_2PO_4-H_2O	-	50	-	-	-	-	-	37
Mg So_4-$7H_2O$	-	-	-	-	25	33	-	-
Ca Cl_2-$2H_2O$	-	-	-	150	-	-	265	-
Na_2 SO_4	-	-	-	-	-	41	-	59
TOTAL	100	50	0	150	25	74	265	96
	(Low Potassium)							
NH_4 NO_3	100	-	-	-	-	-	-	-
Na H_2 PO_4-H_2O	-	50	-	-	-	-	-	37
Mg SO_4-$7H_2O$	-	-	-	-	25	33	-	-
Ca Cl_2-$2H_2O$	-	-	-	150	-	-	265	-
Na_2 SO_4	-	-	-	-	-	41	-	59
K_2 SO_4	-	-	2	-	-	1	-	-
TOTAL	100	50	2	150	25	75	265	96

were sprinkled with water, sometimes several times a day. A hygrothermograph was used to record humidity and temperature from May 24 through September 12. The minimum night temperature usually reached no lower than 60 degrees F and rarely was above 80 degrees F. The maximum day temperature was usually no less than 90 and on several occasions exceeded 110 degrees F, but on most days fell within this range. During the hottest part of the day, between 2 and 5 P. M., the relative humidity fell as low as 20 per cent on a few occasions, but was usually lower than 40 per cent. During the coolest part of the night, between midnight and 8 A. M., the relative humidity was usually 80 per cent or above.

On May 1, four trees in each block were started on plus-potassium and four on minus-potassium nutrition. The ninth tree was not given any alternation in treatment, but received low-potassium (2 ppm) continually. On June 1, one of the four trees in the plus-potassium series was changed to minus-potassium. On July 1, another was changed to minus-potassium, and on August 1, a third was likewise changed. This left one tree of the original four, on plus-potassium for the duration of the experiment, May 1 to September 1. Similarly, of the four trees in the minus-potassium series, one was changed to plus-potassium on June 1, July 1, and August 1, respectively, thus leaving one tree per block on minus-potassium throughout. Table 2 shows the treatments received with the time each tree was on plus or minus-potassium nutrition.

The treatment alternations ended on August 31, but the trees were continued in the greenhouse throughout September on the same treatment they had received during August. At the end of September, all treatments were discontinued with the trees receiving only tap water until December 11. At this time, five blocks remained, and one was saved for a dormant

Table 2. Differential Potassium Treatments Used in the Experiment

Treatment Designation *	Duration of Treatments
+ + + +	Plus K May 1, to Sept. 1
+ + + -	Plus K May 1, to Aug. 1, Minus K to Sept. 1
+ + - -	Plus K May 1, to July 1, Minus K to Sept. 1
+ - - -	Plus K May 1, to June 1, Minus K to Sept. 1
- - - -	Minus K May 1, to Sept. 1
- + + +	Minus K May 1, to June 1, Plus K to Sept. 1
- - + +	Minus K May 1, to July 1, Plus K to Sept. 1
- - - +	Minus K May 1, to Aug. 1, Plus K to Sept. 1
Low K	Low K May 1, to Sept. 1

* Each plus (+) symbol represents one month on plus potassium nutrition; each minus (-) symbol represents one month on minus potassium nutrition.

sample. The other four blocks were set out, in a field of sandy loam soil considered to be of good fertility, four feet apart in eight-foot rows. A sample of the topsoil and subsoil was taken for analysis. Before planting, the green weights were recorded. These trees received no fertilizer during the growing season of 1949 with the exception of one-quarter pound of nitrate of soda per tree applied on June 23. Leaf samples were collected from these trees during the summer, and as soon as leaf fall occurred, the trees were dug and the weights of roots and tops recorded. For weighing, the trunks were cut at the point of bud union, all wood below this point being considered as root, all above as top.

Length of terminal growth of the trees growing in the greenhouse was measured twice monthly beginning on June 1 and ending on September 1. Trunk diameter was obtained on the date of planting, and at monthly intervals thereafter, at a point above the bud union which was marked with a wax pencil. Two measurements were taken on each date at right angles to each other and the average recorded.

Sampling Methods. In order to determine the mineral content of the trees at the time they were set out, six trees other than those used in the experiment, were selected and trimmed just as those that were used by removing all limbs on the trunk and cutting the trunk off at fifteen inches above the bud union. Roots were trimmed back to approximately three inches. With these portions removed, the part of the trees remaining was the same as the portions set out in the experiment. This portion was then divided into three sections, the trunk above the bud union, designated as "scion trunk", the trunk from the roots up to the bud union as "stock trunk", and the remaining roots as "roots". Thus, these six dormant trees were each divided into three portions, each portion from each tree being maintained as a separate sample for chemical analysis. Determinations were made for calcium, magnesium, potassium, phosphorus, and nitrogen on all of these samples.

From the trees growing in the greenhouse, leaf samples consisting of two leaves per tree from the median portion of the shoots, were taken on May 17, June 1, July 19, and July 1, 1948. The leaves were taken from trees which had been either on plus-potassium or minus-potassium treatment from the beginning, and the leaves were composited into two samples only, plus-potassium and minus-potassium leaves.

After treatments had been in progress for one month, monthly sampling of whole blocks began, one block being removed on June 1, July 1, August 1, and September 1. One block was also sampled in the dormant state on December 18 in the same manner as will be presently described for the other blocks, with the exception of leaves, as leaf fall had occurred before this time.

On each of the sampling dates, the trees were carefully removed from the crocks, the sand being washed from the roots with tap water. For chemical analyses, the trees were divided into seven portions as follows:

1. Distal leaves--leaves from the distal half of all the terminal branches.
2. Basal leaves--leaves from the basal half of all terminal branches.
3. Limbs
4. Scion trunk--that portion from bud union up.
5. Stock trunk--that portion from transition zone, where first roots were attached, up to bud union.

6. Old roots--all woody tissue, being the same roots that were present at planting.

7. New roots--those produced during the 1948 growing season.

Green weights of all samples, except new roots, were recorded and the samples placed in paper bags for drying. The new roots were so succulent that it was considered impractical to try to obtain green weights accurately. All samples were dried in a forced-draft oven at 80 degrees C and dry weights recorded. The woody fractions, especially the roots and stock trunks, were very tough and were split into smaller sections with a pair of hand loppers. They were then ground in a large Wiley mill and later reground in a smaller Wiley mill equipped with a 40-mesh screen. Leaves and limbs were ground only in the smaller mill.

<u>Chemical Methods</u>. Chemical analyses were determined on all samples for the following elements: calcium, magnesium, potassium, phosphorus, and nitrogen.

Calcium, magnesium, potassium, and phosphorus determinations were made from aliquots taken from an ash solution which was prepared in the following manner: Two-gram samples of the ground material were weighed out just after removal from a drying oven at 80 degrees C. These were ashed overnight in an electric muffle furnace at 525 degrees C. The ash was taken up with hydrochloric acid, filtered through filter paper into 100 milliliter volumetric flasks and washed free of acid with hot distilled water. After cooling, the solutions were brought up to volume and then transferred to ordinary prescription bottles until used.

Calcium and potassium were determined photometrically on a Beckman (Model DU) Quartz Spectrophotometer equipped with a Flame Spectrophotometer

(Serial number 220) manufactured by National Technical Laboratories. The ash solution to be analyzed by this instrument is fed, in an atomized state by air pressure, into a high intensity oxygen-natural gas flame, which excites the elements, causing them to emit their characteristic spectra. The light thus emitted by the flame is dispersed by the quartz prism, and the intensity of light of the desired wavelength is measured by a photo-electric cell. This method for determining calcium and magnesium in leaf material has been reported by Brown, Lilleland, and Jackson (8), who compared results obtained by this method with chemical methods and reported a satisfactory correlation. These authors also reported that other ions in the sample solution exert an influence upon the one being determined, the rate of interference being most noticeable with the first few parts per million of the interfering element, with less interference upon increasing concentrations. In flame photometry, the concentration of an unknown element is determined by comparing the reading with a known standard solution, and due to interference of other ions, more correct values can be obtained if the known standard solution also contains some of the same interfering ions, which are present in the plant material being analyzed. Thus, Brown and his co-workers (8) concluded:

> ... if the standard solution contains only a few parts per million of the interfering ions, it can be used for comparing with unknown solutions which may vary considerably in the amount of interfering ions present.

Considering the above information, calcium standards were used containing 100, 80, 60, 40, 20, and 0 ppm calcium. Each of the above concentrations also contained 200 ppm potassium, 50 ppm magnesium, and 20 ppm sodium. With the sensitivity knob set at two complete turns from counter-clockwise, slit width at about 0.9 mm., oxygen at 35 inches of water, air pressure at 20 pounds per square inch, and using a wave length of 650 millimicrons, a curve was obtained which was a straight line ranging from 18 on the photometer scale (zero calcium) to 100 on the scale (100 ppm calcium).

Potassium standards were used containing 100, 80, 60, 40, 20, and 0 ppm potassium with each concentration containing 50 ppm calcium and 20 ppm sodium. With the sensitivity knob set at two complete turns from counter-clockwise, the slit width at 0.02 mm., oxygen at 30 inches of water, air pressure at 20 pounds per square inch, and using a wave length of 767 millimicrons, a curve was obtained which slightly curved upward in the middle and ranged from a reading of two on the photometer scale (zero potassium) to 100 on the scale (100 ppm potassium).

The plant material used included woody as well as leafy tissue. The ash solution from the woody tissues was injected directly into the flame without dilution, with few exceptions, but the leaf ash solution was too concentrated and had to be diluted several times to bring the readings within the ranges of calcium and potassium set by the standards. In analyzing samples with the photometer, each sample was read twice. Between the first and second reading, a check was made, using a standard solution of a concentration where the most steady readings were obtained, in order to be sure the instrument had not drifted from the original standardization. The concentration of the unknown solutions was computed by comparing these readings with readings of the known standards.

Phosphorus determinations were made by taking an aliquot from the ash solution and following the method as outlined by the Association of Official Agricultural Chemists (1).

Magnesium determinations were made colorimetrically with titan yellow, following the method as outlined by Gillam (19), using a Beckman

Spectrophotometer to measure color differences.

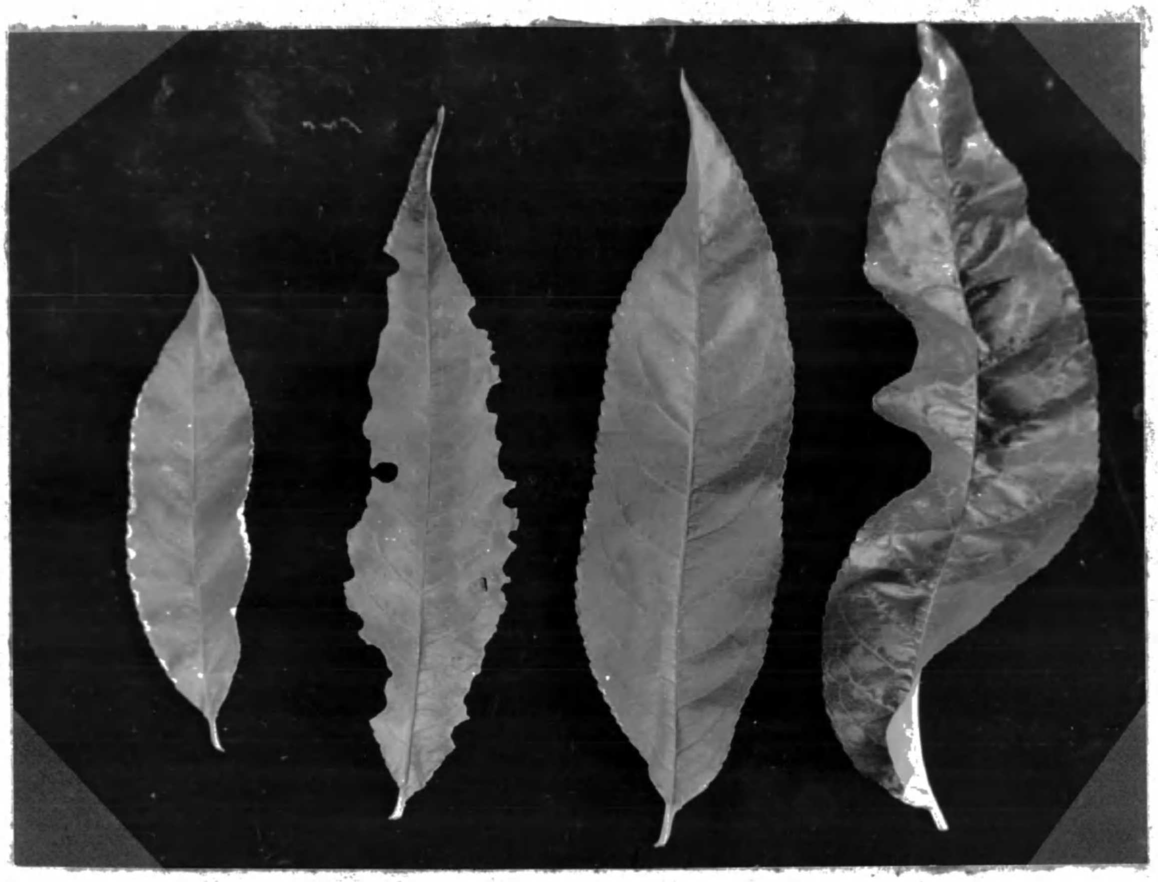
Total nitrogen was determined by the Ranker (30) salicylic-thiosulphate method, using the Kemmerer-Hellatt (25) distillation unit, modified by using boric acid to catch the distillate as used by Stover and Sandin (35), and using brom cresol green-methyl red indicator as suggested by Gauch (18).

EXPERIMENTAL RESULTS

Appearance and Description of Potassium Deficiency Symptoms. Most of the trees started new shoot growth within two weeks after planting. On May 17, thirty-seven days after planting, marginal necrosis affecting one or more leaves on seven of the minus-potassium trees was present. This first symptom appeared, usually on both edges of the affected leaves, as a narrow, light colored, rather uniform strip, though not necessarily continuous, since some portions along the margins contained healthy tissue interspersed among the necrotic areas. The first leaves affected were not the youngest ones. This same symptom showed up on low-potassium trees, being first noticed just five days later than on the minus-potassium trees. Figure 1, leaf 1, shows the marginal necrosis on a leaf taken from a low-potassium tree. A similar condition is shown in leaf 1 of Figure 2, taken from a minus-potassium tree. Even though the low-potassium trees first exhibited symptoms slightly later than minus-potassium trees, the types and progression of symptoms were similar.

Leaves early affected by marginal necrosis most acutely, seemed to be of smaller than average size. These marginal necrotic areas later became loose and fell out, leaving the leaf edges jagged, as shown in Figure 1, leaf 2 and in Figure 2, leaf 4.

A further symptom, which appeared later than marginal necrosis, was a scattering of pin-point necrotic spots on the leaves. This condition showed up on some leaves which had not previously shown marginal necrosis, as shown in leaf 2 of Figure 3. Some such leaves did not develop, to any great extent, any other type of symptoms, with the necrotic pin-point spots



1 2 3 4

Figure 1. Peach leaves from: (1) low-potassium tree showing early symptom of marginal scorch; (2) minus-potassium tree showing ragged edges caused by falling out of marginal necrotic areas; (3) plus-potassium tree showing no symptoms; (4) plus-potassium tree showing crinkling. Photographed on June 17, 1948.

remaining as the outstanding symptom as shown in Figure 14, photographed on July 24. Note the two leaves at central lower left, showing some marginal necrosis and a few small holes in one of the leaves in addition to the pin-points.

The most prominent symptom of potassium deficiency was the development of large necrotic lesions within the leaves, which later broke loose from the surrounding live tissue and dropped out, leaving ragged, irregular holes. This symptom however did not appear independently, but concomitantly with marginal as well as with pin-point necrosis. All these symptoms appearing on the same leaf are shown in Figure 2, leaf 3, and in Figure 3, leaf 4. Both photographs show the severity of symptoms present by June 22.

By May 29, 22 out of the 36 minus potassium trees in the experiment had developed signs of potassium deficiency. On June 19, all but two had become symptomatic. These two had made rather poor growth, perhaps resulting in less dilution of the potassium present in the tree.. Since some minus-potassium trees were affected as early as May 17, and practically all by June 19, it may be assumed that the potassium reserve in the trees had been reduced to a concentration below that required for normal metabolism. This is indicated in the data presented in Table 3, which show the potassium levels on June 1, in basal and distal leaves, from four minus-potassium trees. In all the trees, the potassium concentration in the basal leaves was lower than in the distal leaves. It is interesting to note that the trend toward lower concentrations is correlated with the greater number of symptomatic leaves per tree, with the exception of the last value in the table. Since the highest level of potassium was under 1 per cent in all cases, it is suggested that this concentration was near the deficiency level. A composite leaf sample, taken on June 1 from all minus potassium

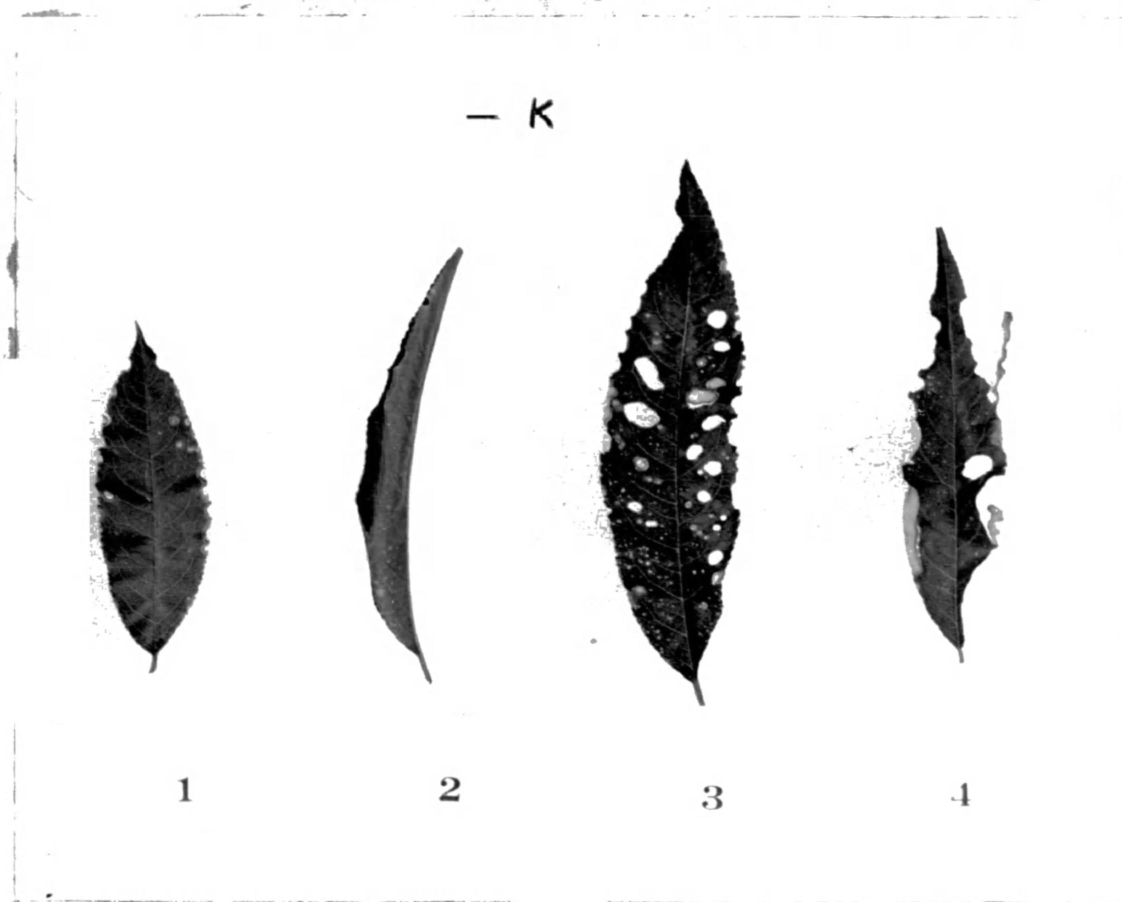


Figure 2. Leaves from minus-potassium trees: (1) showing marginal burning with few interveinal spots; (2) showing upward and inward rolling; (3) showing all main symptoms, marginal burning, large necrotic areas within the leaf, and pin-point necrotic spots; (4) mainly showing marginal burning with dead tissue sloughing off. Photographed on June 22, 1948.

LOW K

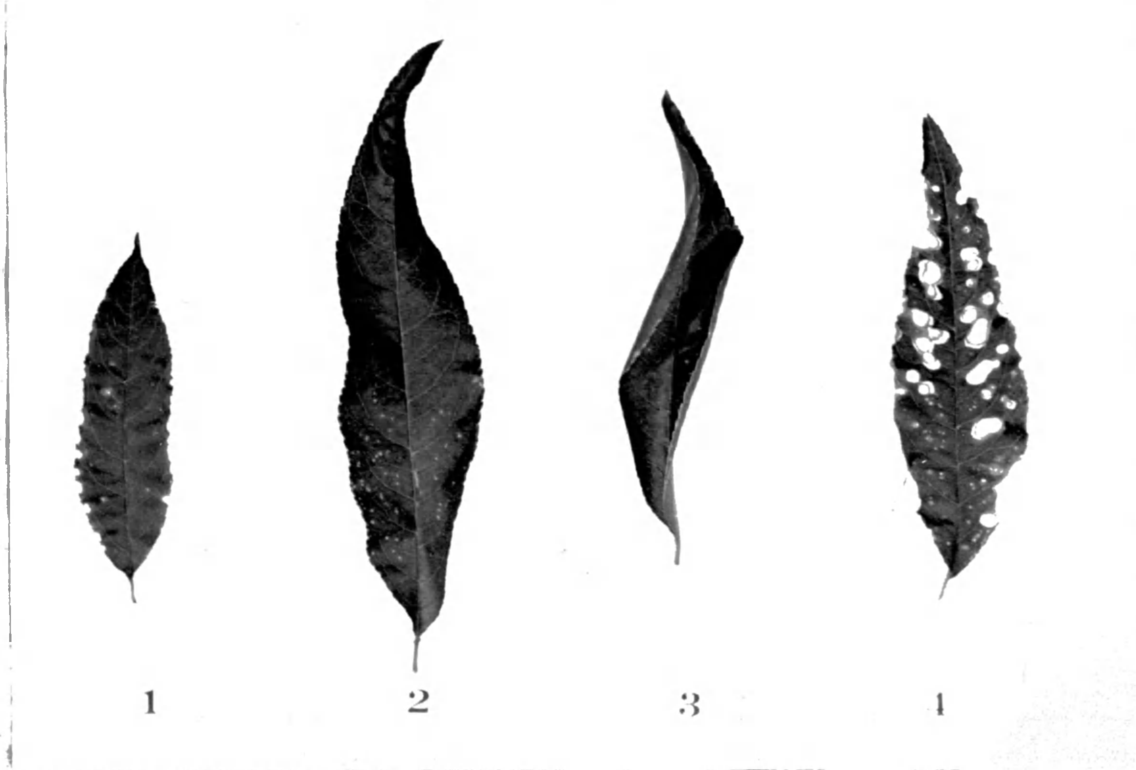


Figure 3. Leaves from low potassium trees: (1) showing marginal scorch and small necrotic spots within the leaf; (2) showing pin-point necrosis; (3) showing leaf-roll and few small necrotic spots; (4) showing severe deficiency symptoms with much dead tissue. Photographed on June 22, 1948.

Table 3. Relationship Between Severity of Potassium Deficiency Symptoms and Potassium Content

Number of Leaves on Four Individual Minus K Trees Showing Deficiency Symptoms on May 29	Potassium Content of Distal and Basal Leaves on June 1.		
	Distal	Basal	Average
	%	%	%
3	.96	.88	.92
13	.72	.60	.66
17	.64	.42	.53
27	.68	.44	.56

trees contained 0.8 per cent potassium. These leaves were taken whether the individual trees were visibly showing potassium deficiency or not. This is a further indication that 1 per cent potassium was about the critical level.

Upward and inward rolling of some of the uppermost leaves was also noticed on minus and low potassium trees. This rolling was not generally associated with the previously described symptoms as is shown in Figure 2, leaf 2, and Figure 3, leaf 3.

Crinkling along the midrib has been described as a potassium deficiency symptom in peach leaves. A form of crinkling was found on healthy trees receiving potassium. Since none of the other symptoms which were found on minus and low potassium trees were present, it must be that this was not due to a deficiency of potassium. Such a leaf from a plus potassium tree is shown in Figure 1, leaf 4. Healthy leaves from plus-potassium trees are shown in Figure 4.

Photographs of entire trees were taken on June 9 to show the effects of the various nutrient treatments on this date. Figure 5 shows a tree which had received potassium from the start; all leaves were a normal green color and healthy with no deficiencies evident. A tree having received low-potassium is shown in Figure 6. At least one leaf, near the end of the branch extending to the left, plainly shows necrotic areas which do not appear to have fallen out by the time photographed on June 9. Figure 7 shows a tree also photographed on June 9, which had received no potassium to this date. Several leaves can be seen from which the margins as well as other necrotic areas within the leaves have fallen out. Other dead spots appear to be still intact.

As the season progressed, leaves on trees showing severe effects of a lack of potassium gradually lost their normal green color, becoming much

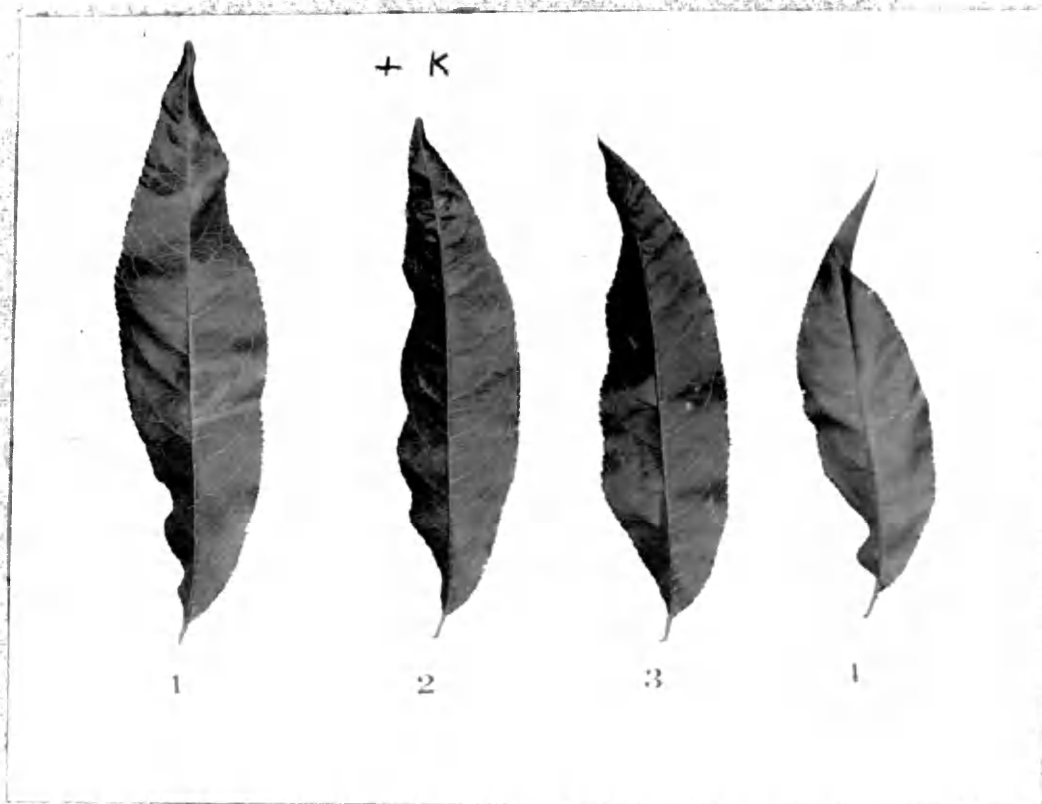


Figure 4. Leaves from plus-potassium trees appearing normal with good color. Photographed on June 22, 1948.

Figure 5. Tree from full nutrient (plus-potassium) treatment. Photographed on June 9, 1948.

Figure 6. Tree from low-potassium treatment. Note deficiency symptoms appearing on leaf near the end of branch extending to left side of picture. Photographed on June 9, 1948.

Figure 7. Tree from minus-potassium treatment. Note holes left by fallen-out necrotic tissue as well as ragged edges resulting from the same. Photographed on June 9, 1948.

lighter and assuming a greenish-tan to bronze color. The new leaves which emerged on such trees were always normal, though perhaps lighter green in color than trees receiving potassium. It was not long, however, until they too became symptomatic. That such was the case in all leaves except the very young ones, is shown in Figures 8 and 9, photographed on July 24, each of which shows a single branch from a low and minus-potassium tree, respectively. All of the foliar symptoms previously described can be observed in these two figures, with many individual leaves exhibiting all types of symptoms. Some of the most severely affected leaves had become so wrinkled and twisted that instead of the upper surface facing out, as normally, part of the underside faced out as is shown at about the center of Figure 9.

Trees which received potassium for one month (May) and then changed to minus-potassium were slow in developing potassium deficiency symptoms. Only two such trees were found in the experiment and these were only slightly affected. In Figure 10, photographed on July 20, one leaf can be seen near the tip of the branch, which shows two or three indentations in its margin where necrotic tissue has dropped out. In the same leaf may be seen two or three small circular spots, the dead tissue having been lost from only one of them. A branch from the other tree is shown in Figure 11, photographed July 24. The three largest leaves near the terminal end, with upper sides facing out, are faintly showing pin-point necrosis. One other leaf can be seen with two small holes, from which dead tissue has fallen.

In no case did a tree show any visible symptoms if it received potassium for two months or more before change to minus-potassium nutrition. Figure 12 shows a typical branch from such a tree, which appears

Figure 8. Branch from a tree receiving low-potassium treatment from May 1 to date photographed, July 24. Note severe symptoms on leaves just back of newly emerged ones, also leaf near center of photograph whose main sympton is pinpoint necrosis.

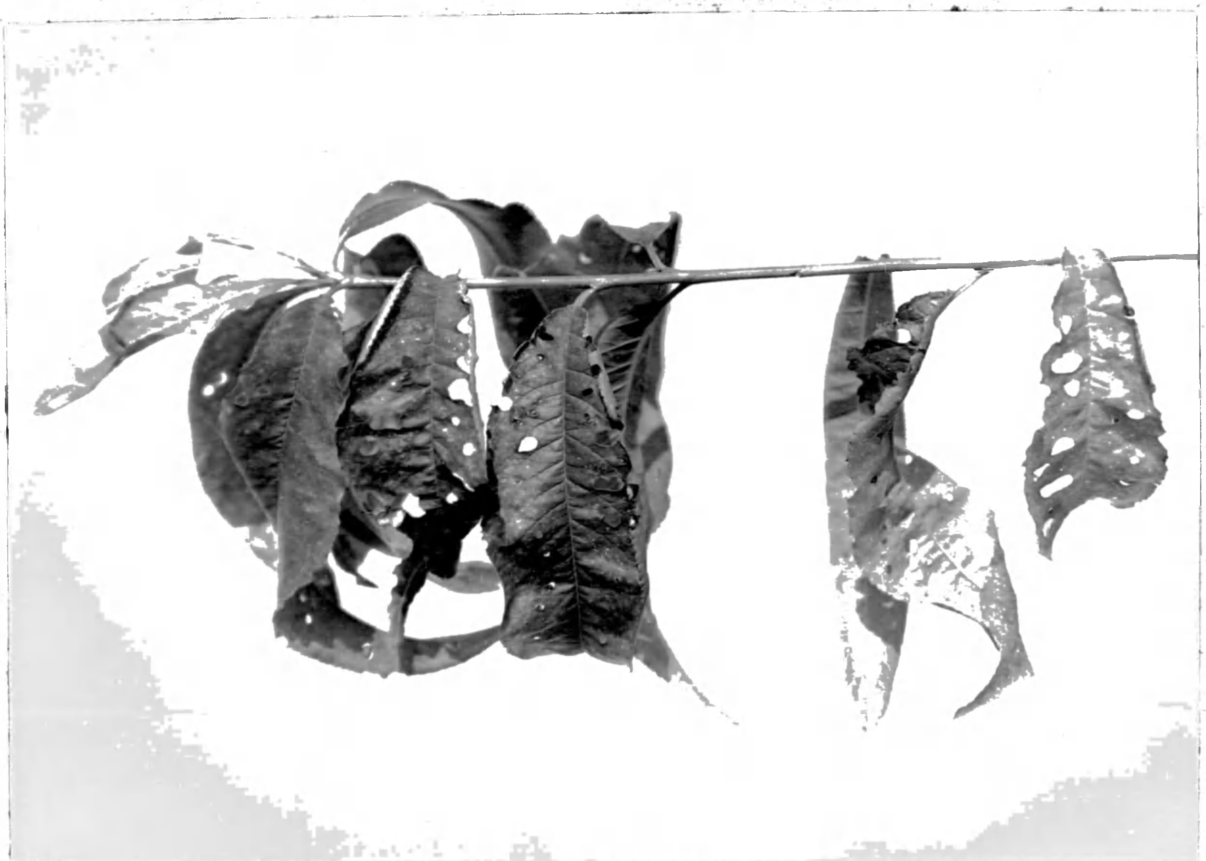


Figure 9. Branch from tree receiving no potassium from date set out, April 10, to date photographed, July 22. In addition to the regular symptoms, note twisting and wrinkled appearance of the leaves.

Figure 10. Branch from tree receiving plus-potassium from May 1 to June 1, then changed to minus-potassium to date photographed, July 20. Note one leaf (right center) showing indentations and three necrotic spots within the leaf.

Figure 11. Branch from tree receiving plus-potassium from May 1 to June 1, then changed to minus-potassium nutrition to date photographed, July 24. Note two largest leaves near terminal end showing faint pin-point necrotic spots; also, leaf (near center) having two holes resulting from fallen-out necrotic tissue.

Figure 12. Branch from tree receiving plus-potassium from May 1 to July 1, then changed to minus-potassium to date photographed, July 20. This branch is apparently normal as no visible symptoms have appeared.

to be normal in every respect.

Recovery from Potassium Deficiency. As previously outlined, one tree per block, of those which were begun on minus-potassium, was changed to plus-potassium at monthly intervals. Since many of the minus-potassium trees had produced symptoms by June 1, the response in these trees to a change to plus-potassium indicated that they were able to utilize the new potassium supply in producing new, healthy growth. One branch from a tree changed to plus-potassium on June 1 is shown in Figure 13, as it appeared on July 20. Several inches of new, healthy growth were produced after the change, the new growth being subtended by symptomatic leaves resulting from minus-potassium nutrition up to June 1. This same ability of the tree to utilize potassium, even when changed from minus to plus-potassium nutrition on July 1, is demonstrated in Figure 14. The photograph was taken 24 days following the change in nutrition.

Not only did these trees develop new growth, but regardless of the time of change from minus to plus-potassium, whether June 1, July 1, or August 1, the leaves of such trees regained some of the green color which they had lost. This occurred even though holes were present in the leaves from which necrotic tissue had fallen. The extent to which normal green color was approached was dependent on the severity of off-color at the time the change was made to plus-potassium nutrition. The trees undergoing this change to plus-potassium early in the season were not as badly discolored, and also had longer to recover, than did the trees which were changed at a later date.

Growth Response. Tree growth response was determined by measuring new shoot growth, increase in green weight as well as dry weight, and increase in trunk diameter.

Figure 13. Branch from tree receiving no potassium from May 1 to June 1, then changed to plus-potassium nutrition. Photographed on July 20, this branch shows several inches of growth with healthy leaves having grown out beyond the area of symptomatic leaves (bottom center).

Figure 14. Branch from tree receiving no potassium from May 1 to July 1, then changed to plus-potassium nutrition. Photographed on July 24, note new growth having emerged which shows no signs of deficiency, but subtended by leaves showing severe deficiency.

Some trees developed several well-spaced branches with few laterals, whereas others put out only one or two branches which, in turn, produced lateral branches throughout their entire length. For a comparison, it was thought best to use the combined total length of both the primary branches and their laterals. Since existing branches were removed when the trees were set out, all branches were current season's growth. Table 4 shows the total shoot growth which accrued up to September 1 in the various treatments (designated in Table 2) for the five blocks which were carried throughout the summer in the greenhouse. An analysis of variance of the data revealed a significant difference between some of the treatments, but there was no consistent relationship between shoot growth and potassium nutrition.

It was possible to obtain the green weights of four blocks of trees on December 18, when they were removed from the greenhouse to be planted in the field. Since the original green weights of all the trees were recorded (Appendix Table 1), weight increases could be easily determined. These increases are recorded in Table 5. The date of change from plus to minus or minus to plus-potassium nutrition is reflected closely in the increase in green weight of the trees, with highly significant differences among treatments.

The increases in dry weight made by the trees, which were sampled as the season progressed, are presented in Table 6. These increases were calculated from an estimate of their original dry weights, derived by using as a basis the dry matter content of the six extra trees, which were sampled and analysed at the beginning of the experiment. When the increases, which were made up to each sampling date, are expressed as a total, it is seen that the accumulation of dry matter was definitely

Table 4. Total Growth of Shoots Including Lateral Branches Produced up to September 1 by Trees Growing in the Greenhouse.

Treatment	Shoot Growth
	cm.
+ + + +	217.0
+ + + -	148.6
+ + - -	182.4
+ - - -	173.2
- - - -	139.2
- + + +	134.8
- - + +	173.8
- - - +	177.8
Low K	130.4

L. S. D. at 5 per cent level......................49
L. S. D. at 1 per cent level......................66

Source	df	Variance	F
Replicates	4	833	.577
Treatments	8	3970	2.75*
Interaction	32	1443	

*Significant beyond the five per cent level.

Table 5. Increase in Green Weight Produced by One-Year-Old Peach Trees from Planting (April 10) to December 18 in Sand Culture.

Treatment	Green Weight
	gms.
+ + + +	334
+ + + -	304
+ + - -	231
+ - - -	175
- - - -	118
- - - +	197
- - + +	238
- + + +	320

L. S. D. at 5 per cent level............... 72.8
L. S. D. at 1 per cent level............... 99.1

Source of Variance	df	Variance	F	
Replicates	3	3,794	1.55	
Treatments	7	23,133	9.43	**
Interaction	21	2,452		

**Significant beyond the 1 per cent level

Table 6. Increase in Dry Weight Produced by Individual Peach Trees, under Different Potassium Treatments, between April 10 and Each Date Given in Table.

Treatment	June 1	July 1	Aug. 1	Sept. 1	Total
	gms.	gms.	gms.	gms.	gms.
+ + + + ...	14.7	32.7	35.4	63.2	146.0
+ + + −	7.3	26.1	37.7	64.9	136.0
+ + − −	14.8	35.1	25.9	52.0	127.8
+ − − −	16.2	23.9	41.1	36.3	117.5
Low K	10.9	20.9	42.7	23.5	98.0
− − − −	6.0	17.6	21.9	25.8	71.3
− − − + ...	12.1	20.9	16.3	39.7	89.0
− − + + ...	13.5	10.7	33.4	45.4	103.0
− + + + ...	10.2	26.8	35.1	52.9	125.0

increased with the longer periods in which the trees received potassium. Potassium nutrition for a short period at the beginning of the season resulted in greater increases than did potassium nutrition for the same length of time when applied at the latter part of the season.

Thus it is seen that increases in both green and dry weight seem to definitely indicate that potassium had a significant effect on growth, the increases in both cases being in proportion to the length of time the trees received plus potassium nutrition.

The increases in trunk diameter from June 1 to September 1 from all treatments were very small (Table 7). The greatest average increase was 0.064 centimeters, which occurred in both the (+ + + +) and (- + + +) treatments. In the trees started on minus-potassium nutrition and subsequently changed to plus-potassium, diameter increases were made in proportion to the length of time potassium was received. On the contrary, trees started on plus-potassium nutrition and later changed to minus, showed no correlation with the period of time potassium was applied in the nutrient solution. Although significant differences between the extreme treatments were obtained, the results do not follow the treatments nearly as well as did the increases in green and dry weight.

An obvious response to potassium nutrition was noted in the amount of new root growth. Up to July 1, only one of the changes from minus to plus-potassium and vice versa had been made. In the block sampled on this date, the dry weights of roots produced by trees under the different treatments were as follows:

Treatment	Grams
Plus potassium May and June	5.3
Plus potassium May; minus potassium June	3.0
Minus potassium May; plus potassium June	3.8
Low potassium May and June	3.0
Minus potassium May and June	1.3

At the end of the four months of differential potassium treatments, the effect of all nine treatments could then be noted on root growth. Photographs of roots as sampled on September 1 are shown in Figures 15 and 16. Figure 15 shows the contrast in root growth made by the continuous plus (+ + + +) potassium and continuous low-potassium trees. Figure 16 denotes the difference in root growth made by the (+ + + -) and the (- - - +) trees, which shows that the longer the trees received potassium the greater was the root growth. The actual dry weights of the new roots produced by the trees in Figures 15 and 16, as well as for the rest of the trees sampled on September 1, were as follows:

Treatment	Grams
+ + + +	12.7
+ + + -	11.4
+ + - -	11.4
+ - - -	7.0
- - - -	5.5
Low K	3.9
- - - +	6.0
- - + +	7.9
- + + +	9.6

Table 7. Increase in Diameter Produced between June 1 and September 1 by Peach Trees Growing in Sand Culture.

Treatment	Diameter Increase
	cm.
+ + + +	.064
+ + + -	.062
+ + - -	.056
+ - - -	.060
- - - -	.022
Low K	.036
- - - +	.034
- - + +	.052
- + + +	.064

L. S. D. at 5 per cent level................. .021
L. S. D. at 1 per cent level................. .028

Source of Variance	df	Variance	F
Replicates	4	.00135	5.00 **
Treatments	8	.00119	4.41 **
Interaction	32	.00027	

** Significant beyond the 1 per cent level.

Figure 15. Root growth produced by peach trees after four months under differential potassium treatments in sand culture Left, plus-potassium May 1 to September 1. Right, low-potassium May 1 to September 1.

Figure 16. Root growth produced by peach trees after four months under differential potassium treatments in sand culture. Left, plus-potassium May 1 to August 1, changed to minus-potassium to September 1. Right, minus-potassium May 1 to August 1, changed to plus-potassium to September 1.

<u>Potassium Concentration as Affected by Changes in Potassium Nutrition</u>. Since the sampling method employed utilized an entire tree, representative of a given treatment, analyses at different dates are from separate trees rather than from periodic analyses of the same tree. In the following figures, 17 through 24, the continuous minus-potassium (- - - -) treatment is included with the plus to minus-potassium series; also, the continuous plus-potassium (+ + + +) treatment is included with the minus to plus-potassium series.

Nutrient treatments were begun on May 1 and the first block was sampled one month later; thus, the concentrations found on June 1 represent the effect of the treatments during the month prior to this date. The same holds true for the later sampling dates, with the exception of December 18.

The alternation of treatments from plus to minus-potassium nutrition and vice versa was reflected very closely in the uptake of potassium by the leaves. For the most part, potassium levels showed a steady increase as long as potassium was supplied and dropped sharply when potassium was withheld, regardless of the time of change. Figure 17, A, shows that the distal leaves from all trees started on plus-potassium nutrition on May 1 were very similar in potassium concentration when sampled on June 1, all falling between 1.5 and 2.0 per cent, and were much higher in concentration than those started on minus-potassium. The spread in the ranges in potassium concentration on September 1 shows a positive correlation with the time of change from plus to minus-potassium nutrition; the earlier the change the lower was the final concentration.

The effects of changing from minus to plus-potassium nutrition on potassium concentration in the distal leaves are shown in Figure 17,B. The potassium concentration on June 1 for all trees begun on minus-potassium

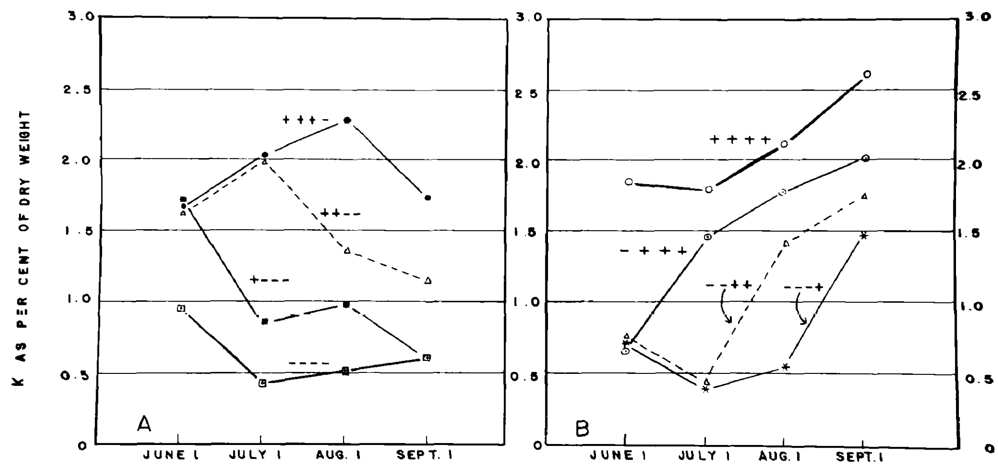


Figure 17. Changes in potassium concentration of peach leaves from distal half of terminals as affected by monthly alternations in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

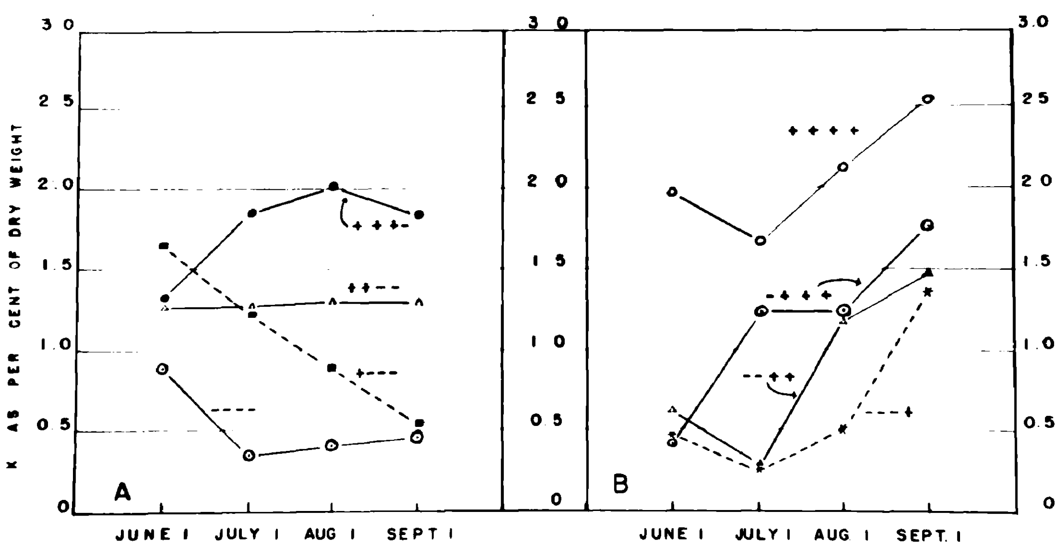


Figure 18. Changes in potassium concentration in peach leaves from basal half of terminals as affected by monthly alternations in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

was about the same, all falling within 0.6 to 1.0 per cent. Trees on minus-potassium nutrition remained at about the same potassium level until changed to plus-potassium, then made consistent and significant increases regardless of the time the change was made. One month after each change, the potassium concentration approximated 1.5 per cent, with later increases taking place as is shown in treatments (- + + +) and (- - + +). This indicates that potassium can be absorbed equally well any time during the season. The spread in the range of potassium concentration on September 1, shows a positive correlation with the time of change from minus to plus-potassium nutrition; the earlier the change the higher was the final concentration. None of the minus to plus treatments resulted in as great a potassium accumulation in the distal leaves by September 1 as was present in the continuous plus-potassium (+ + + +) treatment.

Similar data for basal leaves to that just described in distal leaves are presented in Figure 18. The trends are very much the same as those noted in distal leaves. This is especially true in the spread of the values found on August 1 and September 1 in the series changed from plus to minus-potassium, (Compare Figure 17,A, with 18,A). In both series, the potassium concentration in the basal leaves varied more widely on June 1 than those of the distal leaves on the same date.

The sharp drop in potassium concentration in both basal and distal leaves from the continuous minus (- - - -) series, between June 1 and July 1 may be due to a rapid increase in growth during this period. During the same period, the potassium concentration in the distal leaves tended to increase in trees receiving potassium, whereas, in the basal leaves receiving potassium, there was no such tendency.

As has been stated, one block was sampled on December 18, after leaf fall had occurred. The changes in potassium nutrition had ended on

September 1, but for those blocks still remaining after this date, treatments were continued for another month (September) just as they had been applied during August. The potassium levels found on December 18 are thus presented along with other data in Figures 19 through 24 to show the potassium concentrations present after leaf fall.

Data on potassium concentration in the branches, or limbs, in the series started on minus potassium nutrition, are shown in Figure 19,A. The concentration of potassium on June 1 was very similar from all trees. Limbs from those trees receiving potassium after June 1 did not increase in potassium concentration, but decreased each month, just as did those changed to minus-potassium nutrition. The levels present on September 1, however, revealed a positive correlation with the time of change from plus to minus-potassium; the earlier the change the lower was the final concentration. Levels present on December 18, after leaf fall, further showed a seasonal trend downward. This seasonal downward trend indicates that the limbs acted more as a medium for transporting potassium to the leaves rather than as a storage area. In the series changed from minus to plus-potassium, (Figure 19,B) the changes in nutrition were not noticeably reflected in the potassium concentrations present. The addition of potassium did prevent the potassium concentration from decreasing as the season progressed, the levels present on September 1 being rather close to those present on June 1. The potassium concentration present on December 18 gives little indication that the leaves transported any of their potassium into the limbs prior to leaf fall.

Potassium levels in the new roots are given in Figure 20. On June 1, the concentration from those trees receiving potassium was 2.5 per cent or more, but by July 1 all had dropped to approximately 0.5 per cent,

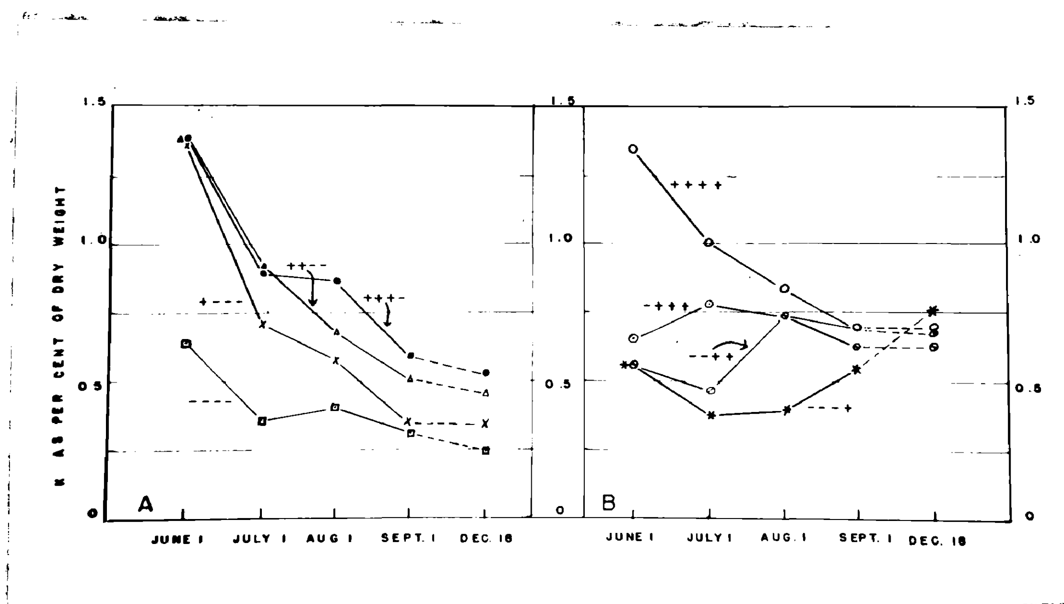


Figure 19. Changes in potassium concentration in limbs from one-year-old peach trees grown in sand culture as affected by changes in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

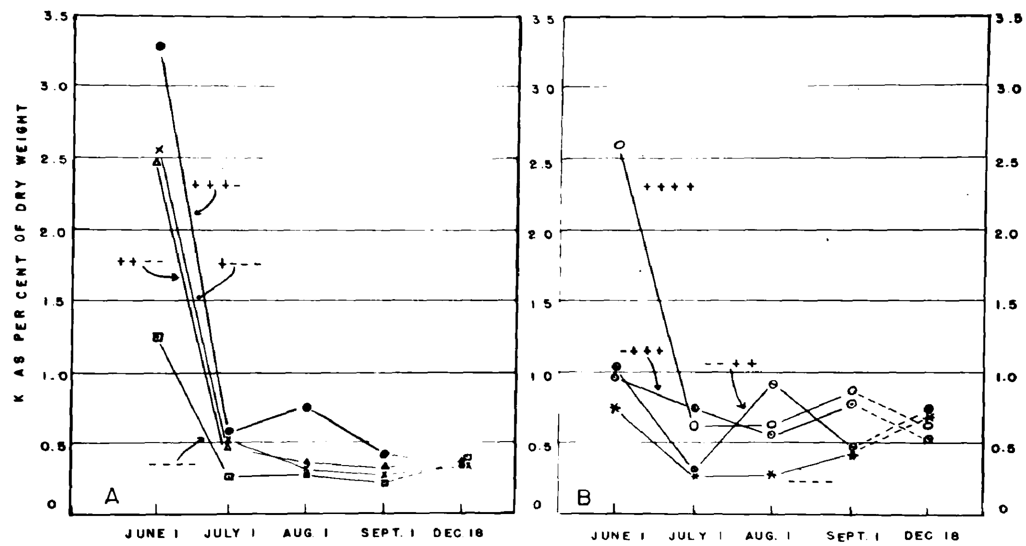


Figure 20. Changes in potassium concentration in new roots from one-year-old peach trees grown in sand culture as affected by changes in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

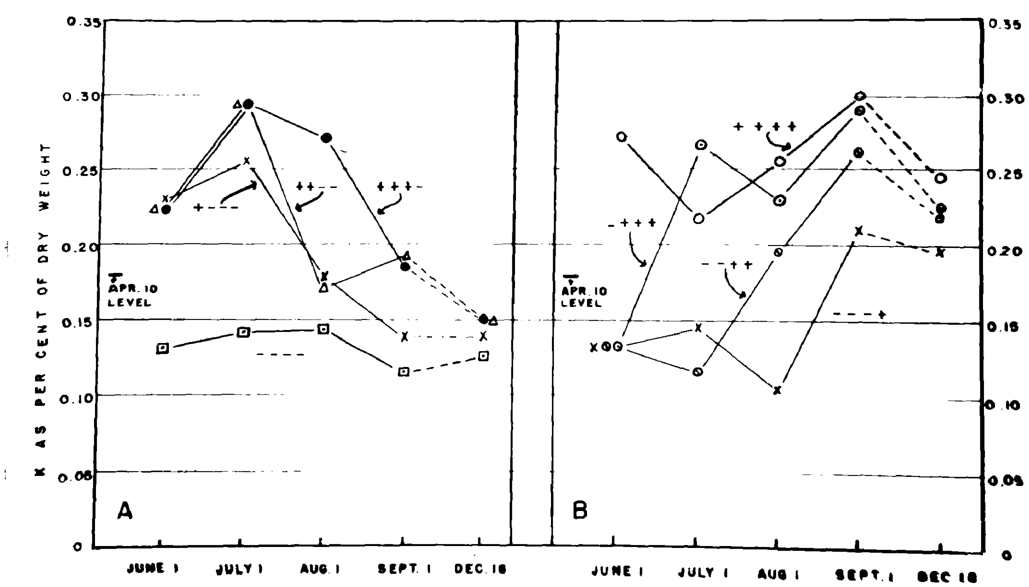


Figure 21, Changes in potassium concentration in old roots from one-year-old peach trees grown in sand culture as affected by changes in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

regardless of whether or not they received potassium during the interim. This sharp drop in potassium level during this period indicates that potassium was absorbed by new roots in large amounts early in the season, but was later translocated to the upper portions of the tree. After July 1, there was still a slight trend toward lower potassium concentrations except in the continuous plus-potassium (+ + + +) treatment, the potassium level for this treatment on September 1, being over 100 per cent greater than in any other treatment in the plus to minus series.

A seasonal decrease was also exhibited by new roots in the series changed from minus to plus-potassium (Figure 20,B), the concentrations of potassium on September 1, as well as on December 18, being lower than those present on June 1, despite changes to plus-potassium in the intervening period. Those roots grown without potassium at the first of the season and subsequently changed to plus-potassium, should have shown an increase in concentration by December 18 if storage of potassium in root tissue were to occur. Thus the results indicate that the new roots were mainly functioning in absorption and transport.

As outlined in "materials and methods", six extra trees were selected on April 10 to serve as checks. These were cut back in similar fashion to those trees used in the experiment. Analyses were then made of scion trunk, stock trunk, and old roots to determine the average potassium concentration in the various parts at the beginning of the experiment. Potassium concentration from those sections are indicated in Figures 21, 22, and 23 in comparison with levels of potassium present in similar parts following the various treatments. Thus the potassium concentration in old roots (Figure 21,A) was higher on June 1, than the average for the same tree part on April 10. Potassium levels on December 18 were lower for all plus to minus treatments than on April 10 before growth began. In

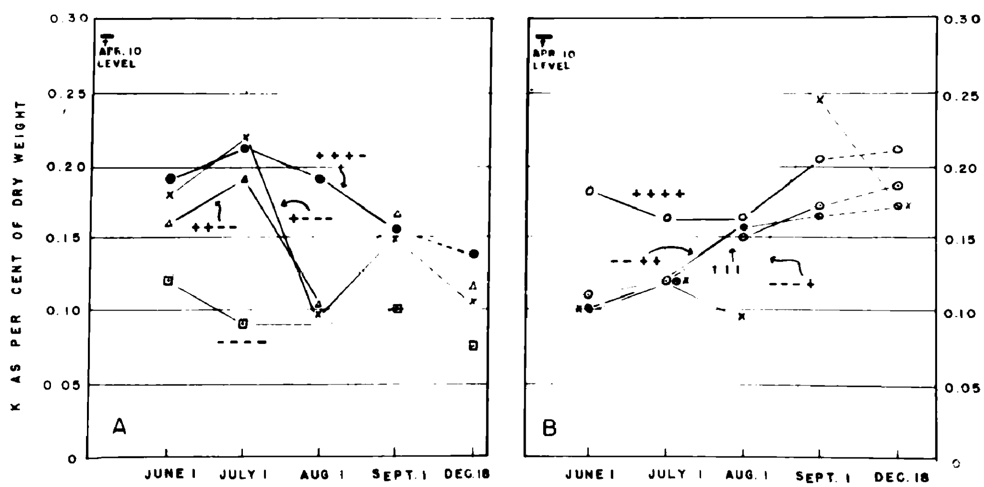


Figure 22. Changes in potassium concentration in scion trunks from one-year-old peach trees grown in sand culture as affected by changes in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

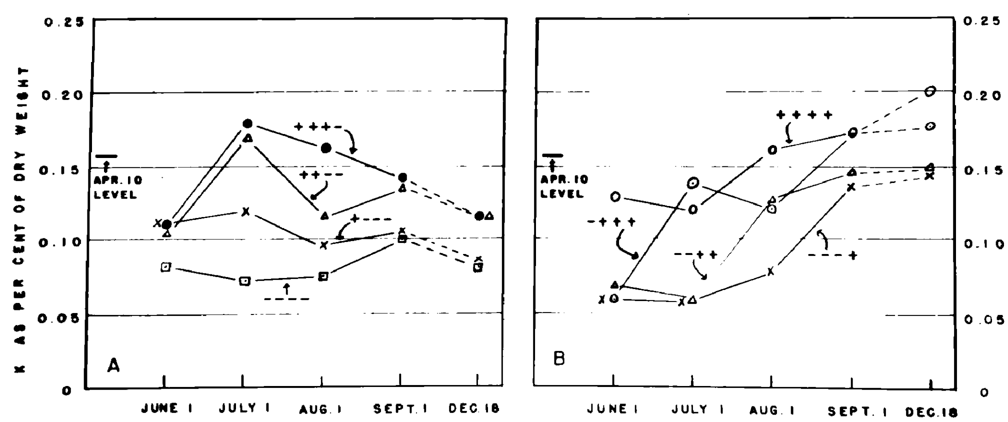


Figure 23. Changes in potassium concentration in stock trunks from one-year-old peach trees grown in sand culture as affected by changes in potassium nutrition. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

contrast, all treatments changed from minus to plus-potassium nutrition (Figure 21,B) showed a marked response from each monthly change and had a higher potassium concentration on December 18 than on April 10. In treatments receiving potassium during the latter part of the season, the levels found on December 18 were lower than on September 1, indicating that some of the potassium in the old roots was translocated to some other part of the tree during this period.

In contrast to the condition found in the old roots, the potassium concentration of the scion trunk on April 10 (Figure 22) was much higher than that present in any of the treatments on June 1, which indicated that the young trees as they were received from the nursery had a reserve of potassium which was used rapidly in the new growth. The potassium concentrations did not in all cases show a decrease in concentration just after the change was made to minus-potassium (Figure 22,A), but the seasonal trend was downward as a result of such changes. The potassium level found in the scion trunk in the continuous minus (- - - -) treatment on August 1, was found to be 0.17 per cent, but this was not considered valid as the new growth had come out near the base; the portion above died and apparently translocated little or no potassium to new growth. Though showing a seasonal trend upward, neither the trees changed to plus-potassium nor the continuous plus-potassium trees, attained as high a potassium concentration by December 18 as was present on April 10 (Figure 22,B). Thus, under the conditions of the experiment, the scion trunk did not attain as high a percentage of potassium by the end of the season as was present at the start, even though potassium was supplied continually.

The stock trunks (Figure 23) contained only about one-half the potassium concentration of the scion trunks on April 10. In the plus to minus series (Figure 23,A) the trends in potassium concentration were rather similar to that occurring in the scion trunk, except that on December 18, the levels were closer to the concentration on April 10 than was true for the scion trunk.

In the minus to plus series, (Figure 23,B) the potassium concentration in the stock trunk was higher on September 1 as well as December 18, in the trees receiving potassium for the longer periods of time, but this was not true in the scion trunks. Although the trends were upward in both scion and stock trunks, the effects of the changes from minus to plus-potassium nutrition were reflected much better in the stock trunks.

Since the potassium concentration and actual weight of the several component parts of the trees were known, the per cent of potassium in the tree as a whole could be determined. These data are shown in Figure 24. The actual potassium concentration in the individual tree during the growing season was much lower than in the leaves, but higher than some other portions, i.e., old roots, stock trunk, and sciòn trunk. Figure 24,A, shows that the trees started on plus-potassium nutrition were very similar in potassium levels on June 1. This was also true for those trees started on minus-potassium, when sampled June 1 (Figure 24,B). The changes made in potassium nutrition, whether from plus to minus or minus to plus, were closely reflected in the potassium levels found after the changes were made. When changed from plus to minus, the potassium concentration decreased thereafter as the season progressed. When started on minus-potassium (Figure 24,B), the levels in all trees were very similar until changed to plus-potassium, then increased thereafter until September 1. In all treatments receiving late season potassium nutrition the potassium percentage in the trees decreased sharply between September 1

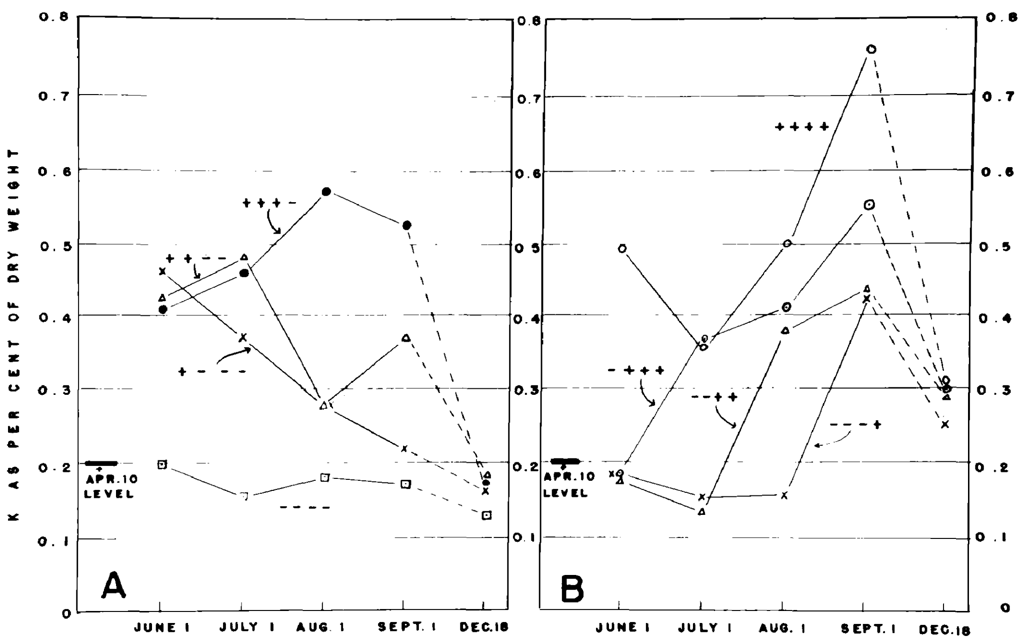


Figure 24. Changes in potassium concentration in whole one-year-old peach trees as affected by monthly alternations of potassium nutrition in sand culture. A, changes from plus-potassium to minus-potassium. B, changes from minus-potassium to plus-potassium.

and December 18. Treatment differences in potassium content were largely determined by leaf content, since the potassium concentrations on December 18, in each of the two series, were remarkably similar, despite the fact that the concentrations present in trees from the same treatments were remarkably dissimilar on September 1. In the continuous minus as well as the plus to minus treatments, the potassium concentrations on December 18 were slightly lower than the estimated value on April 10. This was not true in the continuous plus and minus to plus treatments, all these being higher than the April 10 level. The continuous plus treatment resulted in the highest potassium concentration on December 18. Considering this particular tree as having received normal nutrition, and since the potassium concentration after leaf-fall was much lower than before, we may assume that most of the increased potassium concentration present during the growing season is accounted for by that present in the leaves and that it is lost from the tree when the leaves fall.

The concentrations for the low-potassium treatment have not been included in the foregoing figures, since no alternations were made in this treatment, and the levels were rather similar to those in the continuous minus-potassium treatment. They are, however, included in the appendix tables along with the other potassium percentages.

Concentration of Mineral Elements in the Trees Resulting from Differential Potassium Nutrition. In order to ascertain the effect of potassium nutrition on the mineral concentration of peach leaves early in the season, two leaves per tree were taken from the middle portion of limbs from all trees receiving plus-potassium and from all trees receiving minus-potassium nutrition. Each group was composited into a separate sample. These samples were taken at approximately two-week intervals beginning May 17, the last being taken on July 1, but no leaves were taken from trees which had undergone a change in treatment on June 1. Thus the data presented in Table 8, represent the effect of a two-month period without a change in nutrition.

The potassium concentration in the leaves from plus-potassium trees remained about the same during this period, but in minus-potassium trees it decreased rapidly, the per cent on June 1 being about one-half, and on July 1, about one-fourth that present on May 17. Calcium concentration increased rapidly, whereas magnesium and nitrogen concentrations decreased and phosphorus concentration remained about the same in the leaves during this period (Table 8). These changes apparently were quite independent of potassium concentration, since about the same change took place in both plus and minus-potassium treatments. The actual percentages present on each sampling date, indicated that minus-potassium nutrition caused a slightly greater per cent of magnesium, phosphorus, and nitrogen in the leaves.

Table 9 shows leaf analysis data from trees receiving continuous plus-potassium and continuous minus-potassium nutrition, as they were sampled throughout the summer. In comparing the actual percentages present in both treatments on each sampling date, it appears that a lack of potassium in the nutrient solution resulted in a smaller per cent of calcium and a greater per cent of phosphorus and nitrogen than occurred in the leaves from the plus-potassium treatment.

The periodic changes in concentration of the different elements resulting from plus and minus-potassium nutrition can also be seen in Table 9. Calcium increased during the season in both plus and minus-

[redacted]

Table 8. Concentration of Different Elements in Peach Leaves* as Affected by Plus and Minus-Potassium Nutrition.

Date	Calcium		Magnesium		Potassium		Phosphorus		Nitrogen	
	Elements as Per Cent of Dry Weight									
	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K
	%	%	%	%	%	%	%	%	%	%
May 17	0.22	0.18	0.52	0.50	1.73	1.42	0.49	0.49	4.63	4.78
June 1	0.40	0.33	0.43	0.46	1.52	0.80	0.40	0.46	4.44	4.41
June 19	0.54	0.55	0.29	0.39	1.77	0.44	0.41	0.48	3.44	3.73
July 1	0.56	0.53	0.31	0.39	1.68	0.36	0.48	0.55	3.32	3.82
Average	0.43	0.40	0.39	0.43	1.67	0.75	0.44	0.49	3.96	4.18

*Samples consisted of two leaves each from all trees receiving, to date sampled, either continuous plus or continuous minus-potassium nutrition.

[redacted]

Table 9. Concentration of Different Elements in Peach Leaves as Affected by Plus and Minus-Potassium Nutrition.*

	Elements as Per Cent of Dry Weight									
	Calcium		Magnesium		Potassium		Phosphorus		Nitrogen	
Date	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K
	%	%	%	%	%	%	%	%	%	%
June 1	0.37	0.32	0.29	0.39	1.65	0.68	0.39	0.45	3.90	4.15
July 1	0.68	0.46	0.38	0.37	1.83	0.37	0.50	0.47	3.32	4.00
Aug. 1	0.75	0.58	0.34	0.32	2.16	0.50	0.53	0.67	3.25	3.97
Sept. 1	0.82	0.49	0.30	0.31	2.57	0.50	0.54	0.73	3.29	3.72
Average	0.65	0.46	0.33	0.35	2.05	0.51	0.49	0.58	3.44	3.96

* Percentages on June 1 are averages for four trees, on July 1 for three trees, on August 1 for two trees, and the September 1 percentages from one tree.

potassium leaves, but increased to a higher concentration in the plus-potassium leaves. The concentration of phosphorus increased consistently on each sampling date under both plus and minus-potassium nutrition, but the increase was greater in the latter. Magnesium concentration decreased slightly in minus-potassium leaves, but showed no definite trend in plus-potassium leaves. Nitrogen concentration also decreased on each sampling date, with potassium nutrition apparently having little or no effect.

Data similar to that presented in Table 9 are shown in Table 10, except that the levels of the various elements are those found in whole trees instead of in the leaves only. In comparing the concentration of the elements present in whole trees under both treatments on the individual sampling dates, it is apparent that a lack of potassium in the nutrient solution resulted in a smaller percentage of calcium, magnesium, phosphorus, and nitrogen. The smaller percentage of calcium under minus-potassium nutrition parallels the results obtained in the leaves; however, the smaller percentage of phosphorus and nitrogen is contrary to results found in the leaves.

The changes occurring in the concentration of the various elements as a result of plus and minus-potassium nutrition can also be seen in Table 10. Calcium decreased with time in the minus-potassium trees, but in the plus-potassium trees the calcium level on September 1 was higher than on previous dates, even though no seasonal trends were noted. This decrease in the minus-potassium trees is, as a whole, the reverse of that found in the leaves only from the same trees, which indicates that calcium moved from the woody tree parts into the leaves. Magnesium concentration was higher on September 1 in the plus-potassium trees, but it is difficult

Table 10. Concentration of Different Elements in Whole Peach Trees as Affected by Plus and Minus-Potassium Nutrition.

Date	Elements as Per Cent of Dry Weight									
	Calcium		Magnesium		Potassium		Phosphorus		Nitrogen	
	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K
	%	%	%	%	%	%	%	%	%	%
June 1	.233	.246	.080	.084	.448	.187	.146	.135	.944	.951
July 1	.225	.201	.071	.065	.433	.141	.175	.153	.918	.887
Aug. 1	.231	.192	.071	.062	.537	.166	.238	.202	1.075	.961
Sept. 1	.270	.186	0.101	.070	.764	.169	.285	.220	1.457	1.151
Average	.240	.206	0.081	.070	.545	.166	.211	.177	1.098	0.987

*Percentages on June 1 are averages of four trees, on July 1 for three trees, on August 1 for two trees, and the September 1 percentages from one tree.

to note any seasonal trends. Phosphorus concentration increased progressively in both the plus and minus-potassium trees, which corresponds to the results obtained in the leaves. Nitrogen concentration increased seasonally in trees receiving both plus and minus-potassium nutrition with the exception of the first month, June 1 to July 1. This increase in nitrogen is contrary to results obtained in the leaves of the same trees, where nitrogen decreased on each sampling date. The fact that the percentage of nitrogen in the trees decreased between June 1 and July 1 in both treatments may be due to a more rapid increase in dry matter during this period of active growth. The greater increase in nitrogen percentage in the trees between August 1 and September 1 may be due to slower growth with continued absorption of nitrogen during this period. The decrease in potassium percentage in this period between June 1 and July 1 suggests that dry matter content increased more rapidly than potassium uptake.

The concentrations of potassium in different tree fractions from both plus and minus-potassium treatments are shown in Figure 25, Upper, and are expressed as an average of four monthly samples, June 1 to September 1, inclusive. The greatest differences between treatments in potassium concentration were in the leaves, followed by the new roots and limbs. The smallest difference between treatments was in the old, woody portions. It is interesting to note that the same order obtained in the fractions from the minus-potassium trees.

The actual amount of potassium in the same trees is shown in Figure 25, Lower. Greater uptake of potassium in plus-potassium trees was accounted for largely by increased potassium content of leaves, with comparatively small amounts being accounted for in other tree fractions.

The per cent of calcium in various tree fractions from both plus-potassium and minus-potassium trees are shown in Figure 26. Calcium

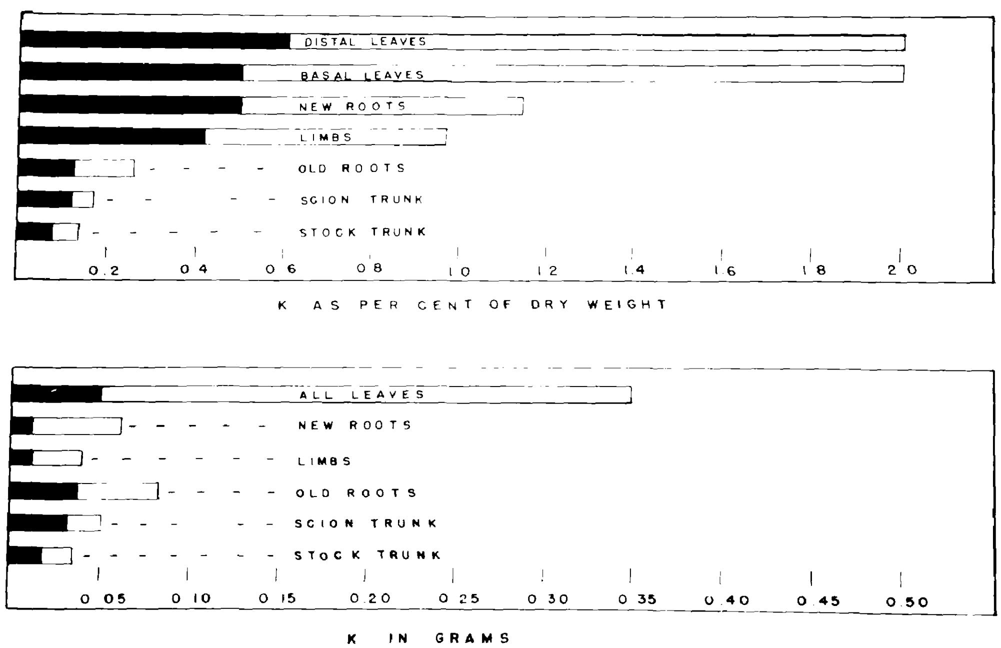


Figure 25. Potassium content of various parts of trees showing increases resulting from plus-potassium over continuous minus-potassium. Upper, per cent of dry weight. Lower, amount in grams. Both are averages of four samples at monthly intervals, June 1 to September 1, inclusive. Black bars denote minus-potassium trees; white bars show accumulation due to plus-potassium nutrition.

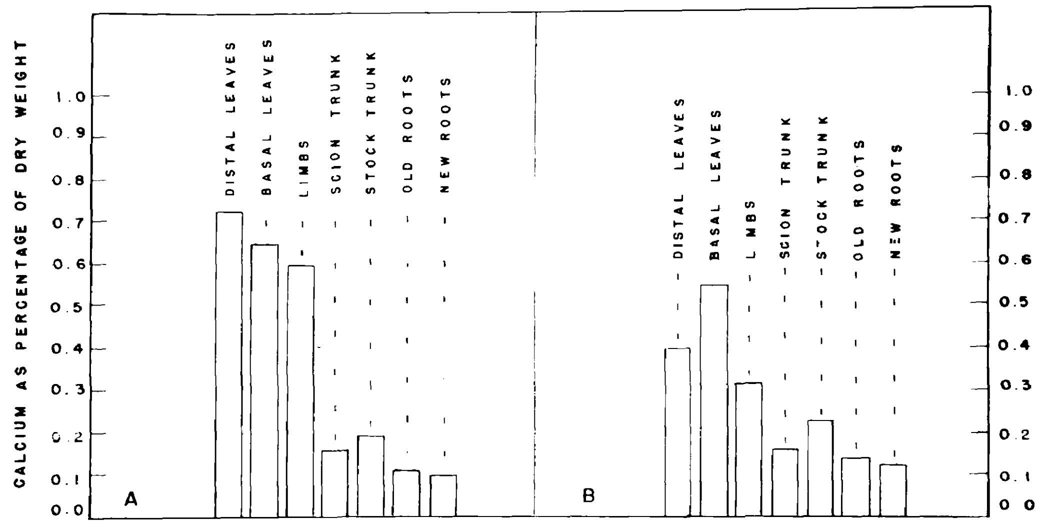


Figure 26. Calcium percentages in various parts of peach trees grown in sand culture. A, continuous plus-potassium. B, continuous minus-potassium. Average of four monthly sampling dates, June 1 to September 1, inclusive.

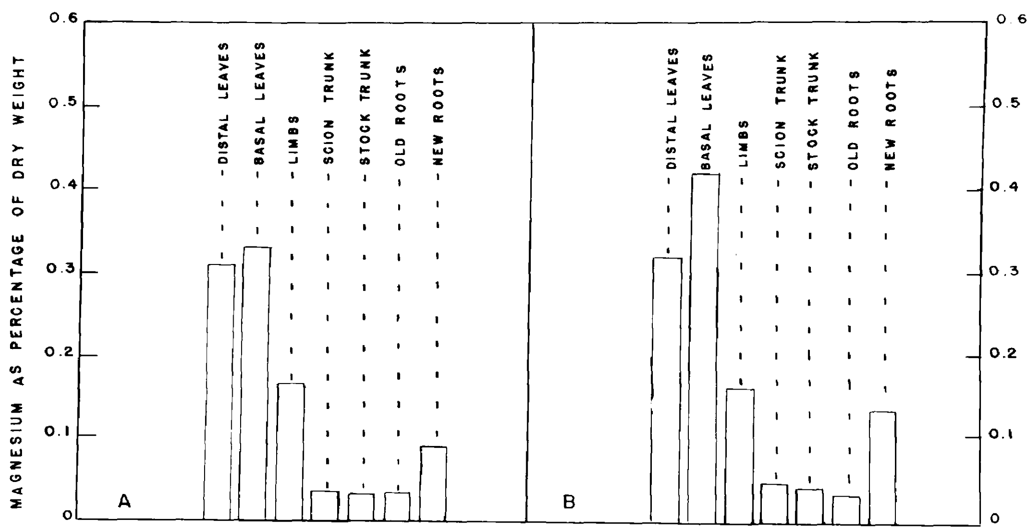


Figure 27. Magnesium percentages in various parts of peach trees grown in sand culture. A, continuous plus-potassium. B, continuous minus-potassium. Average of four monthly sampling dates, June 1 to September 1, inclusive.

concentration in the distal leaves from the plus-potassium trees was almost two times as high as in the minus-potassium trees. The same was true in the limbs. The calcium concentration in the new roots, as well as in the older woody portions, was very close to the same under both treatments.

Basal leaves from plus-potassium and minus-potassium trees were higher in magnesium concentration than distal leaves from both treatments, this being much more evident in the minus-potassium treatment (Figure 27). Limbs from both treatments contained almost the same concentration, whereas the new roots were higher in magnesium concentration from minus-potassium trees.

The greatest difference in phosphorus concentration among the tree parts was in the two leaf fractions, the highest level being in those from the minus-potassium nutrition trees (Figure 28). Limbs from the minus-potassium trees were slightly higher in phosphorus than those from the plus-potassium trees. On the contrary, the new roots from the plus-potassium trees contained a higher per cent of phosphorus than minus-potassium trees. Differences were very small in the woody tree fractions from the two treatments.

Figure 29 shows the nitrogen percentage in the various tree fractions. Both basal and distal leaves from minus-potassium trees contained a higher concentration of nitrogen than did the same fractions from plus-potassium trees. The nitrogen level in the other tree parts was very close to the same from both plus and minus-potassium trees.

<u>Relative Concentration of Mineral Elements in Leaves and Whole Trees.</u> Of the elements for which the leaves were analysed, the relative concentrations under plus-potassium nutrition in ascending order were: magnesium,

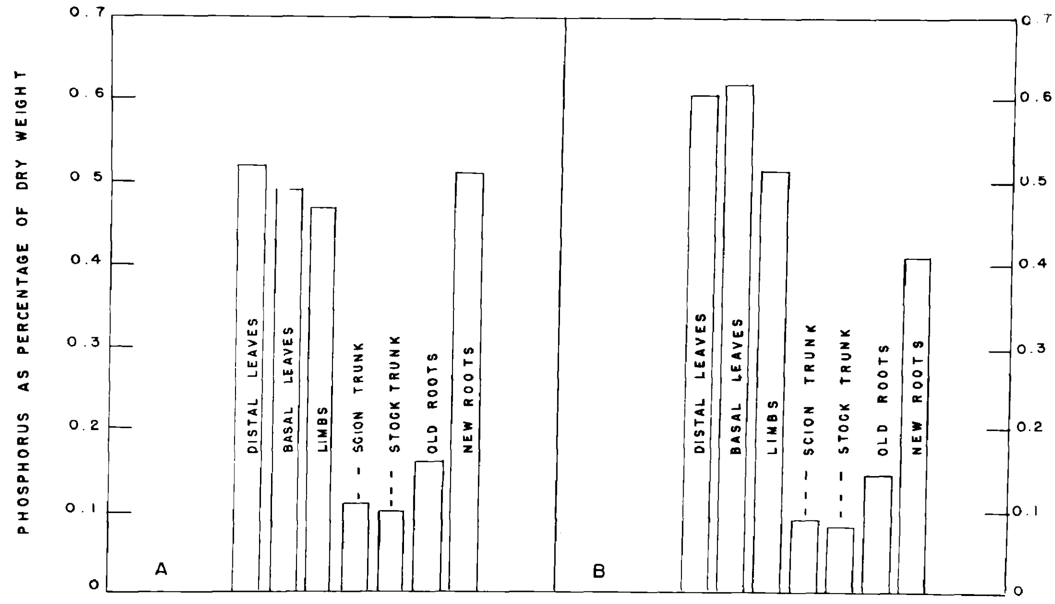


Figure 28. Phosphorus percentages in various parts of peach trees grown in sand culture. A, continuous plus-potassium. B, continuous minus-potassium. Average of four monthly sampling dates, June 1 to September 1, inclusive.

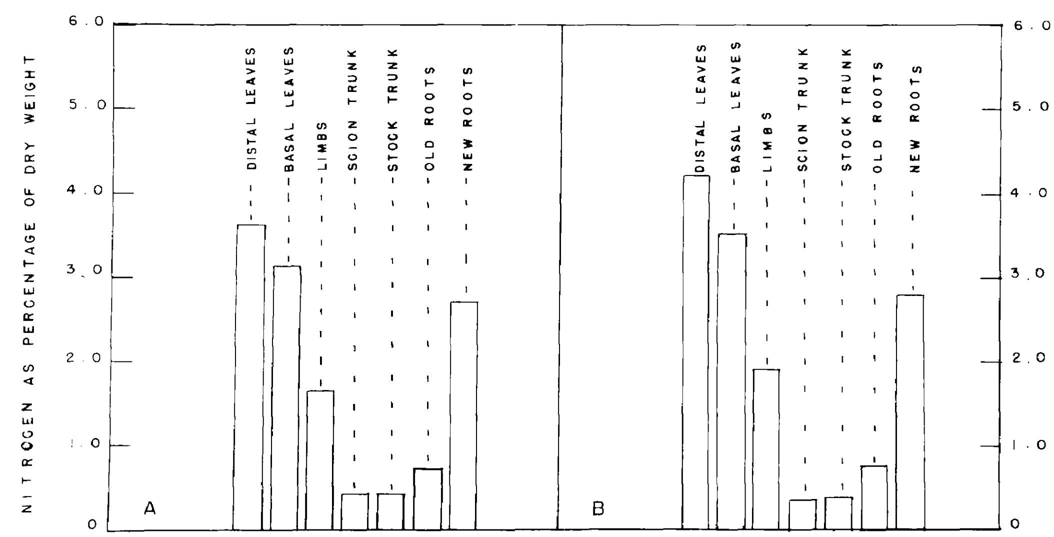


Figure 29. Nitrogen percentages in various parts of peach trees grown in sand culture. A, continuous plus-potassium. B, continuous minus-potassium. Average of four monthly sampling dates, June 1 to September 1, inclusive.

phosphorus, calcium, potassium, and nitrogen, shown in Figure 30,A. Nitrogen and potassium were present in higher concentrations than calcium, phosphorus, and magnesium, the three latter being less than 1 per cent of the dry weight throughout the sampling period. Magnesium increased slightly in the leaves between June 1 and July 1, but no increase occurred considering the season as a whole. The concentration of phosphorus increased slightly between June 1 and September 1, but most of the increase occurred between June 1 and July 1. Nitrogen decreased from 3.9 to 3.3 per cent from June 1 to July 1 and then remained approximately the same. Potassium concentration increased rather uniformly throughout the sampling period from 1.6 per cent on June 1 to 2.6 per cent on September 1. Calcium concentration was very low throughout the sampling period, but more than doubled in concentration from June 1 to September 1, the greatest increase occurring during June. The concentrations of these elements in the leaves from minus-potassium nutrition trees are shown in Figure 30,B, for comparison. The data shown in Figure 30,A, and B, are the same as those presented in tabular form in Table 9.

The relative concentration of different elements in the trees as a whole, which received plus-potassium nutrition, are presented in Figure 31. The magnitude of the different concentrations from June 1 to September 1, inclusive, was calculated from the same trees from which the leaves were taken, as was presented in Figure 30,A. The percentage levels at the beginning of the season, when the trees were planted, were in the following ascending order; magnesium, phosphorus, calcium, potassium, and nitrogen. Of the several dates on which samples were taken, each element was present in its highest concentration on September 1. Both nitrogen and potassium increased in concentration rather rapidly from April 10 to

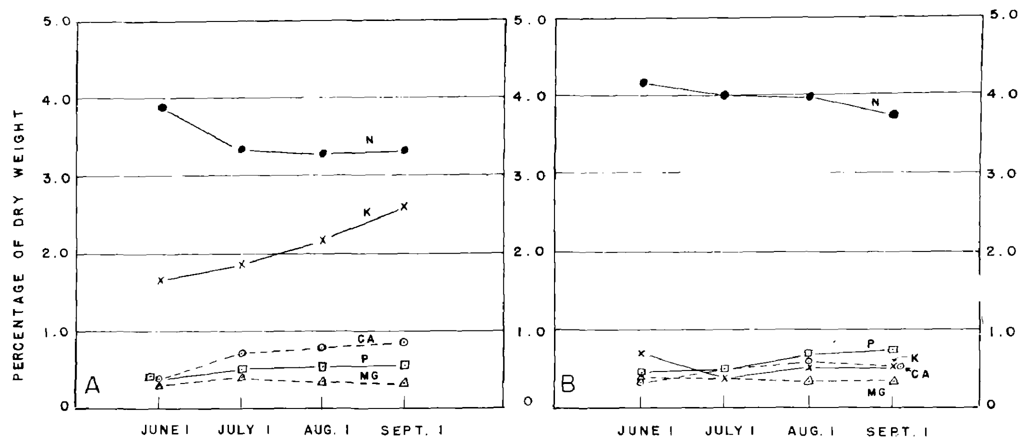


Figure 30. Concentration of different elements on different dates in leaves from peach trees grown in sand culture. A, continuous plus-potassium; B, continuous minus-potassium.

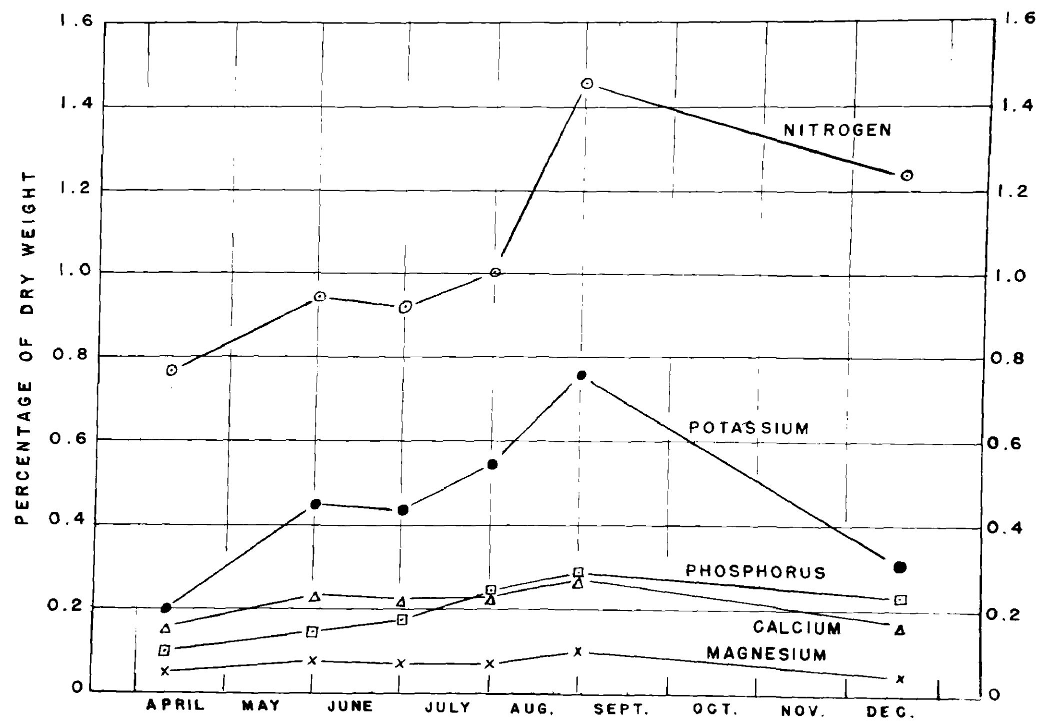


Figure 31. Concentration of different elements throughout the season in whole peach trees grown under continuous plus-potassium nutrition.

June 1, then increased slowly during June and July. During August a rapid increase in concentration of these two elements again occurred; nitrogen concentration increased about 0.4 and potassium about 0.25 per cent during this month. The period of slow increase from June 1 to August 1 indicates that the proportion of dry matter increase to nitrogen and potassium increase was greater during this time than the preceding or succeeding period. The curves for calcium and magnesium showed a much smaller seasonal change on a percentage basis. Phosphorus, though present in considerably lower concentration than nitrogen or potassium, increased steadily between June 1 and September 1, practically doubling in concentration during this time. In the trees considered as a whole, the concentrations of all elements were lower on December 18, which was after leaf fall, than on September 1. The greatest decreases during this period were in potassium and nitrogen.

A comparison of seasonal trends in the leaves and whole trees receiving plus-potassium nutrition can be seen in Figures 30,A, and 31. The outstanding contrast was in the nitrogen concentration, which increased considerably in the whole trees from June 1 to September 1, whereas, a decrease occurred in the leaves during this time. In both leaves and whole trees, magnesium showed practically no increase, whereas potassium increased considerably. Phosphorus concentration increased seasonally in whole trees more than in the leaves only, but calcium increased more in the leaves than in whole trees.

<u>Amount of Mineral Elements in Entire Trees and in Trees Excluding the Leaves</u>. Table 11 shows the total amount of potassium, calcium, magnesium, phosphorus, and nitrogen, both including and excluding leaves, from trees which received continuous plus and continuous minus-potassium

Table 11. Mineral Content of Trees, Including and Excluding Leaves, from Continuous Plus and Continuous Minus-Potassium Trees Grown in Sand Culture

Date Sampled	Calcium: Plus-Potassium Treatment: Including Leaves	Calcium: Plus-Potassium Treatment: Excluding Leaves	Calcium: Minus-Potassium Treatment: Including Leaves	Calcium: Minus-Potassium Treatment: Excluding Leaves	Magnesium: Plus-Potassium Treatment: Including Leaves	Magnesium: Plus-Potassium Treatment: Excluding Leaves	Magnesium: Minus-Potassium Treatment: Including Leaves	Magnesium: Minus-Potassium Treatment: Excluding Leaves	Potassium: Plus-Potassium Treatment: Including Leaves	Potassium: Plus-Potassium Treatment: Excluding Leaves	Potassium: Minus-Potassium Treatment: Including Leaves	Potassium: Minus-Potassium Treatment: Excluding Leaves
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
April 10	.122	.122	.122	.122	.038	.038	.038	.038	.151	.151	.151	.151
June 1	.202	.156	.164	.148	.066	.034	.050	.030	.409	.216	.129	.084
July 1	.279	.185	.167	.123	.080	.035	.071	.032	.442	.245	.137	.100
Aug. 1	.267	.155	.232	.167	.078	.035	.079	.043	.598	.262	.208	.155
Sept. 1	.366	.155	.182	.126	.137	.061	.068	.033	1.035	.373	.165	.105
Dec. 18	.202	.202	.124	.124	.058	.058	.034	.034	.373	.373	.106	.106

Date Sampled	Phosphorus: Plus-Potassium Treatment: Including Leaves	Phosphorus: Plus-Potassium Treatment: Excluding Leaves	Phosphorus: Minus-Potassium Treatment: Including Leaves	Phosphorus: Minus-Potassium Treatment: Excluding Leaves	Nitrogen: Plus-Potassium Treatment: Including Leaves	Nitrogen: Plus-Potassium Treatment: Excluding Leaves	Nitrogen: Minus-Potassium Treatment: Including Leaves	Nitrogen: Minus-Potassium Treatment: Excluding Leaves
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
April 10	.069	.069	.069	.069	.553	.553	.552	.553
June 1	.135	.091	.081	.059	.791	.420	.524	.325
July 1	.206	.147	.163	.111	1.081	.698	.884	.483
Aug. 1	.275	.191	.239	.156	1.273	.775	1.128	.689
Sept. 1	.386	.247	.215	.132	1.972	1.126	1.122	.702
Dec. 18	.277	.277	.140	.140	1.488	1.488	.811	.811

nutrition. These data show that the plus-potassium nutrition resulted in a greater quantity of these elements being present, on practically all sampling dates, in the plus-potassium trees as compared to the minus-potassium trees. This was true whether or not the leaves are included.

The same data for potassium are presented graphically in Figure 32. The amounts present on different dates throughout the season in the minus-potassium series, indicate that no increase in total potassium occurred, since the curve representing the entire tree as well as that for trees excluding the leaves, are approximately parallel. Had the minus-potassium trees all been exactly the same in potassium content at the beginning, the curve for the entire tree would conceivably have been entirely straight, since they received no additional potassium.

The curves for the plus-potassium trees show that the greater amount of the potassium absorbed by the trees moved into the leaves. The most rapid increase in potassium content occurred in the month of August. If additional samples had been taken between September 1 and December 18, the straight curve for the whole tree during this period may not have obtained, but the fact that no increase took place after September 1 in the portion excluding the leaves, indicates that little or no potassium was translocated from the leaves to the woody portions prior to leaf fall.

Mineral Uptake by Trees Expressed in Absolute Amounts. Data in Table 12 show the percentage of the various elements and the per cent dry weight of the six extra trees, which were sampled and analyzed at the beginning of the experiment. The mean values for these trees were used in estimating the per cent dry weight and the amounts of each element present in experimental trees at the time they were planted. Although it is recognized that this would not give absolutely correct values, it should

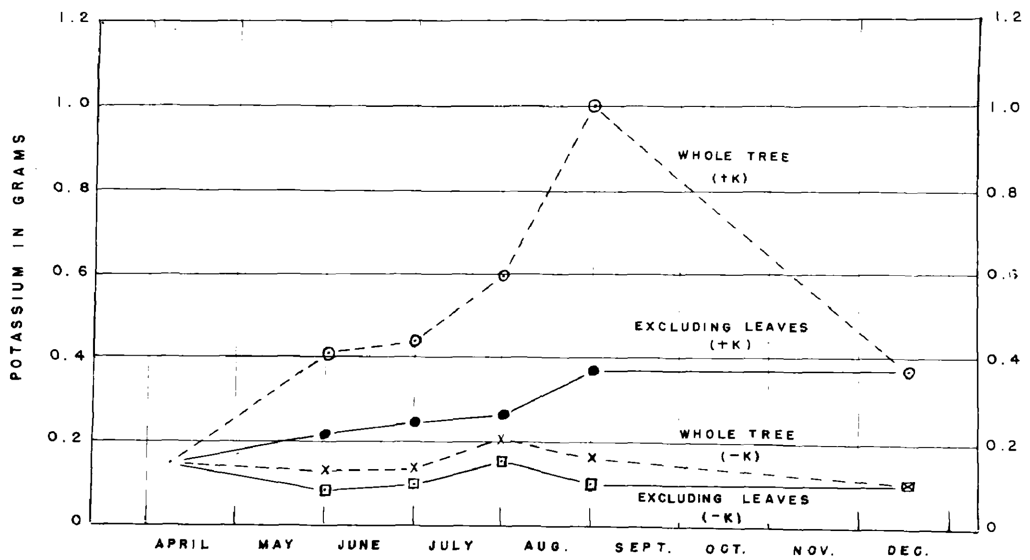


Figure 32. Potassium content of peach trees, including and excluding leaves, receiving continuous plus-potassium and continuous minus-potassium nutrition.

Table 12. Mineral Content and Dry Weight of Six Individual Trees at Beginning of Experiment. (Based on Trees as They Were Planted).

Tree	Calcium	Magnesium	Potassium	Phosphorus	Nitrogen	Dry Weight
	%	%	%	%	%	%
1	.130	.052	.202	.120	.758	48.4
2	.167	.053	.162	.105	.826	50.1
3	.162	.068	.211	.111	.776	48.3
4	.214	.059	.248	.096	.817	49.3
5	.194	.051	.206	.091	.718	48.8
6	.130	.041	.221	.064	.711	50.2
Average	.166	.054	.208	.097	.767	49.2

furnish a fairly accurate method of determining increases in mineral content and dry weight of the individual trees as they were periodically sampled through the season. By such calculations, the estimated dry weight and mineral content in the trees at the beginning of the test were derived and are recorded in Appendix Tables 2 and 4, respectively. In these tables, such values are given only for trees which were subsequently sampled.

The amounts of the various elements contained by the trees on all sampling dates are recorded in Appendix Table 5. Increases in potassium, over the estimated original amount, throughout the season in the various treatments were in accord with the changes made in potassium nutrition. These increases are recorded, as well as the increases of the other elements in the same trees, in Appendix Table 6. Increases in potassium occurring in trees from five of the nine treatments are shown in Figure 33. The fact that the trees represented in this figure showed a loss of potassium on July 1 and August 1, may be accounted for by the fact, as has already been stated, that the original estimates of amounts of elements present at the start are likely to be slightly inaccurate for any individual tree. When potassium was supplied to or withheld from a tree, the amount of potassium increased or decreased accordingly. In the (- - + +) and (- - - +) treatments, the potassium increased to about the same extent one month following each change to plus-potassium nutrition.

The actual increases in calcium, magnesium, phosphorus, and nitrogen that had accumulated by September 1 in all treatments are presented in Figures 34 and 35. Potassium is plotted in both for comparative purposes. On September 1, after all treatment alternations had been made, the amount

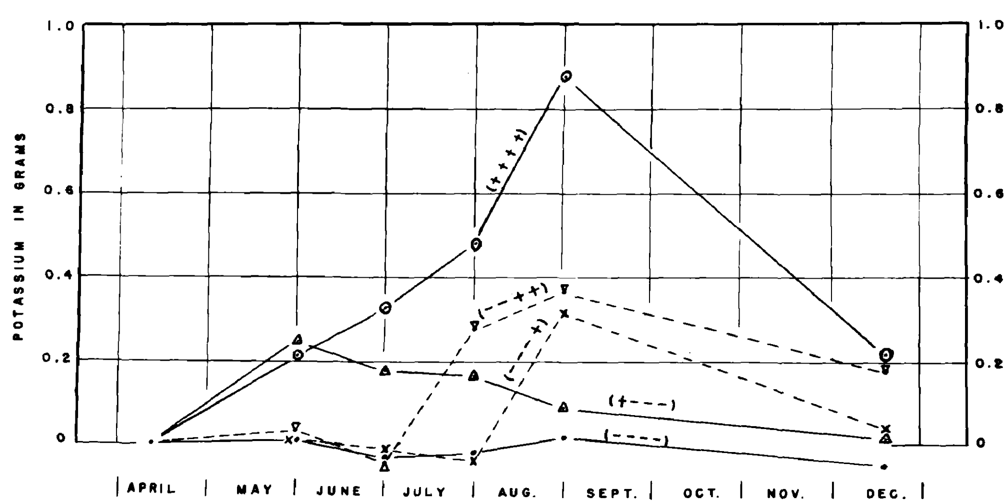


Figure 33. Increase in potassium content in whole trees over amount present in trees when set out.

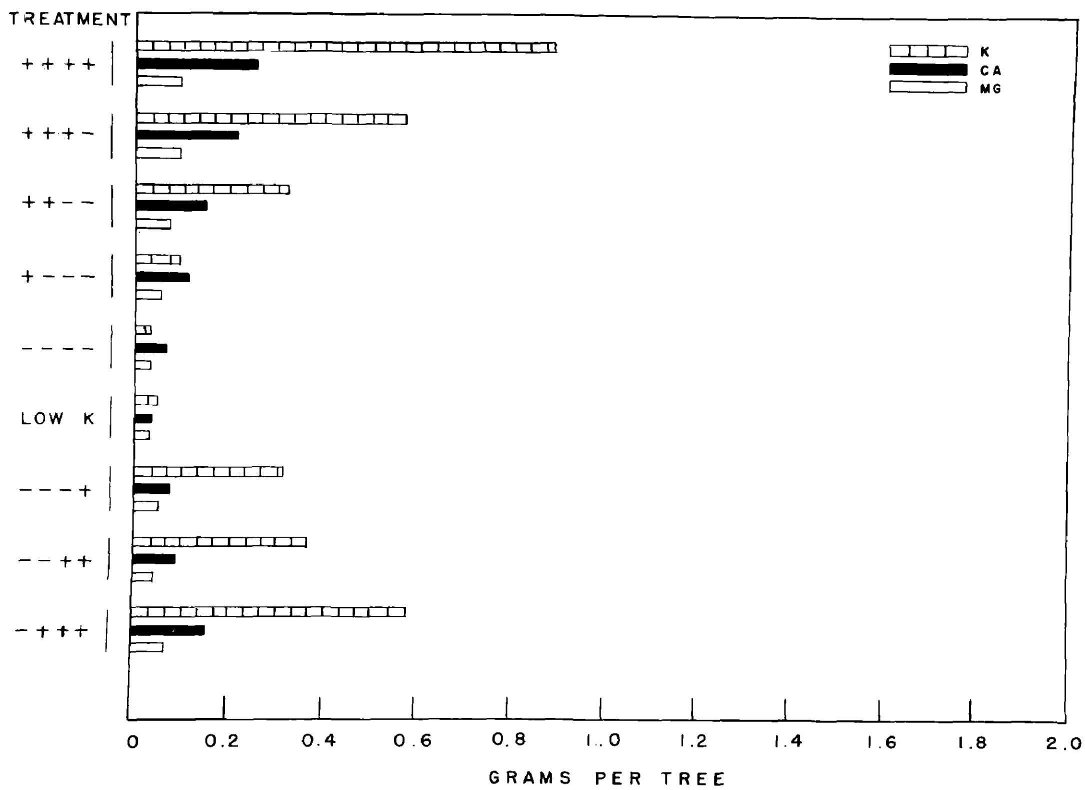


Figure 34. A comparison of actual increases in potassium, calcium, and magnesium occurring in whole trees between April 10 and September 1 resulting from differential potassium nutrition.

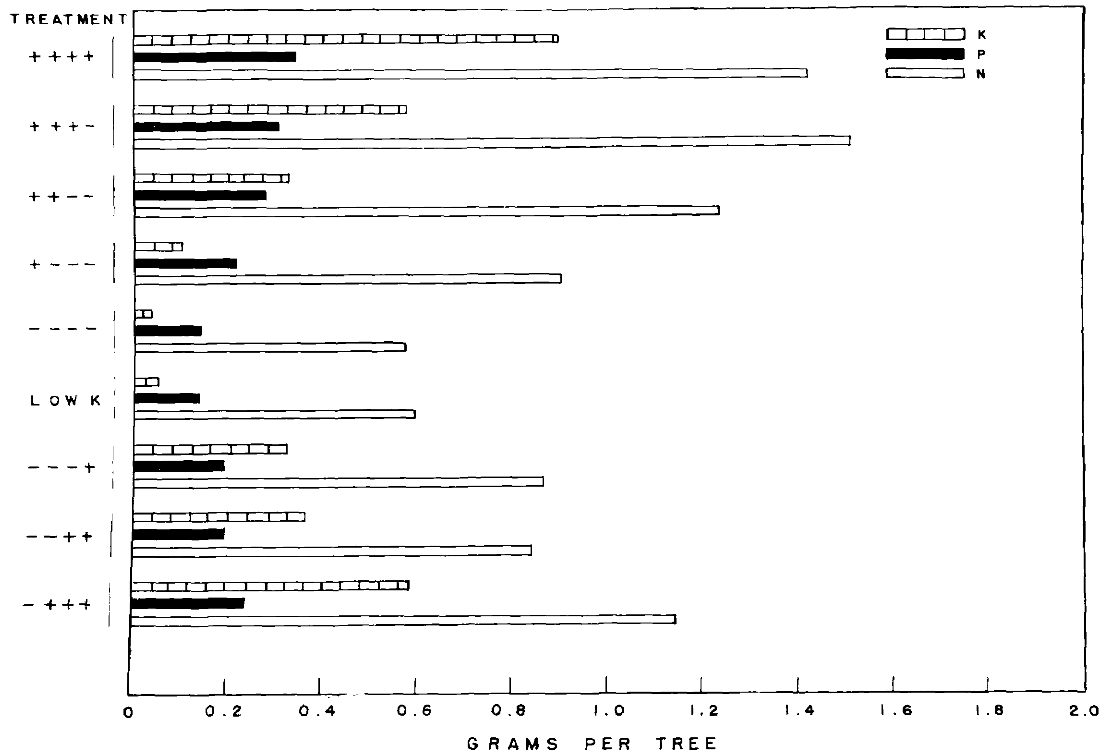


Figure 35. A comparison of actual increases in potassium, phosphorus, and nitrogen occurring in whole trees between April 10 and September 1 resulting from differential potassium nutrition.

of potassium accumulation that had occurred was higher, corresponding to the length of time the trees had received potassium. Both calcium and magnesium increased to a lesser extent in trees that received the least amount of potassium. In other words, when the potassium accumulation was high or low, the accumulation of calcium and magnesium was, in most instances, correspondingly high or low. The same was true of phosphorus and nitrogen as is shown in Figure 35. From the data in Figures 34 and 35 it can be seen that potassium nutrition during the early part of the season resulted in greater increases in calcium, magnesium, phosphorus, and nitrogen than when applied later in the season. For example, in the (+ + + -) series, these elements increased in greater quantity by September 1 than in the (- + + +) series.

The seasonal increases of all elements that occurred above the estimated original amounts under normal continuous plus-potassium nutrition are shown in Figure 36. The increases of the various elements, for the season as a whole, in ascending order were magnesium, calcium, phosphorus, potassium, and nitrogen. Nitrogen was absorbed in considerably greater quantity than the other elements. The amount of the total increase that remained in the trees after leaf fall was also much greater for nitrogen than for any other element. Practically all the increase in magnesium was lost at leaf fall, but as for the other elements, the trees maintained at least a part of the increased amounts after leaf fall. Potassium was lost in the falling leaves in relatively greater amounts than the other elements.

The actual increases of the various elements in whole trees under minus-potassium nutrition are shown in Figure 37. By comparing this with Figure 36, it is easily seen that the various elements were absorbed in

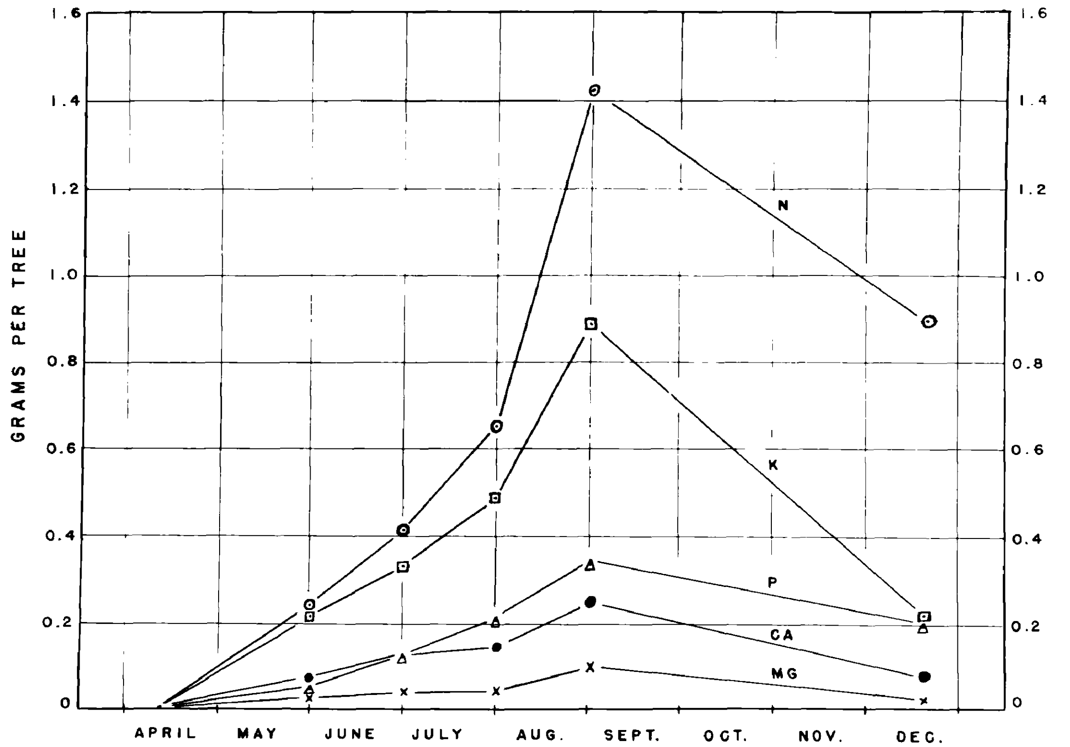


Figure 36. Increase in grams of various elements occurring in whole peach trees under continuous plus-potassium nutrition.

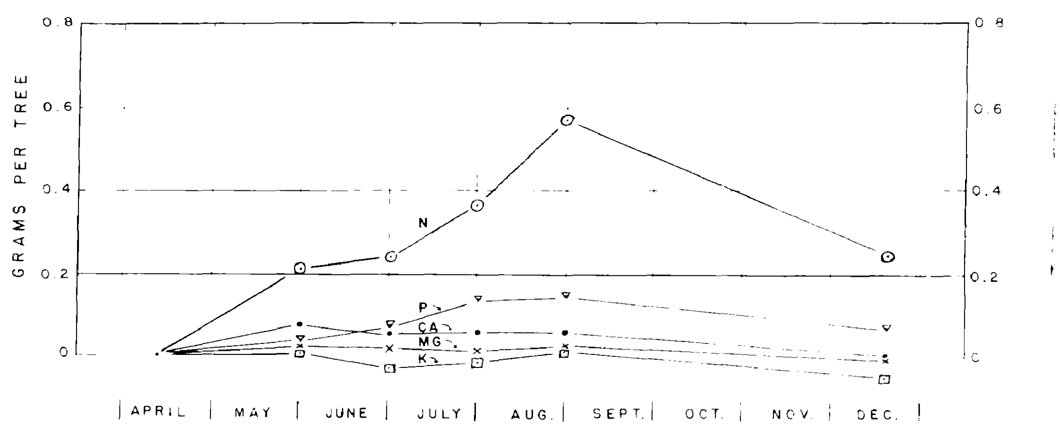


Figure 37. Increase in grams of various elements occurring in whole peach trees under continuous minus-potassium nutrition.

much smaller quantities by the minus-potassium trees. The increase of the various elements in ascending order was similar to that which occurred in the plus-potassium trees, except for potassium which did not increase, since none was supplied. The potassium curve shows that in the falling leaves the trees lost potassium, which resulted in an actual seasonal decrease. Both calcium and magnesium increased slightly in the minus-potassium trees throughout the season, but lost this increase in the falling leaves, thus resulting in no seasonal increase.

Proportionate Distribution of Minerals in Various Tree Fractions. In the following graphs (Figures 38 through 42), data are presented on the proportionate distribution of different elements in various tree fractions, the amounts being expressed as the percentage of the absolute total in the whole tree. The proportionate amounts for June 1 and September 1 of the continuous plus-potassium and minus-potassium trees are presented graphically as typical of treatment and seasonal trends. Since these graphs are self explanatory, only brief consideration will be given them in the text. The numerical data for all treatments are given in detail in Appendix Tables 16 through 20.

For all elements except phosphorus, the proportion present in the leaves on both June 1 and September 1 was higher from plus-potassium than from minus-potassium trees, phosphorus showing no appreciable difference between the treatments. New growth, other than that of the leaves, i.e., new roots and limbs, in general, contained all elements in larger proportion in trees under plus-potassium nutrition than under minus-potassium nutrition. In contrast, the older portions, i.e., scion trunks, stock trunks, and old roots, in some instances contained all elements in larger proportions in minus-potassium than in plus-potassium trees.

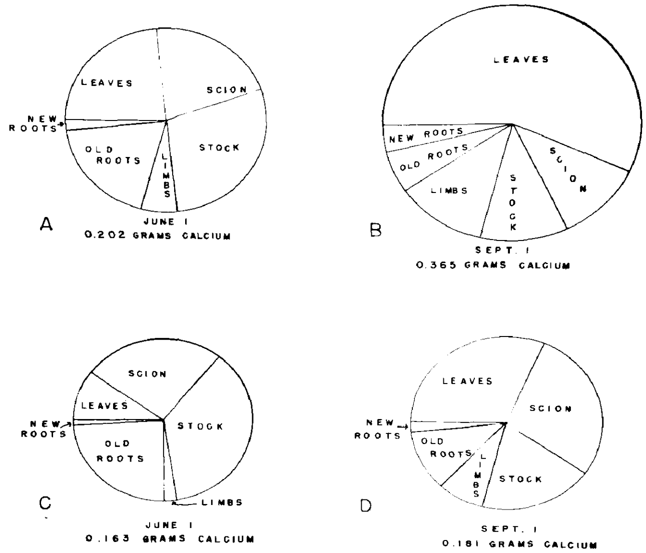


Figure 38. Calcium content as per cent of absolute total in different parts of one-year-old peach trees grown in sand culture. A, B, continuous plus-potassium nutrition; C, D, continuous minus-potassium nutrition.

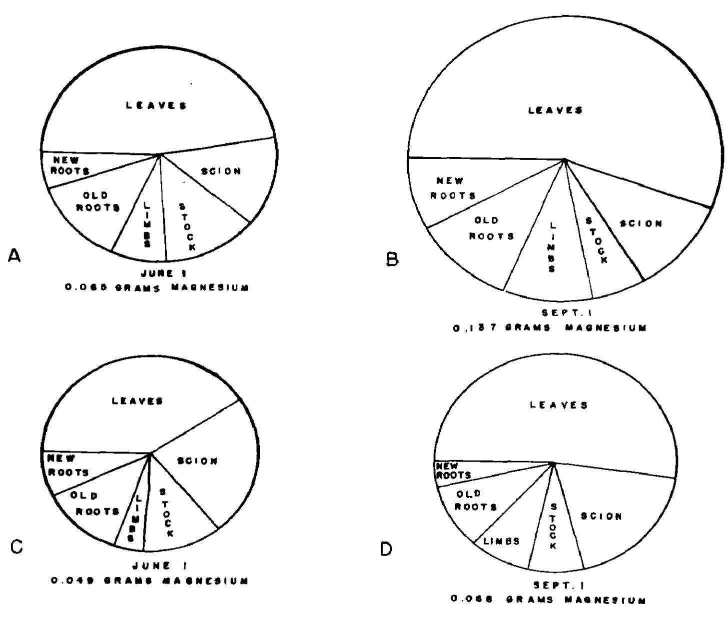


Figure 39. Magnesium content as per cent of absolute total in different parts of one-year-old peach trees grown in sand culture. A, B, continuous plus-potassium nutrition; C, D, continuous minus-potassium nutrition.

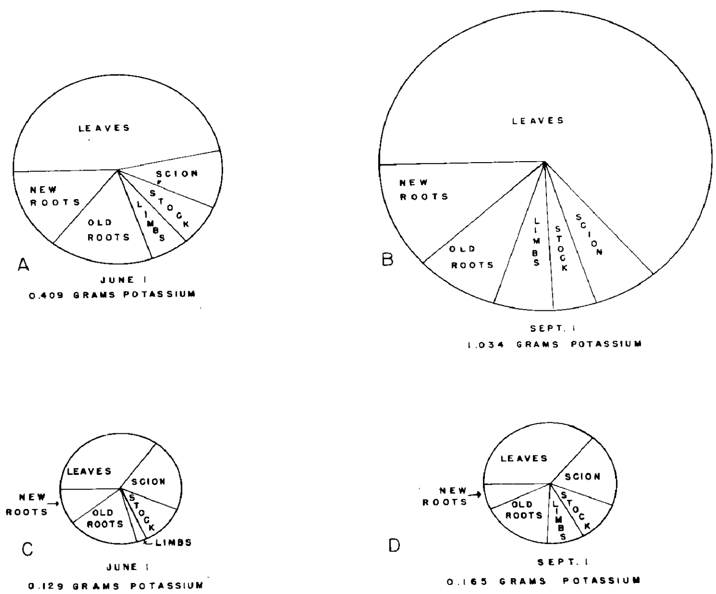


Figure 40. Potassium as per cent of absolute total in different parts of one-year-old peach trees grown in sand culture. A, B, continuous plus-potassium nutrition; C, D, continuous minus-potassium nutrition.

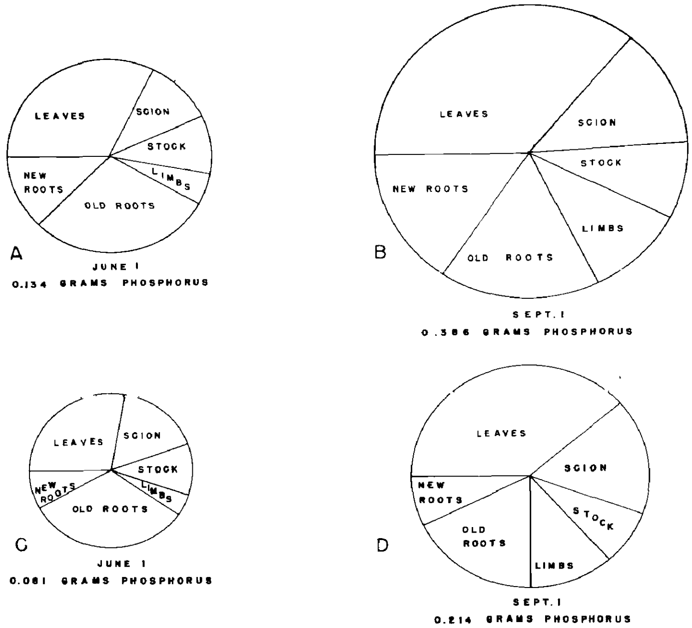


Figure 41. Phosphorus as per cent of absolute total in different parts of one-year-old peach trees grown in sand culture. A, B, continuous plus-potassium nutrition; C, D, continuous minus-potassium nutrition.

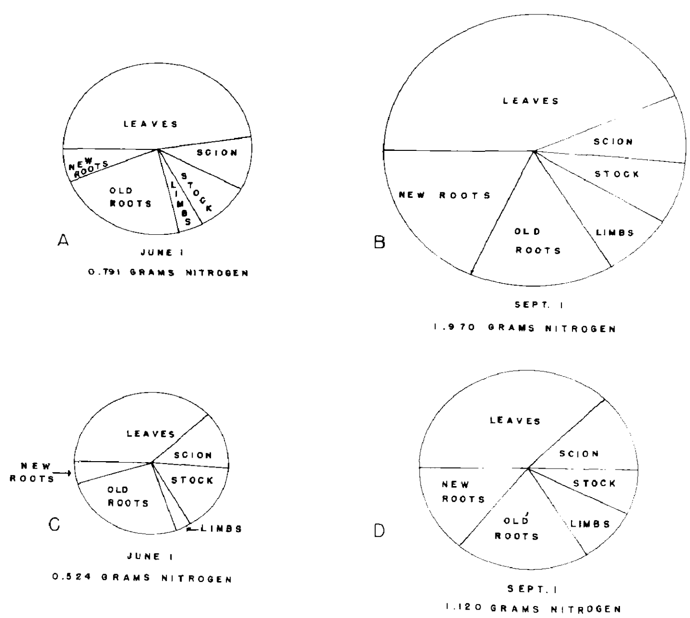


Figure 42. Nitrogen as per cent of absolute total in different parts of one-year-old peach trees grown in sand culture. A, B, continuous plus-potassium nutrition; C, D, continuous minus-potassium nutrition.

As is easily noticed in the pie-graphs, the proportionate amounts of the elements present in the leaves under both plus and minus-potassium nutrition, normally increased from June 1 to September 1. Nitrogen was an exception, which decreased under both treatments. An increase was also generally noted for other new growth, i.e., limbs and new roots, under both treatments. Potassium in new roots was the notable exception, which decreased under both treatments between June 1 and September 1. This might be expected in light of the fact that the actual per cent of potassium in the new roots decreased rapidly between June 1 and July 1, as was shown in Figure 20, A, and B.

More detailed data on the percentage of the total elements present in whole trees found in the leaves on different dates are shown in Table 13. The proportionate percentage of calcium present in the leaves increased seasonally in both plus and minus-potassium treatments, the greater increase being in the former. The proportionate percentage of magnesium increased under both treatments, being slightly greater under plus-potassium nutrition. The per cent of total potassium in the tree present in the leaves, increased about 20 per cent between June 1 and September 1 in the plus-potassium trees, but leaves from minus-potassium trees showed very little increase between these dates. The per cent of the total tree phosphorus present in the leaves on September 1 was slightly higher than on June 1, but the increase was not manifested seasonally. The proportionate percentage of the total tree nitrogen present in the leaves decreased as the season progressed to about the same extent under both plus and minus-potassium nutrition.

In comparing the proportionate amounts of the elements present in the leaves under both plus and minus-potassium nutrition on the same dates,

Table 13. Proportionate Amount of Different Elements in Peach Leaves from Plus-Potassium and Minus-Potassium Nutrition Trees, Expressed as Per Cent of the Total Amount of Each Element in the Entire Tree.*

Date Sampled	Calcium		Magnesium		Potassium		Phosphorus		Nitrogen	
	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K
	%	%	%	%	%	%	%	%	%	%
June 1	18.0	12.5	41.7	44.2	42.2	34.5	32.3	32.6	47.2	42.4
July 1	32.1	20.5	56.8	50.2	46.2	23.5	30.4	27.8	39.5	40.7
Aug. 1	45.5	28.5	56.5	48.9	56.5	28.8	31.3	31.5	42.4	39.4
Sept. 1	57.6	30.7	55.5	52.1	63.9	36.1	36.1	38.6	42.9	37.4

*Figures for June 1 are averages from four trees; July 1 from three trees, Aug. 1 from two trees, and Sept. 1 from one tree.

it can be noted (Table 13) that a smaller proportionate percentage of calcium, magnesium, potassium, and nitrogen accumulated in the leaves under minus-potassium nutrition.

Table 14 shows the proportionate concentration of potassium in different tree fractions from both plus and minus-potassium treatments. It is evident that the scion trunk, stock trunk, and old roots from trees under minus-potassium nutrition contained a higher proportion of the total potassium than the same fractions from trees which received plus-potassium nutrition. These three fractions consisted of the actual tree as it was planted, the other fractions being the current season's growth. In the new growth of leaves and new roots, the proportionate percentage of the total potassium in these parts was higher in trees from the plus-potassium than in minus-potassium trees. This, however, was not the case in the limbs.

<u>Field Growth Response in 1949 of Certain Trees Used in Greenhouse Experiment in 1948</u>. After all samples were obtained from the greenhouse experiment in 1948, four blocks (36 trees) remained. These trees were planted in the field on December 11, 1948 to determine differences in growth and potassium content, which might be caused by the previous season's treatments in sand culture.

In the spring of 1949, all of the trees started growing vigorously, except for an indication that they needed nitrogen; therefore, about one-fourth pound of nitrate of soda was spread around each tree. From then on all of the trees made excellent growth; the foliage was normal green in color and no symptoms of potassium deficiency were apparent in any of the trees. There were no visible differences between the trees which had received potassium the previous summer in sand culture and those which had not.

Table 14. Proportionate Amount of Potassium in Different Tree Fractions from Plus-Potassium and Minus-Potassium Trees, Expressed as Percentage of Absolute Total.*

Date	Leaves		Scion Trunk		Stock Trunk		Limbs		Old Roots		New Roots	
Sampled	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K	Plus K	Minus K
	%	%	%	%	%	%	%	%	%	%	%	%
June 1	42.2	34.5	12.4	18.8	6.2	9.0	7.7	7.6	14.4	19.5	16.3	10.6
July 1	46.2	23.5	10.4	22.9	8.1	10.1	6.6	8.5	20.6	31.0	5.9	3.7
Aug. 1	56.5	28.8	9.0	19.4	5.3	11.8	6.0	9.7	14.7	23.7	8.4	6.5
Sept. 1	63.9	36.1	6.4	19.9	4.2	11.5	6.0	8.5	8.7	17.6	10.7	7.0
Dec. 18	-	-	16.2	16.7	10.7	16.7	14.0	10.2	29.5	34.3	29.5	22.0

*Figures for June 1 are averages from four trees; July 1 from three trees; August 1 from two trees; September 1 and December 18 represent only one tree.

Leaf samples were taken from the trees on three dates during the summer. Ten leaves were taken per tree from the median portion of the shoots, and leaves from trees which had received the same potassium treatments in the greenhouse were composited into one sample. The results of the potassium determinations are presented in Table 15. It is plainly evident, since leaves from all the treatments were very similar in potassium concentration, that the trees which had received no potassium the previous summer were able to absorb adequate potassium for their needs.

The trunk diameters of these trees after a years growth in the field, as measured on September 28, 1949 are presented in Table 16. An analysis of variance of these data revealed no significant differences which might have been caused by the treatments in the greenhouse the previous summer. It has been shown previously (Table 7) that the tree trunks made very little growth in sand culture in the greenhouse, whereas the same trees planted in the field for one season made good growth.

Since it was found in the greenhouse study that increase in weight gave the best measure of the effect of potassium on growth, all of the trees were dug in December 1949, after one year in the field. Digging was begun about two and one-half feet from the trunks and as many of the roots were saved as was possible. The roots had made good growth, and extended beyond the spread of the branches. The total weights of the trees are shown in Table 17. An analysis of variance of the data showed that there was no significant differences among the various treatments.

In order to determine if a lack of potassium in young peach trees when set out might result in a small ratio of roots to tops, the trees, when dug, were sawed in two at the point of bud union and the weights of

Table 15. Potassium Percentage in Leaves from Peach Trees Grown in Field During Summer of 1949, Which Had Received Different Potassium Treatments in Sand Culture the Previous Year, 1948.

Greenhouse Treatment - 1948	June 23, 1949	Aug. 22, 1949	Sept. 28, 1949
+ + + +	1.98	2.10	2.10
+ + + -	1.98	1.98	1.98
+ + - -	1.92	2.10	2.04
+ - - -	2.10	2.10	2.10
- - - -	1.98	1.98	1.98
- - - +	2.16	2.07	2.16
- - + +	2.07	1.92	2.07
- + + +	1.92	2.10	2.10
Low	2.16	2.16	2.10

Table 16. Trunk Diameter of Peach Trees on September 28, 1949 After One Year in the Field, Having Grown in Sand Culture Experiment in 1948.

Treatment in Greenhouse, 1948	Diameter (Cm)
≠ ≠ ≠ ≠	3.50
≠ ≠ ≠ -	3.41
≠ ≠ - -	3.24
≠ - - -	3.45
- - - -	3.25
- - - ≠	3.44
- - ≠ ≠	3.52
- ≠ ≠ ≠	3.45

Differences shown among treatments are not statistically significant.

Source	df	Variance	F
Replicates	3	451.7	
Treatments	7	916.6	
Interaction	21	932.0	

Table 17. Total Weight of Peach Trees in December, 1949 After One Year in the Field, Having Grown in Sand Culture Experiment in 1948.

Treatment in Greenhouse, 1948	Weight (Kg)
+ + + +	3.46
+ + + -	3.41
+ + - -	3.19
+ - - -	2.78
- + + +	2.71
- - + +	3.58
- - - +	3.50
- - - -	2.71

Differences shown among treatments are not statistically significant.

Source	df	Variance	F
Replicates	3	0.036	
Treatments	7	0.561	1.51
Interaction	21	0.371	

the two portions recorded. The top-root ratios proved to be quite similar in all treatments, as shown below. Each ratio is an average of four trees.

Treatment	Top-Root ratio
+ + + +	1:0.979
+ + + -	1:1.105
+ + - -	1:1.172
+ - - -	1:1.027
- + + +	1:1.052
- - + +	1:1.123
- - - +	1:1.119
- - - -	1:1.165

The following facts were revealed by the analysis of the topsoil and subsoil samples which were taken from the plot where the trees were planted. The pH of the topsoil was 4.9 and the subsoil, 4.5. There was 0.6 per cent organic matter in the topsoil and practically none in the subsoil. Calcium was available in very small amounts, magnesium in medium amounts, nitrate nitrogen in small amounts, ammonia nitrogen in very small amounts, and phosphorus in very small amounts in both topsoil and subsoil. Aluminum was available in small amounts in the topsoil and in high amounts in the subsoil, whereas, manganese was available in medium amounts and small amounts in the same soil fractions, respectively. As has been shown previously, no evidences of potassium deficiency was apparent either from visual symptoms or chemical analyses, yet according to the soil tests, potassium was available only in small amounts in the topsoil and in very small amounts in the subsoil. These facts would seem to indicate that if potassium is present in available form in the soil, young peach trees will absorb it and the roots will develop normally even though low or deficient in potassium when planted.

PART 2

POTASSIUM NUTRITION STUDIES UNDER FIELD CONDITIONS

MATERIALS AND METHODS

Fertilizer Plots. The fertilizer study was conducted in a block of Shippers Late Red peach trees in the R. S. Dillon orchard near Hancock, Maryland. The study was begun in the summer of 1947, at which time the trees were in their second year of growth. Some of these trees had shown foliar symptoms the previous year, believed to be caused by a lack of potassium, and the same season responded within a period of a few weeks to an application of potassium fertilizer.

Previous cultural practice, which was continued throughout the experiment, consisted of cultivation close to the trees with a summer cover crop growing between rows. The trees received annual applications of nitrogen, but were given no other fertilizers, except those which were applied for purposes of the experiment. The cover crop, however, was given applications of a complete fertilizer comparable to standard practice.

The orchard was planted in straight rows regardless of the contour of the land. Part of the orchard was fairly level, but a portion sloped off to a wooded area. In selecting the trees for the experiment, the lower areas were avoided, as well as trees which were smaller than average in size.

Four blocks were laid out containing thirty-six trees each, with six treatments per block, making six trees per treatment as given in Table 18.

Table 18. Treatments Applied to Fertilizer Plots on August 14, 1947*

BLOCK	TREATMENT PER TREE	NUMBER OF TREES
J	1. Straw mulch, 40 lbs.	6
	2. 20% Super phosphate, 5 lbs.	6
	3. Potassium chloride, 1 lb. : 40 lbs. straw mulch	6
	4. Potassium chloride, 1 lb.	6
	5. Potassium chloride, 1 lb. : 20% Super phos., 5 lbs.	6
	6. Check	6
K	DUPLICATE OF BLOCK J	36
L	1. Potassium chloride, ½ lb.	6
	2. Potassium chloride, 1 lb.	6
	3. Potassium chloride, 2 lbs.	6
	4. Potassium chloride, 4 lbs.	6
	5. Ammonium nitrate, 2 lbs.	6
	6. Check	6
M	DUPLICATE OF BLOCK L	36
	Total number of trees	144

* The same fertilizers were applied again on June 25, 1948 with the exception that no additional straw was added.

The treatments were applied on August 14, 1947 and were repeated on June 25, 1948, with the exception that no additional straw was added to those trees which received it in 1947.

Leaf samples were taken on the same day the first treatments were applied in 1947. Two subsequent samples were taken the same fall and two samples each of the following two years, 1948 and 1949. The leaves were taken from the median portion of well developed terminal branches around the periphery of the trees at a height of about four to six feet. Fifteen leaves were taken per tree. Leaves from the six trees in each treatment were composited into a single sample. On sampling dates when there was any visible evidence of spray residue, the leaves were washed for one minute in 1 per cent hydrochloric acid solution. If they could not be washed the same day, they were stored overnight in a 40 degree F room until the next day. The leaves were dried in a forced draft oven at 80 degrees C and dry weights recorded. Grinding was done in a Wiley Mill equipped with a 40-mesh screen.

Potassium Spray Applications. In the same orchard in which the fertilizer plots were located, five blocks of twelve trees each were selected for applications of potassium-carrying foliar sprays. The following materials were used in amounts to equal 1 per cent potassium in the spray solution: potassium nitrate, potassium chloride, potassium phosphate, and potassium tartrate. The fifth block was a check. Each spray material was applied to twelve trees, each tree being thoroughly sprayed three times, with time being allowed between applications for the leaves to dry.

On the day the sprays were applied, September 11, 1947, but before spraying, leaf samples were taken from each block consisting of the lowest leaf on three-inch terminal twigs, the twigs also being taken for chemical analysis. Twelve such twigs were taken per tree making 72 twigs and leaves, respectively, per sample. A series of leaf and twig samples were taken again on October 17, 1947. The following spring, on April 3, 1948, more three-inch terminal twig samples, consisting of 1947 growth, were taken just prior to time of blooming.

On the day the sprays were applied, but after the leaves had dried, duplicate leaf samples were taken from each spray treatment. The purpose of these duplicate samples was to run analyses on one which was washed in 1 per cent hydrochloric acid solution, and on the other without washing to determine the effect of washing on potassium concentration.

Chemical Procedure. Samples were ashed in the same manner as was described in Part 1 for the greenhouse material and analyses were determined for the same elements, i.e., calcium, magnesium, potassium, phosphorus, and nitrogen. The methods of determination were the same as used in the greenhouse study, except for the samples taken from the fertilizer and spray plots in 1947. On these samples, calcium was determined by the method as outlined by the Association of Official Agricultural Chemists (1) and potassium was determined with a Perkin-Elmer Model 18 Flame Photometer. Magnesium, phosphorus, and nitrogen were determined by the same methods for all samples, both in field and greenhouse studies.

Soil Sampling. Soil samples were taken on November 11, 1947, approximately three months after the first fertilizer application. These were taken around the trees where the fertilizers had been applied, and also, a representative sample was taken from the middles of the rows in each block. Twenty samples were taken to a depth of twelve inches and were divided into three portions, 0-3 inches, 3-6 inches, and 6-12 inches. These were analyzed for available calcium, magnesium, aluminum, iron, nitrate nitrogen, ammonia nitrogen, phosphorus, potassium, and manganese, by the methods used by the Soil Testing Service of the Agronomy Department at the University of Maryland. The results of the tests are discussed, using the availability designations employed by the Soil Testing Service. No specific quantities are associated with these designations. The per cent of organic matter and pH was also determined.

EXPERIMENTAL RESULTS

<u>Effect of Fertilizer Treatments on Potassium Content of Leaves.</u> The data from all the analyses of the leaves from the fertilizer plots are presented in Appendix Tables 21 to 25. The results of the potassium analyses only are shown in Table 19. The figures for the duplicate blocks are given as averages of the two. At the first sampling, on August 14, 1947, the potassium percentage ranged from 1 to 1.5 and increased subsequently, being higher on October 17. It is not believed that these increases were due to the fertilizer applications, since the increases were of about the same magnitude in plots which received no potassium as for those which received potassium. The effects of the potassium fertilizer was evident, however, in the 1948 samples. In blocks J and K, no tree in any plot received over one pound of potassium chloride, yet on both June 25 and September 10, 1948, these trees had a higher per cent of potassium in the leaves than the check. The leaves from the plots which received straw mulch were also slightly higher in potassium percentage than those which received no potassium, indicating that the mulch had the effect of making more potassium available from the soil. The same influence of the mulch was also shown in the plots which received straw mulch in addition to one pound of potassium chloride.

In blocks L and M, trees in the plots which received from one-half up to four pounds of potassium chloride, contained a higher per cent of potassium in the leaves on both June 25 and September 10, 1948, in line with the higher potassium applications. On both dates the per cent of potassium present in the leaves of trees which had received four pounds of potassium chloride was over 1 per cent higher than for the check trees on the same dates. As in 1947, the potassium concentration was higher on the later sampling dates in all treatments.

[redacted]

Table 19. Potassium Percentage in Peach Leaves From Trees in Fertilizer Plots* (Dry Weight Basis)

	Treatment Per Tree	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
B		%	%	%	%	%	%	%
L								
O	Straw mulch - 40 lbs.	1.19	1.42	1.60	1.65	1.68	1.62	1.70
C	P_2O_5, 5 lbs.	1.30	1.45	1.78	1.21	1.40	1.45	1.37
K	KCl 1 lb. ≠ 40 lbs. straw	1.01	1.27	1.56	2.03	2.23	2.33	2.14
	KCl 1 lb.	1.43	1.52	1.90	1.62	1.76	2.17	2.00
J	KCl 1 lb. - P_2O_5, 5 lbs.	1.12	1.44	1.48	1.60	1.92	2.14	2.00
&	Check (No fertilizer)	1.34	1.62	1.80	1.41	1.51	1.51	1.62
K								

B								
L								
O	KCl ½ lb.	1.40	1.39	1.76	1.32	1.56	1.70	1.70
C	KCl 1 lb.	1.45	12.9	1.60	1.51	1.81	2.20	2.00
K	KCl 2 lbs.	1.35	1.55	1.85	1.98	2.07	2.58	2.33
	KCl 4 lbs.	1.42	1.63	1.99	2.39	2.42	2.94	2.66
L	NH_4NO_3 2 lbs.	1.50	1.44	1.77	1.24	1.75	1.51	1.56
&	Check (No fertilizer)	1.53	1.36	1.73	1.20	1.33	1.54	1.51
M								

* Each value is an average of two like treatments, representing twelve trees.

[redacted]

The straw applications, which were made in August 1947, were apparently still somewhat effective in affecting potassium availability in 1949. This was evident in the plots which received one pound of potassium chloride plus straw mulch in blocks J and K, as the leaves from these plots had a slightly higher concentration of potassium on both sampling dates than did those plots which received one pound of potassium chloride per tree but no straw.

The heavier applications of potassium fertilizer to some plots in blocks L and M were still very noticeable in the potassium levels present in the leaves in 1949, even though the last fertilizers were applied in June, 1948. The leaves from trees in plots which received four pounds of potassium chloride per tree contained almost 3 per cent potassium on June 25, which was practically double the concentration present in the leaves from the check plots or in the ammonium nitrate and super phosphate plots.

One striking difference in the potassium concentrations in 1949 was the lower level on the later sampling date in most instances, whereas, in the two previous years the concentrations were higher on the later dates.

None of the samples taken in 1947 showed potassium concentrations as high as 2 per cent. On both sampling dates in 1949, leaves from all plots having received as much as one pound of potassium chloride per tree per fertilizer application, contained 2 per cent potassium or more, whereas leaves from all other treatments contained less than 2 per cent. The trees that received no potassium were maintaining a potassium level of about 1.5 per cent in their leaves.

The number of leaves and dry weights of the leaf samples taken from the fertilizer plots were recorded. The average weight per leaf from the different treatments on all sampling dates is shown in Table 20. In 1947,

[redacted]

Table 20. Average Weight Per Leaf in Milligrams of Peach Leaves on Different Dates from Fertilizer Plots

Treatment Per Tree	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		mg.	mg.	mg.	mg.	mg.	mg.	mg.
Straw mulch	J	274	350	303	271	426	255	368
" "	K	281	317	314	283	417	265	407
5 lbs. Super phosphate	J	297	347	326	276	426	255	373
" " "	K	273	281	277	286	430	247	392
KCl 1 lb. plus straw	J	241	302	288	300	443	272	398
" " " "	K	261	332	286	288	416	256	396
KCl 1 lb.	J	293	374	320	277	430	248	377
" "	K	290	346		288	460	290	421
KCl 1 lb. ≠ 5 lbs. Super phosphate	J	251	325	289	283	431	273	390
" " " "	K	267	332	308	301	452	271	411
Check	J	284	350	296	271	433	253	380
"	K	277	313	306	284	411	264	386
KCl ½ lb.	L	282	322	304	282	405	258	394
" " "	M	263	307	307	266	456	251	372
KCl 1 lb.	L	281	334	332	283	454	267	386
" " "	M	230	296	304	287	456	265	390
KCl 2 lbs.	L	260	308	290	290	458	261	393
" " "	M	295	348	320	311	478	256	385
KCl 4 lbs.	L	268	320	288	297	433	266	390
" " "	M	263	307	278	295	480	276	376
2 lbs. Amm. nitrate	L	271	331	322	268	475	238	387
" " " "	M	272	323	308	295	441	264	395
Check	L	272	336	327	280	431	255	388
Check	M	277	314	324	275	481	253	378

[redacted]

the leaves increased in dry weight between August 14 and September 12, but by October 17 the leaves from a large majority of the plots had decreased somewhat in dry weight. The results of 1948 and 1949 showed that the dry weight of leaves increased considerably between the latter part of June and about the middle of September.

Potassium Spray Applications. All samples taken in connection with the spray applications were analyzed for calcium, magnesium, potassium, phosphorus, and nitrogen. These data are presented in Appendix Tables 26 and 27. Of especial interest were the results of the potassium analyses, to determine if there was any indication that potassium was absorbed by the leaves or terminal twigs. These data are shown in Table 21. Before sprays were applied on September 11, the leaves from all five blocks were uniform in potassium concentration. On the same day, but after the sprays were applied, the leaves were approximately 0.6 per cent higher in potassium than before the sprays were applied; the potassium concentration was about the same, whether the leaves were washed in 1 per cent hydrochloric acid or not. On October 17, the leaves from trees which had been sprayed still contained a slightly higher concentration of potassium than did the check.

The three-inch terminal twigs contained approximately 0.5 per cent potassium before sprays were applied on September 11, and all had increased somewhat by October 17, but it is doubtful if the differences were caused by the sprays, since the check increased almost as much. Potassium concentration in the twigs on April 3 of the following year was slightly higher in the spray plots than in the check plot.

Table 21. Potassium in Leaves and Three-inch Terminal Twigs Before and After Potassium Spray Applications. Expressed as Percent of Dry Weight.

Leaf Samples

Spray Treatment	Sept. 11, 1947 Before Sprays	Sept. 11, 1947 Washed after Sprays	Sept. 11, 1947 Unwashed after Sprays	Oct. 17, 1947
	%	%	%	%
Check	1.33	-	-	1.51
Potassium Nitrate	1.46	2.12	2.16	1.95
Potassium Chloride	1.31	2.06	2.18	1.76
Potassium Phosphate	1.38	2.11	2.03	1.76
Potassium Tartrate	1.47	1.94	2.09	1.95

Twig Samples

Spray Treatment	Sept. 11, 1947 Before Sprays	Oct. 17, 1947	Apr. 3, 1948
	%	%	%
Check	0.47	0.54	0.87
Potassium Nitrate	0.51	0.55	0.92
Potassium Chloride	0.48	0.59	0.97
Potassium Phosphate	0.48	0.58	0.97
Potassium Tartrate	0.49	0.56	0.97

Soil Samples. The fertilizer materials, when applied in August 1947, were scattered uniformly under and beyond the spread of the branches. On November 20, 1947 soil samples were taken around the trees where the fertilizers had been applied and also from the middles of the rows in the various blocks. Twenty samples were taken, which were divided into three sections according to depth, i.e., 0 to 3, 3 to 6, and 6 to 12 inches. The purpose of taking soil samples was to gain some information as to the general condition of the soil, as well as available nutrient element constituents, and also, to determine whether or not the applied potassium fertilizer materials had penetrated into the soil to any extent.

The soil type was classified as silt loam. The pH of the upper three inches of soil was, in most instances, between six and seven. Soil from the 3 to 6 inch level was much lower, being close to 4.5 in most samples. The organic matter content of the upper six inches ranged from 1 to 2 per cent, but in some instances was below 1 per cent in the 6 to 12 inch level.

Nutrient elements were measured in terms of availability and expressed by the following terms: very high, high, medium, small, very small, detectable, and none. No potassium was available at the 6 to 12 inch depth; hence, only the data for the 0 to 3 and 3 to 6 inch depths are presented (Table 22). These results show that the potassium fertilizers applied approximately three months earlier had increased the amount of available potassium in the soil. This effect was most pronounced in the upper three inches. In blocks L and M, only where four pounds of potassium chloride were applied, a very small amount of potassium was found to be available at the 3 to 6 inch depth. The only places where medium amounts of potassium were available were in the plots having received two and four pounds of potassium chloride in blocks L and M, and in the middle of the rows in block K, where fertilizer

Table 22. Available Potassium in Field Plots Approximately Three Months After Potassium Fertilizer Applications *

Location from which sample was taken	BLOCK J 0 to 3 inches	BLOCK J 3 to 6 inches	BLOCK K 0 to 3 inches	BLOCK K 3 to 6 inches
KCl 1 pound plus straw mulch	L	-	L	-
KCl 1 pound	L	-	T	T
Straw mulch	L	-	T	-
Check	T	-	T	-
Middle of rows	T	-	M	-

	BLOCK L 0 to 3 inches	BLOCK L 3 to 6 inches	BLOCK M 0 to 3 inches	BLOCK M 3 to 6 inches
KCl 1 pound	L	-	T	-
KCl 2 pounds	M	-	M	-
KCl 4 pounds	M	T	M	T
Check	T	-	T	-
Middle of rows	T	T	T	-

* Key to availability test symbols

M Medium amount
L Small amount
T Very small amount
\- None

had been applied to the cover crop. In the check plots, where no potassium was applied, only the 0 to 3 inch level had any available potassium and that in very small amounts only.

Available calcium was high in the upper six inches of blocks J and K and was present mostly in very small amounts at the 6 to 12 inch depth. In blocks L and M, available calcium was more variable in the upper levels, but was high in the majority of cases in the 0 to 3 inch depth. As was true in blocks J and K, only a very small amount of calcium was available at 6 to 12 inches.

Available magnesium was present in high to very high amounts in the upper six inches of soil and in low to medium amounts in the 6 to 12 inch depth in blocks J and K. In blocks L and M, available magnesium was medium in most instances in the upper six inches and low in the next six inches.

Available aluminum was found almost exclusively in the 6 to 12 inch depth and ranged from high to low.

Both nitrate and ammonia nitrogen were available in practically all samples at all depths, but usually in only detectable or very small amounts.

Phosphorus was present, available in detectable to small amounts, being found in blocks J and K in more instances than blocks L and M; in the latter block, even a detectable amount was found in only one instance.

Manganese was found in all samples at all depths, usually in detectable amounts only.

DISCUSSION

It was formerly the concensus of those engaged in fruit growing that nitrogen was the only element needed in fertilization of fruit trees. Recommendations to this effect are still given for orchards in deep, fertile soils where no symptoms have appeared indicating the lack of other elements. Certain investigators in this country failed to show any definite beneficial response from the application of potassium to fruit trees under orchard conditions, Chandler, 1934 and 1936 (10), (11), Potter and Percival, 1938 (29) and Potter and Fisher, 1939 (28). Other workers, however, have obtained a favorable response from soil applications of potassium carrying fertilizers, Rawl, 1936 (31), Dunbar and Anthony, 1938 (17), and Burrell and Boynton, 1943 (9). These workers observed an abnormal condition of the foliage on the trees and obtained a beneficial response from potassium applications.

It is perhaps true that in the earlier work in which no beneficial response was obtained, the trees under investigation were already receiving ample amounts of potassium from the soil. In some areas where potassium deficiency has been found, the orchards had been planted in soil that had been cropped for many years and was in a low state of fertility. Under such conditions, it is not surprizing to find a lack of certain essential elements.

The trees in the orchard fertilizer plots in the present investigation had shown symptoms of potassium deficiency their first year in the orchard, 1946, and had responded the same season to potassium applications in June. There is evidence in the literature that potassium deficient peach trees are able to utilize potassium rather quickly after it is applied to the soil. Such results have been obtained by Dunbar and Anthony, 1938 (17), Waugh and Cullinan, 1941 (39), and Boynton, 1944 (6). In some instances, the potassium percentage in the leaves increased to three or four times that found in the checks during the same season in which applications were made.

Even though the trees used in this study were not showing any evidences of a lack of sufficient potassium at the time the fertilizer treatments were applied, an increase in the potassium concentration in the leaves was evident in the following two seasons. Exceptionally large increases similar to those mentioned above could not be expected, since potassium was already present in adequate amounts, as shown by leaf analysis. When trees absorb potassium to a point above which no apparent benefits are obtained, the term "luxury" consumption has been applied. Such consumption may occur in the instance of peach trees, but it would be difficult to prove that the tree was not benefited by at least reasonable amounts above the so-called adequate level. This, however, might be termed as an unbalanced nutritional condition, according to the concept of Shear, Crane, and Myers (34).

The results of the greenhouse experiment showed that potassium could be absorbed equally well at different times during the growing season. If a similar response could be obtained in the field, then potassium could be applied at practically any time during the growing season and expected to be taken up by the trees, provided there was sufficient rainfall to cause it to go into solution. Terminal growth in bearing peach trees may cease about July 1 or possibly earlier. It is important that the trees have adequate available potassium during the active growth period in order to have good fruit bud formation and adequate diameter of current shoot growth. When the fruit ripens, there is evidence that potassium is translocated from leaves to the fruit (26). Such a transfer was also suggested by results obtained in the present fertilizer plot studies. For this reason an application of potassium in mid-summer might be feasoble in some instances in order to keep the leaf potassium concentration at an adequate level. Even though terminal growth ceases comparatively early, a measurement of weight of leaves in the fertilizer plots, revealed that they continued to increase in dry weight as late as sometime in September. Similar results were obtained for entire trees in the greenhouse experiment. These facts suggest the continued activity of the leaves in their function of photosynthesis in supplying carbohydrates for growth as well as for reserve food material, even though apparent vegetative growth has ceased and fruit maturation taken place.

The foliage of the trees grown in the greenhouse in the present experiment showed no yellowing of the foliage as a first symptom of potassium deficiency, as has been reported from field observations, (31), (17), (33). The first symptom observed was marginal scorch of the leaves, which was later followed by a yellowing and bronzing of the leaves. This symptom was caused by a complete lack of potassium in the nutrient solution, resulting in a more abrupt appearance of the deficiency than would happen under field conditions, in which gradual depletion of available potassium occurs. The appearance of necrotic areas inside the leaf, as well as around the margins, agrees with the symptoms obtained by other workers using controlled nutrient culture, (15), (41), (7).

Crinkling along the midrib has been described as a symptom of potassium deficiency under field conditions by Dunbar and Anthony, 1938 (17). Puckering of the lamina as an early symptom under nutrient culture conditions was reported by Weinberger and Cullinan, 1937 (41). The leaves from minus-potassium trees in this experiment, however, did not show such a symptom. On the contrary, a puckering of the lamina was noted in some leaves from plus-potassium trees as was shown in leaf 4 of Figure 1. This puckering may not have shown the regularity and number of individual folds or wrinkles as had been found in the field. In this particular instance, the condition could not have been due to a lack of potassium and must have been caused by an abnormal amount of growth of intervascular tissue in proportion to the veins.

In recent years, much attention has been focused on the use of leaf analysis as an indicator of the nutritional status of fruit trees. Since, in the present greenhouse study, entire trees were divided into various parts for chemical analysis, the mineral concentration of various parts could be compared with that of the entire tree, in regard to the nutritional status. The potassium concentration in the leaves showed them to be very responsive to the changes in potassium nutrition. Other tree portions also reflected the changes, some parts better than others, but none portrayed the changes as well as the leaves. There are advantages to the use of the leaves as a measure of nutrition, such as the ease in collecting the leaves as compared to any other tree part. Also, the various elements are ordinarily present in much higher concentrations there than elsewhere, expediting the chemical analyses.

It is very difficult to say with any degree of certainty what the critical level of potassium percentage is in peach leaves. There seems to be fairly good agreement in the literature that leaves containing 1 per cent or more of potassium are unlikely to show any visible deficiency symptoms. Where symptoms have occurred, the level was found to be less then 1 per cent as reported by Cullinan, Scott, and Waugh, (13) and Baker, (4).

The results obtained in the greenhouse in this study agree with the foregoing statement in that foliage of a tree with only a very few leaves showing deficiency symptoms contained slightly less than 1 per cent potassium, whereas, other trees with more pronounced symptoms showed potassium concentration as low as 0.5 per cent.

In some cases, even though the leaf potassium may be far below 1 per cent, no deficiency symptoms occur. Thus, it has been reported by Lilleland and Brown, (27), that 0.45 per cent potassium in the leaves in July caused no foliage disorders in a California peach orchard. In October of the same year, the level was as low as 0.27 per cent and yet no distinctive symptoms occurred. Just why such a low level of potassium would not cause a visible deficiency, possibly may be due to the ratio of potassium to other elements in the leaves, so that a severely unbalanced nutritional status may not have existed. From the available evidence, it would appear that under most conditions, 1 per cent leaf potassium might be regarded as approaching the critical point.

Little or no effect on length of shoot growth of the peach due to a lack of potassium has been reported, (41), (33). Although a significant difference in shoot growth was obtained between some of the treatments in this experiment, there was no consistent relationship between shoot growth and potassium nutrition. A possible explanation would be that the amount of potassium necessary in the terminal meristem for elongation is very low, or that the available amounts keep moving up to the growing point in sufficient concentration to effect cell division. It is known that potassium accumulates at growing points and is translocated from older tissues to meristematic areas (21). Thus, even under conditions of a severe lack of potassium, the growing points apparently are able to function rather efficiently. For increase in diameter, more potassium may be required, for in the minus-potassium trees, the new growth was very slender. This has also been observed by other workers (41), (13).

As has been shown, the peach trees in sand culture increased in green weight in proportion to the length of time the trees received potassium. On the September 1 sampling date, the amounts of the various elements which had accrued to this time in the whole trees were determined. Each of the elements, calcium, magnesium, phosphorus, and nitrogen had increased in proportion to the period of time that potassium was supplied to the trees. This is in agreement with results obtained with apple trees by Thomas, (36) who found that the omission of either phosphorus, nitrogen or potassium resulted in a decreased absorption of the remaining elements. It appears that the increases of the various elements were merely associated with the increase in green weights made by the trees; thus, on a weight basis it is likely that a lack of potassium decreased growth which, in turn, resulted in less accumulation of the various elements. Hoagland, (21) concurs with the above results in the following statement:

> Moreover, within the plant itself the balance that is determinative of plant growth is not confined to the proportional relationships of inorganic nutrients. The significant balance is rather governed by the interractions of inorganic nutrients with the carbon compounds synthesized and metabolized.

When the effects of plus or minus-potassium nutrition on the concentration of calcium, magnesium, phosphorus, and nitrogen in the leaves were considered, it was found that calcium was present in higher percentages in the plus-potassium leaves than in minus-potassium leaves. On the contrary, nitrogen and phosphorus was present in higher concentration throughout the sampling period in the minus-potassium leaves, the difference amounting to about 0.5 per cent in the case of nitrogen. These results with nitrogen are not in agreement with a report by Cullinan, Scott, and Waugh, (13), who found no marked difference in nitrogen concentration in peach leaves from sand culture experiments as a result of using from zero to sixty parts per million potassium. The results however, do agree to a general statement made by Hoagland (21): "...a large amount of evidence...indicates that soluble organic nitrogen is often higher in concentration in low potassium plants than in high potassium plants..."

When the effects of plus or minus-potassium nutrition on the concentration of calcium, magnesium, phosphorus, and nitrogen in whole trees are considered, averages for all sampling dates revealed a higher concentration of each element in the plus-potassium trees as compared to minus-potassium trees. Even though the leaves showed a higher concentration of nitrogen and phosphorus from minus-potassium nutrition, the results in the trees as a whole, show that a lack of potassium caused a lower concentration of all the elements for which analyses were made. Thus, it would seem that in the tree as a whole, these results are indicative of the fact that a lack of potassium lowered the metabolic activity of the trees.

At the present time there is interest in the matter of supplying nitrogen to apple trees by means of foliar sprays. Burrell and Boynton, (9) have reported a doubling of leaf potassium in six-year-old McIntosh apple trees as a result of several sprays using a 1 per cent potassium sulphate solution. However, Weinberger, Prince, and Havis (42) obtained no definite response in nitrogen content of foliage or on terminal growth by spraying peach trees with urea sprays. In the potassium foliar sprays applied to the peach trees in this experiment, the question arose as to whether or not an apparent increase in leaf potassium may be due simply to the dried spray material which may be adhering to the surface of the leaf only, and not actually absorbed by the leaf. In an attempt to determine whether or not this might be the case, duplicate samples were taken from the same trees on the same day after spray applications were applied. One of the samples was washed for one minute in 1 per cent hydrochloric acid solution, and the other sample was left unwashed. The potassium concentration found in the two samples was quite similar, whether washed or unwashed, but both were about 0.6 per cent higher in potassium than were leaves taken from the same trees before the sprays were applied. This suggests two possibilities, either the potassium entered the leaves and was not removed by washing, or the potassium merely adhered to the leaf surfaces and was not removed by the wash bath. Approximately five weeks later, the potassium concentration in the leaves from the check trees had increased slightly, whereas leaves from the sprayed trees showed a slight decrease. At this time however, leaves from the sprayed trees contained approximately 0.3 per cent more potassium than did the check trees. No definite conclusion can be drawn and further work would be desirable.

It might be stated that if the inconclusive results were due to the washing procedure used, a more effective method might be employed. A longer washing period or a stronger acid solution might be more effective, but such a procedure also may result in a severe loss of potassium from within the leaf tissue (38).

In the young peach plantings in western Maryland which showed potassium deficiency their first year in the field, it was thought that possibly the condition might be due to a lack of available potassium in the soil or to poorly fed nursery trees. One factor leading to the belief that it might be due to the trees themselves, was that deficient young trees seemed to recover somewhat in a year or two without any potassium applications, indicating that potassium was available in the soil but not taken up by newly planted trees. Four of the trees in this experiment, which were grown in the greenhouse one summer and later removed to the field, had received no potassium whatsoever. If these particular trees were able to absorb enough potassium from the soil for normal growth in the field, it would indicate that young trees showing potassium deficiency in the field did not have access to potassium from the soil. The results confirmed this point, for regardless of the previous season's treatment in the greenhouse, all the trees when moved to the field made excellent growth the following season. The leaves from all these trees contained adequate potassium of approximately 2 per cent. Thus it would seem that potassium deficiency showing up in newly planted peach trees is due to the lack of available potassium in the soil rather than to a poorly nourished tree as it is received from the nursery.

Furthermore, it was found that the top-root ratios of the trees at the end of the growing season in the field were quite similar, regardless of their previous nutritional status in the greenhouse. Thus it would seem that even those trees which had very poorly developed root systems when transferred to the field, were able to obtain potassium efficiently from the soil under the prevailing conditions. It had been shown in the greenhouse work that a lack of potassium in the nutrient solution greatly inhibited the amount of roots produced. A possibility as to the failure of young trees to obtain adequate potassium during their early growth might be due to a failure to surround the roots with topsoil containing available potassium at planting time.

Several factors may have entered into the results obtained from the young peach trees taken from the greenhouse and set in the field. Since all of these trees grew well and contained adequate potassium in the leaves, it was evident that they obtained enough potassium from the soil. An analysis of this soil showed only a small amount of available potassium. Calcium and magnesium were present in small and medium amounts, respectively, and the pH was relatively low, being 4.9.

A comparison of this soil with that in which the fertilizer plots were located near Hancock, Maryland, is interesting, since peach trees growing in the latter soil exhibited potassium deficiency during their first year in the orchard. Soil tests showed that potassium was available only in very small amounts where no fertilizer had been applied. This might be accounted for by the fact that the pH was rather high, ranging between six and seven, and by the fact that calcium was available in high and magnesium in medium to very high amounts. Such a condition could possibly be conducive to making potassium unavailable. Another factor which probably contributed to the appearance of potassium deficiency symptoms was that in only very few instances was any available potassium present lower than three inches, and most of the peach feeding roots were below this depth.

The present work was not designed to investigate the function of potassium in plants. Hoagland (21) and Hoffer (24) have presented the theories as to the role of potassium in plant nutrition. The report of Gregory (20) showed a higher respiration rate in barley plants to be correlated with a lack of potassium. It would be interesting to know if this holds true in peach leaves as well. It is possible that a high rate of respiration may be responsible for the so-called leaf "scorching" in cases of potassium deficiency in that the high respiration rate may use up reserve carbohydrates, resulting in death of the affected cells.

SUMMARY AND CONCLUSIONS

The greenhouse studies were conducted in the horticultural greenhouses at the University of Maryland, College Park, Maryland during 1948. The peach trees were grown in sand culture using a nutrient solution with potassium as the only variable. The changes in nutrition were so arranged that certain trees were started on plus-potassium nutrition and at successive monthly intervals were changed to minus-potassium. Other trees were started on minus-potassium nutrition and then changed to plus-potassium at comparable intervals. There were also trees which received either continuous plus-potassium or continuous minus-potassium throughout. A low-potassium (2ppm) treatment was carried throughout the experiment. Entire trees were sampled at the time of the monthly changes in nutrition and were divided into several parts for chemical analyses.

Field fertilizer studies were conducted in an orchard near Hancock, Maryland. Leaf samples were taken over a period of three seasons to determine the effect of the potassium fertilizers applied. In the same orchard some trees were sprayed with several potassium-carrying compounds, and leaf and twig samples taken to determine the effect of the sprays.

From the results obtained from these investigations, the following conclusions may be drawn:

1. Trees which received potassium for one month only (May) and subsequently grown without potassium, were slow in showing potassium deficiency symptoms. No such trees exhibited severe foliar abnormalities.

2. Leaves from trees which were grown without potassium at the beginning of the experiment and later changed to plus-potassium nutrition,

regained much of their normal color despite the loss of necrotic tissue. New leaves which emerged following the change in nutrition were normal, although subtended by symptomatic leaves caused by previous minus-potassium nutrition.

3. The low-potassium (2ppm) treatment was insufficient for the maintenance of normal metabolism. Leaves from such trees exhibited the same foliar symptoms as did the minus-potassium trees, although the first symptoms appeared a few days later.

4. There was no consistent relationship between shoot growth and the length of time during which the trees received potassium in the nutrient solution.

5. Increases in green and dry weight, as obtained in the greenhouse trees, showed a consistent correlation with the periods of time that potassium was supplied. Supplying potassium during the early or latter part of the season for comparable periods of time had little effect on the results.

6. Young peach trees growing in sand culture without potassium, absorbed this element equally well at any time during the season, when subsequently supplied. The effect was apparent in both basal and distal leaves.

7. Potassium concentration in distal leaves clearly reflected the effect of changing from plus-potassium to minus-potassium nutrition.

8. On the basis of the potassium concentrations found in the distal leaves and by the fact that they closely reflected all changes in potassium nutrition, it is suggested that the younger leaves would be the most reliable index for use in determining the potassium nutritional status of peach trees.

9. Potassium content, whether expressed in per cent or on an actual weight basis, was much higher in the leaves than in any other tree fraction.

10. Nitrogen concentration in leaves from both plus and minus-potassium trees decreased seasonally, but when expressed for entire trees on the same dates, the reverse was true.

11. In leaves from minus-potassium trees, the per cent of nitrogen was higher than in the plus-potassium trees. However, nitrogen concentration in entire trees was slightly higher under plus-potassium nutrition. The same relationship existed in regard to phosphorus. Calcium concentration under plus-potassium nutrition was higher in both leaves and in the entire tree as compared to minus-potassium nutrition trees.

12. Continuous plus-potassium nutrition resulted in higher percentages of calcium, magnesium, phosphorus, and nitrogen in entire trees as compared to minus-potassium nutrition, when considered as an average of four sampling dates.

13. Of the various dates on which samples were taken, calcium, magnesium, potassium, phosphorus, and nitrogen were present in continuous plus-potassium trees in greatest amounts on September 1.

14. The longer the period during which the trees received plus-potassium nutrition, the greater was the actual increase of the other elements: calcium, magnesium, phosphorus, and nitrogen. This was shown by trees sampled September 1, which had undergone the complete cycle of potassium nutrition changes as used in the experiment.

15. The greater amounts of calcium, magnesium, phosphorus, and nitrogen absorbed by the trees under plus-potassium nutrition appeared to be more of a function of increased growth as it was correlated with potassium nutrition, rather than the result of any direct effect of the nutrition.

16. Trees which received plus-potassium as well as those which received minus-potassium nutrition, deposited much greater amounts of their total calcium in the leaves as the season progressed, but a much larger proportion was deposited in the leaves of the plus-potassium trees.

17. Over 50 per cent of the total calcium, magnesium, and potassium found in the plus-potassium trees on September 1 was in the leaves, with a smaller proportion being present in the minus-potassium leaves on the same date. At no time was over 50 per cent of the total phosphorus or nitrogen present in the leaves from the plus or minus-potassium treatments.

18. When some of the differentially treated experimental trees were transplanted to the field, no significant differences in trunk diameter or total weight were found, regardless of the previously received treatments. Leaf analyses showed all to contain adequate potassium. No significant differences in the ratio of roots to tops were found after one year's growth in the field.

19. Analyses of leaves from the fertilizer plots revealed greater percentages of potassium with greater amounts of potassium fertilizer applied to the soil.

20. The results of the soil samples taken from the fertilizer plots suggested that low potassium availability may have been due to a high pH as well as to comparatively high amounts of available calcium and magnesium.

21. Results from spraying peach foliage with various potassium-carrying sprays were inconclusive.

LITERATURE CITED

1. Association of Official Agricultural Chemists. Official and tentative methods of analysis. Washington, D.C. 6th Edition, 1945. 932 pp.

2. Baker, C. E. The effect of different methods of soil management upon the potassium content of apple and peach leaves. Proc. Amer. Hort. Sci. 39: 33-37. 1941.

3. ____________ Further results on the effect of different mulching and fertilizer treatments upon the potassium content of apple leaves. Proc. Amer. Soc. Hort. Sci. 42: 7-10. 1943.

4. ____________ The effectiveness of some organic mulches in correcting potassium deficiency in peach trees on a sandy soil. Proc. Amer. Soc. Hort. Sci. 51: 205-208. 1948.

5. ____________ Further studies of the effectiveness of organic mulches in correcting potassium deficiency of peach trees on a sandy soil. Proc. Amer. Soc. Hort. Sci. 53: 21-22. 1949.

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

7. Brown, D. S. The growth and composition of the tops of peach trees in sand culture in relation to nutrient-element balance. W. Va. Agr. Exp. Sta. Bul. 322: 1-72. 1945.

8. Brown, J. G., Lilleland, Omund, and Jackson, R. K. The determination of calcium and magnesium in leaves using flame methods and a quartz spectrophotometer. Proc. Amer. Soc. Hort. Sci. 52: 1-6. 1948.

9. Burrell, A. B., and Boynton, Damon. Response of apple trees to potash in the Champlain valley 111. Proc. Amer. Soc. Hort. Sci. 42: 61-64. 1943.

10. Chandler, R. F., Jr. A study of the effect of various potassium carrying fertilizers upon the growth and yield of apples and peaches. Proc. Amer. Soc. Hort. Sci. 30: 67-69. 1934.

11. ______________ 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 trees. Jour. Agr. Res. 53 (1) : 19-42. 1936.

12. Colby, H. L. Seasonal absorption of nutrient salts by the French prune grown in solution cultures. Plant Physiol. 8: 1-34. 1933.

13. Cullinan, F. P., Scott, D. H., and Waugh, J. G. The effects of varying amounts of nitrogen, potassium, and phosphorus on the growth of young peach trees. Proc. Amer. Soc. Hort. Sci. 36: 61-68. 1939.

14. ______________, and Waugh, J. G. Response of peach trees to potassium under field conditions. Proc. Amer. Soc. Hort. Sci. 37: 87-94. 1940.

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

16. ______________, ______________ Nutrient deficiency and nutrient balance with the peach. Proc. Amer. Soc. Hort. Sci. 35: 339-346. 1938.

17. Dunbar, C. O., and Anthony, R. D. Two cases of potassium deficiency in peach orchards in south central Pennsylvania. Proc. Amer. Soc. Hort. Sci. 35: 320-325. 1938.

18. Gauch, Hugh G. Private communication.

19. Gillam, W. Sherman. A photometric method for the determination of magnesium. Indus. and Engin. Chem., Analyt. Ed. 13: 499-501. 1941.

20. Gregory, F. G., and Richards, F. J. Physiological studies in plant nutrition. 1. The effect of manurial deficiency on the respiration and assimilation rate of barley. Ann. Botany 43: 119-161. 1929.

21. Hoagland, D. R. Lectures on the inorganic nutrition of plants. Chronica Botanica Co., Waltham, Mass. 1948. 226 pp.

22. ______________, and Chandler, W. H. Some effects of deficiencies of phosphate and potassium on the growth and composition of fruit trees under controlled conditions. Proc. Amer. Soc. Hort. Sci. 29: 267-271. 1933.

23. ______________, and Snyder, W. C. Nutrition of strawberry plant under controlled conditions: (a) effects of deficiencies of boron and certain other elements: (b) susceptibility of injury from sodium salts. Proc. Amer. Soc. Hort. Sci. 30: 288-294. 1934.

24. Hoffer, G. N. Potash in plant metabolism: deficiency symptoms as indicators of the role of potassium. Indus. and Engin. Chem. 30: 885-889. 1938.

25. Kemmerer, George, and Hallet, L. T. Improved micro-Kjeldahl ammonia distillation apparatus. Indus. and Engin. Chem. 19: 1295-1296. 1927.

26. Lilleland, Omund, and Brown, J. G. The potassium nutrition of fruit trees 11. Leaf analyses. Proc. Amer. Soc. Hort. Sci. 36: 91-98. 1939.

27. ______________. The potassium nutrition of fruit trees 111. A survey of the potassium content of peach leaves from one hundred and thirty orchards in California. Proc. Amer. Soc. Hort. Sci. 38: 37-48. 1941.

28. Potter, G. F., and Fisher, E. G. Phosphorus and potassium as supplements to nitrogen in sod mulch orchards in New Hampshire. Proc. Amer. Soc. Hort. Sci. 36: 41-44. 1939.

29. ______________, and Percival, G. P. Availability to apple trees of potassium applied on the surface of sod mulch orchards in New Hampshire. Proc. Amer. Soc. Hort. Sci. 35: 335-338. 1938.

30. Ranker, Emery R. A modification of the salicylic-thiosulphate method suitable for the determination of total nitrogen in plants, plant solutions, and soil extracts. Jour. Assoc. Official Agr. Chem. 10: 230-251. 1927.

31. Rawl, E. H. Peach tree abnormalities developing from applications of nitrogen fertilizers alone. Proc. Amer. Soc. Hort. Sci. 33: 293-298. 1936.

32. __________ Peach tree fertilizer demonstration results. Proc. Amer. Soc. Hort. Sci. 37: 85-86. 1940.

33. Scott, L. E. Response of peach trees to potassium and phosphorus fertilizers in the sandhill area of the southeast. Proc. Amer. Sco. Hort. Sci. 36: 56-60. 1939.

34. Shear, C. B., Crane, H. L., and Myers, A. T. Nutrient-element balance: a fundamental concept in plant nutrition. Proc. Amer. Soc. Hort. Sci. 47: 239-248. 1946.

35. Stover, Norman M., and Sandin, Reuben B. Use of boric acid in micro-Kjeldahl determination of nitrogen. Indus. and Engin. Chem., Analyt. Ed. 3: 240-242. 1931.

36. Thomas, Walter. Absorption, utilization, and recovery of nitrogen, phosphorus, and potassium by apple trees grown in cylinders and subjected to differential treatment with nutrient salts. Jour. Agr. Res. 47: 565-581. 1933.

37. Wallace, T. Experiments on the manuring of fruit trees - 1. Jour. Pom. and Hort. Sci. 4: 117-140. 1925.

38. __________ Experiments on the effects of leaching with cold water on the foliage of fruit trees. 1. The cause of leaching of dry matter, ash and potash from leaves of apple, pear, plum, black currant and gooseberry. Jour. Pom. and Hort. Sci. 8: 44-60. 1930.

39. Waugh, J. G., and Cullinan, F. P. The nitrogen, phosphorus, and potassium content of peach leaves as influenced by soil treatments. Proc. Amer. Soc. Hort. Sci. 38: 13-16. 1941.

40. ____________, ________________, and Scott, D. H. Response of young peach trees in sand culture to varying amounts of nitrogen, phosphorus, and potassium. Proc. Amer. Soc. Hort. Sci. 37: 95-96. 1940.

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

42. ______________, Prince, Victor E., and Havis, Leon. Tests on foliar fertilization of peach trees with urea. Proc. Amer. Soc. Hort. Sci. 53: 26-28. 1949.

APPENDIX

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Appendix Table 1. Green Weight of the Trees as They Were Set Out at Beginning of Experiment

Treatment	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	103.4	109.0	138.5	134.0	138.3	157.4	146.6	185.8	169.8
+ - - -	101.5	122.0	138.8	131.8	133.8	140.3	128.0	119.5	172.5
+ + - -	119.0	132.5	124.2	121.0	143.4	152.1	157.0	147.2	163.8
+ + + -	116.4	116.1	115.6	134.4	122.7	165.7	146.2	191.0	175.6
- - - -	100.0	102.6	120.6	148.5	129.0	150.8	145.8	154.1	189.1
- + + +	107.1	112.0	117.1	118.3	102.3	151.3	171.2	159.0	162.3
- - + +	105.0	113.0	120.8	127.0	137.8	145.7	148.5	174.3	173.6
- - - +	100.7	113.0	115.5	118.0	130.0	144.4	140.0	149.0	191.0
Low K	117.7	107.8	126.6	131.5	147.0	129.1	135.7	167.1	214.0

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Appendix Table 2. Original Dry Weight of Trees When Set Out; Also, Dry Weight of the Same Trees on Date Sampled.

(Original dry weights were estimated by multiplying the green weights of the trees as set out by 49.2 per cent. This figure is the average per cent dry weight of six trees similar to the ones used in the experiment.)

Treat-ment	Block 5 Tree No.	Block 5 Original Dry Wt. (gms.)	Block 5 Dry Wt. June 1 (gms.)	Block 8 Tree No.	Block 8 Original Dry Wt. (gms.)	Block 8 Dry Wt. July 1 (gms.)	Block 9 Tree No.	Block 9 Original Dry Wt. (gms.)	Block 9 Dry Wt. Aug. 1 (gms.)
+ + + +	41	68.1	82.8	81	91.4	124.1	48	85.5	118.9
+ - - -	32	68.3	84.5	71	58.8	82.7	16	84.9	126.0
+ + - -	11	61.1	75.9	15	72.4	107.5	76	80.6	106.5
+ + + -	70	56.9	64.1	30	94.0	120.1	55	86.4	124.1
- - - -	8	59.8	65.8	35	75.8	93.4	68	93.0	114.9
- + + +	10	57.6	67.8	77	78.2	105.0	92	79.8	114.9
- - + +	36	59.4	72.9	44	85.7	96.4	43	85.4	118.8
- - - +	26	56.8	68.9	27	73.3	94.2	72	94.0	110.5
Low N	14	62.3	73.2	20	82.2	103.1	94	105.3	148.0

Treat-ment	Block 7 Tree No.	Block 7 Original Dry Wt. (gms.)	Block 7 Dry Wt. Sept. 1 (gms.)	Block 6 Tree No.	Block 6 Original Dry Wt. (gms.)	Block 6 Dry Wt. Dec. 18 (gms.)
+ + + +	21	72.1	155.3	25	77.4	119.1
+ - - -	35	63.0	99.3	51	69.0	95.3
+ + - -	52	77.2	129.2	18	74.8	106.6
+ + + -	7	71.9	136.8	66	81.5	100.9
- - - -	74	71.7	97.5	75	74.2	85.1
- + + +	53	84.2	157.1	56	74.4	122.7
- - + +	42	73.0	116.4	9	71.7	112.9
- - - +	95	65.9	102.6	49	71.0	73.5
Low N	91	66.7	90.2	79	63.5	81.2

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Appendix Table 5. Dry Weight of Various Tree Fractions for all Treatments of Blocks Sampled Throughout the Experiment

Block 5 - Sampled June 1, 1948

Treatment:	Distal Leaves	Basal Leaves	Scion Trunk	Stock Trunk	Limbs	Old Roots	New Roots	Total Dry Weight
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	5.0	5.1	22.5	21.2	1.8	25.0	2.3	82.8
+ - - -	5.7	4.9	24.7	22.4	2.9	21.8	2.1	84.5
+ + - -	5.8	3.3	24.3	17.9	2.0	20.7	2.5	75.9
+ + + -	5.5	2.9	22.8	14.7	1.6	17.1	1.5	64.1
- - - -	8.5	2.4	22.7	18.0	0.6	18.0	1.1	65.3
- + + +	4.4	2.7	22.4	16.0	1.7	19.2	1.4	67.8
- - + +	3.9	3.5	22.1	17.6	1.8	22.5	1.5	72.7
- - - +	4.2	3.5	22.5	16.9	2.5	17.7	1.6	68.9
Low K	4.5	3.0	25.7	20.5	2.0	16.0	1.7	73.2

Block 8 - Sampled July 1, 1948

Treatment	Distal Leaves	Basal Leaves	Scion Trunk	Stock Trunk	Limbs	Old Roots	New Roots	Total Dry Weight
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	7.8	3.4	25.9	27.2	2.7	51.8	5.3	124.1
+ - - -	8.6	3.9	24.3	15.0	5.3	22.6	3.0	82.7
+ + - -	10.3	5.3	30.9	24.5	4.8	27.1	4.6	107.5
+ + + -	8.4	3.1	28.2	27.3	7.2	40.0	5.9	120.1
- - - -	6.2	3.6	31.6	16.0	3.9	30.4	1.7	93.4
- + + +	8.1	4.1	30.8	24.5	4.1	29.6	3.8	105.0
- - + +	5.1	1.7	22.2	27.1	1.4	37.2	1.7	96.4
- - - +	6.9	2.1	31.8	21.2	4.1	26.6	[illegible]	94.2
Low K	9.5	4.0	24.5	26.5	3.4	32.[illegible]	[illegible]	103.1

Block 6 - Sampled December 18, 1948

Treatment	Scion Trunk	Stock Trunk	Limbs	Old Roots	New Roots	Total Dry Weight
	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	28.8	20.0	7.5	45.0	17.8	119.1
+ - - -	22.8	19.5	9.5	33.0	10.5	95.3
+ + - -	27.5	23.5	7.5	37.1	11.0	106.6
+ + + -	28.5	21.8	3.3	39.0	8.3	100.9
- - - -	23.7	21.7	4.5	29.2	6.0	85.1
- + + +	27.5	19.2	10.6	45.5	19.9	122.7
- - + +	32.7	17.0	5.0	41.7	16.5	112.9
- - - +	11.2	19.0	4.1	32.5	6.7	73.5
Low K	25.0	17.8	6.7	25.3	6.4	81.2

Block 9 - Sampled August 1, 1948

Treatment:	Distal Leaves	Basal Leaves	Scion Trunk	Stock Trunk	Limbs	Old Roots	New Roots	Total Dry Weight
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	10.7	5.1	33.7	23.4	3.7	34.2	8.1	118.9
+ - - -	10.0	7.6	39.4	23.4	6.7	31.5	7.4	126.0
+ + - -	7.7	3.5	32.7	25.0	2.5	[illegible].7	5.6	106.5
+ + + -	12.5	5.9	33.7	19.7	5.4	[illegible].9	8.0	124.1
- - - -	7.4	5.8	26.7	30.2	5.9	[illegible].9	4.0	114.9
- + + +	11.5	4.7	35.0	24.5	4.[illegible]	[illegible].6	6.5	114.9
- - + +	10.7	6.5	35.7	26.4	5.2	[illegible].0	4.3	118.8
- - - +	6.1	4.2	29.9	26.7	3.7	[illegible].7	4.0	110.3
Low K	11.1	8.0	29.2	47.4	8.0	[illegible].8	5.5	148.0

Block 7 - Sampled September 1, 1948

Treatment	Distal Leaves	Basal Leaves	Scion Trunk	Stock Trunk	Limbs	Old Roots	New Roots	Total Dry Weight
		gms.	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	16.2	9.5	32.4	25.5	9.0	30.0	12.7	135.3
+ - - -	9.7	5.6	27.7	17.7	7.3	24.3	7.0	99.3
+ + - -	14.2	5.5	23.6	25.6	9.2	39.7	11.4	129.2
+ + + -	16.9	9.9	35.9	19.4	[illegible]	35.9	11.4	136.8
- - - -	7.9	3.4	31.7	19.0	[illegible]	25.3	5.5	97.5
- + + +	16.2	5.9	32.7	31.7	[illegible]	35.9	9.6	137.1
- - + +	11.2	6.3	33.0	26.2	6.2	29.6	7.9	118.4
- - - +	12.0	4.4	36.8	22.1	5.2	22.1	6.0	108.6
Low K	7.9	3.5	30.6	19.7	4.4	20.2	3.9	90.2

Appendix Table 4. Mineral Composition of Whole Trees as Set Out in Greenhouse, Expressed as Absolute Amount of Elements in Grams Per Tree.*

Block 5

Designated treatment	Tree No.	C_a	M_g	K	P	N
		gms.	gms.	gms.	gms.	gms.
+ + + +	41	.115	.037	.142	.066	.522
+ + + -	75	.094	.031	.118	.055	.456
+ + - -	11	.101	.035	.137	.059	.467
+ - - -	32	.113	.037	.142	.066	.534
Low K	14	.103	.034	.130	.060	.479
- - - -	8	.098	.032	.123	.057	.455
- - - +	26	.094	.031	.112	.055	.436
- - + +	36	.097	.032	.124	.053	.456
- + + +	10	.096	.031	.120	.056	.442

Block 8

Designated treatment	Tree No.	C_a	M_g	K	P	N
		gms.	gms.	gms.	gms.	gms.
+ + + +	81	.152	.049	.190	.089	.701
+ + + -	80	.156	.051	.195	.091	.721
+ + - -	13	.120	.039	.151	.070	.555
+ - - -	71	.098	.032	.122	.057	.451
Low K	30	.136	.044	.171	.080	.630
- - - -	33	.126	.041	.158	.073	.581
- - - +	27	.122	.040	.152	.071	.562
- - + +	44	.142	.046	.178	.083	.657
- + + +	77	.130	.042	.163	.076	.600

Block 6

Designated treatment	Tree No.	C_a	M_g	K	P	N
	gms.	gms.	gms.	gms.	gms.	gms.
+ + + +	23	.128	.042	.161	.075	.594
+ - - -	66	.135	.044	.169	.079	.625
+ + - -	18	.124	.040	.156	.073	.574
+ - - -	51	.114	.037	.143	.067	.529
Low K	79	.105	.034	.132	.062	.487
- - - -	73	.123	.040	.154	.072	.569
- - - +	49	.118	.038	.148	.069	.545
- - + +	9	.119	.039	.149	.069	.550
- + + +	56	.123	.040	.155	.072	.571

Block 9

Designated treatment	Tree No.	C_a	M_g	K	P	N
		gms.	gms.	gms.	gms.	gms.
+ + + +	46	.139	.045	.174	.081	.640
+ + + -	55	1143	.047	.180	.084	.665
+ + - -	76	.154	.043	.168	.078	.610
+ - - -	16	.141	.046	.177	.082	.651
Low K	94	.175	.057	.219	.102	.806
- - - -	68	.154	.050	.195	.090	.713
- - - +	72	.156	.051	.195	.091	.721
- - + +	43	.149	.046	.178	.083	.655
- + + +	92	.138	.045	.166	.077	.612

Block 7

Designated treatment	Tree No.	C_a	M_g	K	P	N
		gms.	gms.	gms.	gms.	gms.
+ + + +	21	.120	.039	.150	.070	.553
+ + + -	7	.119	.039	.150	.070	.551
+ + - -	52	.128	.042	.161	.075	.592
+ - - -	35	.105	.034	.131	.061	.483
Low K	91	.111	.036	.139	.065	.512
- - - -	74	.119	.039	.149	.069	.550
- - - +	93	.114	.037	.143	.066	.528
- - + +	42	.121	.039	.152	.071	.560
- + + +	58	.140	.045	.175	.082	.646

* An estimate based on the analyses of a comparable lot of trees at beginning of experiment

[redacted]

Appendix Table 5. Mineral Composition of Whole Trees at Time of Sampling Expressed as Absolute Amount of Elements in Grams Per Tree.

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
+ + + +	.202	.279	.267	.366	.202
+ - - -	.172	.202	.250	.214	.163
+ + - -	.205	.222	.213	.280	.176
+ + + -	.140	.296	.297	.331	.164
- - - -	.164	.167	.252	.182	.124
- + + +	.186	.243	.266	.292	.230
- - + +	.171	.221	.213	.207	.217
- - - +	.157	.186	.204	.190	.101
Low K	.169	.255	.284	.147	.117

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
+ + + +	.066	.080	.078	.137	.058
+ - - -	.064	.064	.090	.088	.045
+ + - -	.069	.088	.065	.117	.055
+ + + -	.049	.084	.096	.135	.041
- - - -	.050	.071	.079	.068	.034
- + + +	.063	.078	.074	.110	.060
- - + +	.058	.056	.082	.082	.049
- - - +	.062	.060	.061	.083	.029
Low K	.070	.075	.106	.069	.034

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
+ + + +	.409	.442	.598	1.034	.374
+ - - -	.389	.303	.345	.223	.152
+ + - -	.321	.521	.299	.481	.189
+ + + -	.267	.553	.711	.718	.169
- - - -	.130	.137	.208	.165	.106
- + + +	.122	.379	.473	.755	.370
- - + +	.137	.123	.455	.516	.326
- - - +	.125	.141	.168	.460	.186
Low K	.162	.172	.247	.184	.119

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
+ + + +	.135	.206	.275	.386	.277
+ - - -	.118	.180	.310	.269	.804
+ + - -	.108	.200	.207	.346	.221
+ + + -	.092	.218	.304	.372	.178
- - - -	.061	.163	.239	.215	.140
- + + +	.099	.188	.244	.315	.297
- - + +	.091	.129	.273	.262	.243
- + + +	.101	.144	.217	.259	.150
Low K	.114	.198	.364	.196	.170

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
+ + + +	.791	1.081	1.272	1.972	1.488
+ - - -	.821	.905	1.382	1.386	1.160
+ + - -	.759	1.090	.983	1.827	1.278
+ + + -	.545	1.047	1.341	2.063	1.035
- - - -	.524	.884	1.128	1.182	.811
- + + +	.675	.946	1.199	1.787	1.597
- - + +	.723	.776	1.232	1.396	1.375
- + + +	.696	.857	1.039	1.390	.846
Low K	.772	1.101	1.600	1.101	.895

Block 3 sampled on June 1, Block 8 on July 1, Block 9 on August 1, Block 7 on September 1, and Block 6 on December 18.

[redacted]

Appendix 6. Increase in Mineral Composition of Whole Trees From Time of Planting to Sampling Date, Expressed in Grams of Increase of each Element Per Tree.

Potassium Increase

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	gms.	gms.	gms.	gms.	gms.
+ + + +	.268	.252	.424	.385	.213
+ − − −	.247	.181	.1688	.092	.009
+ + − −	.194	.370	.131	.321	.033
+ + + −	.147	.357	.532	.569	.0003
− − − −	.006	−.020	.015	.016	−.048
− + + +	.003	.217	.307	.580	.215
− − + +	.013	−.055	.278	.365	.177
− − − +	.009	−.011	−.027	.317	.038
Low K	.032	.001	.028	.046	−.014

Calcium Increase

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	gms.	gms.	gms.	gms.	gms.
+ + + +	.089	.127	.129	.246	.074
+ − − −	.059	.104	.109	.109	.049
+ + − −	.103	.102	.060	.151	.052
+ + + −	.045	.140	.154	.212	.028
− − − −	.065	.042	.077	.063	.001
− + + +	.090	.113	.133	.153	.106
− − + +	.073	.078	.072	.086	.098
− − − +	.063	.065	.047	.075	−.017
Low K	.066	.098	.109	.037	.012

Nitrogen Increase

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	gms.	gms.	gms.	gms.	gms.
+ + + +	.269	.380	.632	1.419	.894
+ − − −	.297	.454	.731	.903	.631
+ + − −	.291	.534	.365	1.235	.704
+ + + −	.109	.326	.678	1.512	.410
− − − −	.069	.303	.415	.572	.242
− + + +	.233	.346	.586	1.141	1.026
− − + +	.268	.119	.577	.837	.828
− − − +	.261	.295	.312	.862	.301
Low K	.294	.471	.792	.589	.409

Magnesium Increase

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	gms.	gms.	gms.	gms.	gms.
+ + + +	.029	.031	.033	.095	.016
+ − − −	.027	.032	.044	.054	.008
+ + − −	.036	.049	.020	.070	.015
+ + + +	.018	.033	.049	.095	−.004
− − − −	.018	.030	.029	.030	−.006
− + + +	.032	.036	.031	.064	.020
− − + +	.026	.010	.036	.042	.010
− − − +	.031	.020	.010	.046	−.009
Low K	.036	.031	.049	.032	−.0004

Phosphorus Increase

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	gms.	gms.	gms.	gms.	gms.
+ + + +	.063	.117	.194	.340	.202
+ − − −	.052	.133	.227	.203	.137
+ + − −	.049	.130	.129	.271	.148
+ + + +	.037	.127	.221	.302	.099
− − − −	.024	.089	.143	.145	.068
− + + +	.043	.112	.167	.234	.225
− − + +	.034	.046	.190	.191	.173
− − − +	.046	.073	.136	.193	.081
Low K	.054	.118	.262	.131	.108

Appendix Table 7. Mineral Composition of Distal Leaves on Dry Weight Basis. (All Treatments on All Sampling Dates).

Treatment	Potassium				Calcium				Magnesium			
	June 1	July 1	Aug. 1	Sept. 1	June 1	July 1	Aug. 1	Sept. 1	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%	%	%	%	%	%	%	%	%
+ + + +	1.84	1.80	2.13	2.60	.42	.87	.76	.87	.29	.40	.26	.29
+ - - -	1.68	.86	.99	.56	.26	.51	.58	.45	.26	.26	.26	.28
+ + - -	1.62	2.01	1.36	1.26	.34	.47	.79	.73	.30	.34	.30	.28
+ + + -	1.66	2.04	2.28	1.75	.38	.76	.79	.73	.26	.39	.28	.29
- - - -	.96	.42	.51	.56	.22	.41	.54	.45	.33	.36	.30	.29
- + + +	.64	1.47	1.77	2.02	.26	.63	.75	.66	.33	.34	.28	.27
- - + +	.72	.42	1.42	1.75	.22	.66	.49	.49	.31	.43	.24	.22
- - - +	.68	.41	.54	1.48	.30	.41	.54	.49	.36	.31	.29	.27
Low K	.78	.47	.44	.69	.24	.49	.47	.31	.38	.31	.29	.28

Treatment	Nitrogen				Phosphorus			
	June 1	July 1	Aug. 1	Sept. 1	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%	%	%	%	%
+ + + +	3.78	3.66	3.53	3.41	.49	.53	.52	.54
+ - - -	4.15	3.77	3.80	3.58	.43	.54	.67	.64
+ + - -	4.62	3.34	3.71	3.31	.43	.46	.57	.61
+ + + -	4.02	3.45	3.35	3.65	.47	.59	.53	.53
- - - -	4.59	4.21	4.10	3.91	.49	.54	.71	.70
- + + +	4.56	3.61	3.32	3.61	.49	.49	.51	.53
- - + +	4.64	3.98	3.98	3.63	.45	.54	.64	.52
- - - +	4.57	4.40	4.29	3.56	.54	.48	.61	.57
Low K	4.53	4.10	4.06	4.06	.47	.58	.75	.63

[redacted]

Appendix Table 8. Mineral Composition of Basal Leaves on Dry Weight Basis. (All Treatments on All Sampling Dates).

Treatment	Potassium June 1	Potassium July 1	Potassium Aug. 1	Potassium Sept. 1	Calcium June 1	Calcium July 1	Calcium Aug. 1	Calcium Sept. 1	Magnesium June 1	Magnesium July 1	Magnesium Aug. 1	Magnesium Sept. 1
	%	%	%	%	%	%	%	%	%	%	%	%
+ + + +	1.98	1.65	2.13	2.53	.50	.77	.60	.73	.32	.41	.30	.30
+ - - -	1.66	1.23	.88	.56	.32	.76	.70	.60	.27	.30	.35	.32
+ + - -	1.28	1.29	1.32	1.26	.42	.53	.70	.66	.37	.37	.35	.30
+ + + -	1.34	1.83	2.01	1.84	.30	.62	.78	.60	.27	.34	.35	.28
- - - -	.88	.31	.41	.45	.44	.51	.65	.60	.49	.47	.37	.37
- + + +	.42	1.23	1.22	1.75	.40	.62	.46	.39	.51	.42	.31	.31
- - + +	.60	.24	1.20	1.46	.34	.28	.59	.49	.42	.34	.34	.25
- - - +	.44	.17	.49	1.35	.38	.23	.62	.42	.39	.24	.32	.32
Low K	.70	.38	.32	.66	.24	.53	.49	.46	.40	.40	.33	.37

Treatment	Nitrogen June 1	Nitrogen July 1	Nitrogen Aug. 1	Nitrogen Sept. 1	Phosphorus June 1	Phosphorus July 1	Phosphorus Aug. 1	Phosphorus Sept. 1
	%	%	%	%	%	%	%	%
+ + + +	3.57	2.82	2.95	3.09	.38	.49	.55	.54
+ - - -	3.67	2.93	2.81	3.23	.35	.49	.61	.59
+ + - -	3.77	3.17	2.91	2.66	.38	.36	.57	.62
+ + + -	3.24	2.82	2.75	3.20	.35	.49	.54	.52
- - - -	3.43	3.84	3.51	3.27	.41	.51	.78	.81
- + + +	3.41	2.84	2.89	2.78	.42	.47	.52	.56
- - + +	3.66	2.99	3.14	3.03	.37	.28	.64	.54
- - - +	3.75	3.44	3.61	3.07	.42	.25	.58	.56
Low K	3.54	3.22	3.64	3.41	.38	.53	.81	.63

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Appendix Table 9. Mineral Composition of Leaves (Basal Plus Distal) on Dry Weight Basis. (All treatments on all sampling dates). Data given were derived from tables 7 and 8 by using actual leaf weights and percentages of potassium in distal and basal leaves.

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	1.91	1.76	2.13	2.58
+ - - -	1.67	.97	.95	.56
+ + - -	1.49	1.76	1.01	1.26
+ + + -	1.51	1.98	2.19	1.79
- - - -	.93	.38	.48	.53
- + + +	.56	1.39	1.61	1.95
- - + +	.67	.38	1.37	1.66
- - - +	.57	.35	.52	1.45
Low K	.75	.44	.39	.68

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	.46	.84	.71	.82
+ - - -	.29	.59	.63	.50
+ + - -	.37	.49	.58	.71
+ + + -	.34	.72	.79	.68
- - - -	.33	.45	.58	.49
- + + +	.31	.63	.66	.59
- - + +	.28	.57	.53	.49
- - - +	.34	.37	.58	.47
Low K	.24	.50	.48	.36

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	.31	.41	.37	.30
+ - - -	.26	.27	.30	.29
+ + - -	.33	.35	.24	.28
+ + + -	.27	.38	.30	.29
- - - -	.41	.40	.35	.31
- + + +	.40	.37	.29	.28
- - + +	.36	.41	.28	.23
- - - +	.37	.30	.30	.28
Low K	.39	.34	.31	.31

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	3.67	3.42	3.34	3.29
+ - - -	3.92	3.51	3.38	3.45
+ + - -	4.31	3.28	3.64	3.13
+ + + -	3.67	3.28	3.16	3.48
- - - -	4.07	4.09	3.92	3.72
- + + +	4.12	3.35	3.19	3.39
- - + +	4.22	3.75	3.67	3.44
- - - +	4.19	4.18	4.03	3.43
Low K	4.13	3.84	3.89	3.86

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	.33	.52	.53	.54
+ - - -	.40	.52	.65	.62
+ + - -	.41	.43	.43	.63
+ + + -	.42	.56	.53	.53
- - - -	.46	.53	.74	.73
- + + +	.46	.48	.52	.54
- - + +	.41	.48	.64	.53
- - - +	.49	.43	.60	.57
Low K	.43	.57	.78	.63

[redacted]

Appendix Table 10. Mineral Composition of Limbs on Dry Weight Basis. (All treatments on all sampling dates).

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	1.34	1.00	.90	.69	.70
+ - - -	1.34	.70	.58	.34	.32
+ + - -	1.40	.90	.68	.50	.45
+ + + -	1.40	.88	.86	.58	.52
- - - -	.64	.34	.39	.30	.24
- + + +	.64	.78	.74	.69	.67
- - + +	.55	.46	.74	.62	.64
- - - +	.55	.36	.38	.55	.76
Low K	.78	.50	.34	.32	.24

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.64	.68	.60	.49	.74
+ - - -	.64	.56	.22	.30	.59
+ + - -	.62	.34	.40	.34	.66
+ + + -	.62	.52	.52	.46	.98
- - - -	.42	.24	.30	.32	.46
- + + +	.42	.42	.22	.62	.68
- - + +	.38	.52	.30	.42	1.00
- - - +	.38	.24	.22	.30	.66
Low K	.40	.38	.22	.24	.28

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.270	.145	.110	.145	.115
+ - - -	.270	.095	.110	.128	.145
+ + - -	.280	.080	.130	.130	.145
+ + + -	.280	.080	.120	.130	.153
- - - -	.345	.100	.100	.118	.115
- + + +	.345	.100	.110	.110	.135
- - + +	.260	.150	.110	.118	.135
- - - +	.260	.080	.120	.110	.165
Low K	.290	.090	.120	.100	.070

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	1.66	1.57	1.67	1.72	2.05
+ - - -	1.66	1.36	1.57	1.95	2.21
+ + - -	2.04	1.34	1.94	1.72	2.25
+ + + -	2.04	1.20	1.52	1.92	2.38
- - - -	2.23	1.72	1.49	2.09	2.46
- + + +	2.23	1.35	1.76	2.12	1.90
- - + +	2.07	2.23	1.57	1.65	1.99
- - - +	2.07	1.67	1.92	2.16	2.26
Low K	2.51	1.99	2.58	2.38	2.45

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.367	.526	.563	.441	.281
+ - - -	.367	.465	.526	.502	.502
+ + - -	.471	.441	.588	.497	.514
+ + + -	.471	.428	.526	.477	.490
- - - -	.553	.490	.490	.526	.502
- + + +	.553	.409	.514	.502	.392
- - + +	.495	.588	.551	.441	.379
- - - +	.495	.477	.575	.514	.441
Low K	.518	.588	.575	.588	.441

[redacted]

Appendix Table 11. Mineral Composition of Scion Trunks on Dry Weight Basis. (All Treatments on All Sampling Dates).

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.180	.160	.160	.205	.210
+ - - -	.180	.220	.095	.150	.105
+ + - -	.160	.190	.105	.165	.115
+ + + -	.190	.210	.190	.155	.137
- - - -	.120	.090	.172	.100	.075
- + + +	.110	.120	.150	.172	.185
- - + +	.100	.120	.155	.165	.172
- - - +	.100	.120	.095	.245	.172
Low K	.170	.110	.105	.132	.095

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.190	.170	.155	.124	.140
+ - - -	.170	.160	.110	.255	.145
+ + - -	.220	.120	.150	.140	.145
+ + + -	.190	.170	.155	.150	.135
- - - -	.190	.110	.185	.165	.140
- + + +	.300	.140	.190	.115	.135
- - + +	.200	.210	.105	.115	.180
- - - +	.220	.170	.140	.105	.135
Low K	.270	.150	.160	.165	.170

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.040	.032	.030	.045	.045
+ - - -	.042	.037	.022	.055	.042
+ + - -	.052	.035	.025	.045	.042
+ + + -	.060	.045	.030	.045	.032
- - - -	.050	.040	.060	.040	.040
- + + +	.055	.035	.020	.055	.035
- - + +	.040	.040	.030	.040	.030
- - - +	.047	.045	.025	.035	.037
Low K	.062	.035	.030	.045	.037

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.352	.423	.408	.503	.636
+ - - -	.382	.498	.382	.569	.742
+ + - -	.346	.406	.390	.444	.703
+ + + -	.373	.381	.409	.534	.678
- - - -	.299	.352	.406	.433	.616
- + + +	.381	.403	.394	.420	.559
- - + +	.386	.406	.408	.400	.604
- - - +	.391	.387	.390	.592	.574
Low K	.493	.450	.415	.542	.727

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.067	.104	.147	.153	.144
+ - - -	.079	.110	.122	.098	.147
+ + - -	.055	.110	.110	.104	.122
+ + + -	.055	.091	.153	.134	.116
- - - -	.061	.091	.091	.110	.085
- + + +	.061	.104	.134	.116	.098
- - + +	.055	.085	.110	.122	.091
- - - +	.055	.085	.134	.122	.098
Low K	.073	.110	.104	.098	.104

[redacted]

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Appendix Table 12. Mineral Composition of Stock Trunks on Dry Weight Basis. (All Treatments on All Sampling Dates).

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.130	.120	.160	.172	.200
+ - - -	.110	.120	.095	.105	.085
+ + - -	.105	.170	.115	.137	.115
+ + + -	.110	.180	.160	.142	.115
- - - -	.080	.070	.075	.100	.082
- + + +	.060	.140	.120	.172	.177
- - + +	.070	.060	.125	.145	.150
- - - +	.060	.060	.080	.137	.145
Low K	.075	.060	.092	.085	.100

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.270	.190	.180	.155	.210
+ - - -	.210	.220	.185	.172	.205
+ + - -	.330	.220	.185	.205	.180
+ + + -	.250	.260	.190	.155	.200
- - - -	.330	.230	.190	.185	.165
- + + +	.370	.230	.210	.180	.232
- - + +	.320	.250	.180	.172	.255
- - - +	.250	.220	.240	.185	.135
Low K	.230	.260	.185	.172	.165

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.040	.035	.022	.030	.037
+ - - -	.032	.035	.020	.032	.027
+ + - -	.040	.035	.020	.035	.035
+ + + -	.035	.035	.022	.032	.032
- - - -	.032	.030	.020	.026	.025
- + + +	.042	.035	.020	.029	.030
- - + +	.042	.027	.020	.030	.025
- - - +	.030	.035	.022	.037	.015
Low K	.040	.035	.020	.035	.040

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.355	.335	.432	.560	.827
+ - - -	.356	.354	.583	.515	.538
+ + - -	.366	.358	.350	.583	.702
+ + + -	.341	.351	.396	.551	.588
- - - -	.443	.326	.404	.421	.480
- + + +	.385	.326	.374	.491	.767
- - + +	.425	.349	.359	.459	.705
- - - +	.317	.333	.342	.472	.646
Low K	.407	.381	.318	.417	.645

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.061	.079	.122	.134	.122
+ - - -	.049	.091	.122	.162	.091
+ + - -	.061	.104	.122	.116	.110
+ + + -	.061	.061	.116	.122	.104
- - - -	.049	.079	.110	.091	.091
- + + +	.044	.091	.110	.110	.116
- - + +	.020	.067	.116	.104	.110
- - - +	.038	.083	.079	.116	.098
Low K	.067	.055	.091	.110	.128

[redacted]

Appendix Table 13. Mineral Composition of Old Roots on Dry Weight Basis. (All Treatments on All Sampling Dates).

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.270	.215	.255	.300	.245
+ - - -	.230	.255	.175	.37	.137
+ + - -	.220	.295	.170	.190	.150
+ + + -	.220	.295	.270	.185	.150
- - - -	.130	.140	.142	.115	.125
- + + +	.130	.265	.250	.290	.225
- - + +	.130	.115	.195	.260	.220
- - - +	.130	.145	.105	.210	.195
Low K	.150	.135	.140	.132	.142

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.160	.125	.100	.075	.100
+ - - -	.140	.105	.105	.050	.075
+ + - -	.210	.135	.070	.050	.085
+ + + -	.150	.135	.075	.060	.105
- - - -	.230	.155	.100	.080	.100
- + + +	.160	.155	.100	.080	.110
- - + +	.190	.155	.060	.145	.105
- - - +	.160	.150	.030	.067	.075
Low K	.160	.135	.095	.045	.075

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.035	.020	.027	.050	.040
+ - - -	.032	.032	.032	.035	.027
+ + - -	.050	.027	.025	.037	.045
+ + + -	.035	.025	.037	.040	.037
- - - -	.035	.030	.032	.027	.032
- + + +	.035	.025	.025	.035	.037
- - + +	.030	.0[illegible]2	.027	.035	.040
- - - +	.040	.025	.025	.030	.030
Low K	.040	.020	.035	.030	.037

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.725	.586	.669	.999	1.179
+ - - -	.613	.657	.787	1.065	1.122
+ + - -	.711	.696	.614	1.107	1.212
+ + + -	.601	.560	.641	.998	1.044
- - - -	.754	.683	.688	.863	.990
- + + +	.834	.618	.678	.978	1.234
- - + +	.796	.715	.511	.840	1.193
- - - +	.807	.674	.653	.984	1.158
Low K	.965	.710	.760	.925	1.005

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.158	.122	.165	.214	.220
+ - - -	.110	.159	.159	.232	.183
+ + - -	.1[illegible]2	.134	.140	.189	.189
+ + + -	.134	.140	.171	.196	.171
- - - -	.146	.147	.143	.153	.165
- + + +	.146	.140	.134	.147	.229
- - + +	.134	.122	.134	.177	.208
- - - +	.134	.134	.159	.196	.218
Low K	.181	.155	.183	.159	.245

[redacted]

Appendix Table 14. Mineral Composition of New Roots on Dry Weight Basis. (All Treatments on All Sampling Dates).

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	2.550	.600	.610	.370	.620
+ - - -	2.550	.500	.330	.265	.345
+ + - -	2.490	.480	.350	.330	.370
+ + + -	3.240	.590	.760	.410	.355
- - - -	1.240	.260	.275	.210	.390
- + + +	.920	.730	.550	.760	.560
- - + +	1.020	.310	.920	.470	.730
- - - +	.720	.320	.330	.450	.660
Low K	1.020	.300	.300	.230	.390

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.170	.110	.050	.070	.110
+ - - -	.170	.100	.050	.020	.090
+ + - -	.170	.100	.050	.020	.120
+ + + -	.140	.110	.060	.070	.100
- - - -	.080	.090	.140	.060	.090
- + + +	.080	.100	.050	.075	.130
- - + +	.080	.170	.090	.045	.130
- - - +	.100	.170	.040	.035	.130
Low K	.080	.150	.070	.055	.120

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.150	.050	.080	.085	.060
+ - - -	.175	.115	.080	.055	.075
+ + - -	.200	.060	.080	.080	.070
+ + + -	.180	.045	.065	.100	.065
- - - -	.360	.070	.075	.050	.070
- + + +	.250	.070	.065	.090	.070
- - + +	.260	.080	.100	.065	.070
- - - +	.260	.080	.065	.058	.080
Low K	.260	.080	.090	.050	.055

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	2.44	2.82	2.66	2.87	2.56
+ - - -	2.32	2.39	2.61	2.98	2.81
+ + - -	2.17	2.59	2.76	3.15	2.74
+ + + -	2.60	2.68	2.65	2.92	2.75
- - - -	2.44	2.64	2.92	3.07	2.69
- + + +	2.68	2.47	2.88	2.96	2.68
- - + +	2.87	2.51	2.91	2.97	2.79
- - - +	2.33	2.49	2.61	2.91	2.83
Low K	2.80	2.46	2.82	3.10	2.83

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.750	.404	.441	.465	.514
+ - - -	.530	.441	.453	.355	.428
+ + - -	.564	.355	.379	.416	.477
+ + + -	.896	.404	.465	.465	.477
- - - -	.594	.543	.493	.294	.490
- + + +	.548	.416	.416	.465	.514
- - + +	.454	.355	.537	.379	.539
- - - +	.548	.379	.404	.416	.514
Low K	.594	.543	.465	.363	.465

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Appendix Table 15. Mineral Composition of Whole Trees on Dry Weight Basis. (All Treatments on All Sampling Dates)

Calcium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.243	.224	.224	.270	.169
+ - - -	.203	.244	.198	.215	.171
+ + - -	.269	.206	.200	.216	.165
+ + + -	.218	.246	.239	.242	.162
- - - -	.250	.179	.201	.186	.146
- + + +	.274	.231	.231	.213	.187
- - + +	.235	.229	.179	.174	.192
- - - +	.227	.197	.184	.174	.137
Low K	.230	.227	.191	.163	.144

Magnesium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.079	.064	.065	.101	.048
+ - - -	.075	.077	.071	.088	.047
+ + - -	.090	.081	.059	.086	.051
+ + + -	.076	.069	.077	.098	.040
- - - -	.076	.076	.069	.070	.039
- + + +	.093	.074	.064	.079	.049
- - + +	.079	.058	.069	.069	.043
- - - +	.090	.063	.055	.076	.039
Low K	.095	.072	.071	.075	.041

Potassium

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.494	.356	.502	.764	.313
+ - - -	.460	.366	.273	.224	.159
+ + - -	.423	.484	.280	.372	.177
+ + + -	.414	.460	.573	.525	.167
- - - -	.198	.146	.181	.169	.124
- + + +	.180	.361	.412	.550	.300
- - + +	.188	.127	.383	.436	.288
- - - +	.181	.149	.152	.423	.252
Low K	.221	.167	.166	.204	.145

Phosphorus

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.162	.165	.231	.285	.232
+ - - -	.139	.217	.245	.270	.214
+ + - -	.142	.185	.194	.267	.206
+ + + -	.143	.181	.245	.271	.176
- - - -	.124	.174	.207	.220	.164
- + + +	.145	.178	.212	.230	.242
- - + +	.125	.133	.229	.221	.215
- - - +	.146	.153	.197	.238	.203
Low K	.156	.192	.246	.216	.209

Nitrogen

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	.955	.871	1.070	1.457	1.249
+ - - -	.971	1.093	1.097	1.396	1.217
+ + - -	1.000	1.013	.923	1.414	1.199
+ + + -	.850	.871	1.080	1.508	1.026
- - - -	.802	.946	.981	1.151	.953
- + + +	.995	.901	1.043	1.303	1.301
- - + +	.995	.805	1.037	1.179	1.217
- - - +	1.010	.909	.942	1.280	1.151
Low K	1.054	1.067	1.080	1.220	1.103

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Appendix Table 16. Distribution of Calcium in Peach Trees, Expressed as Per Cent of Total Amount in Tree Found in Various Tree Parts.

Leaves

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	23.0	33.8	42.1	57.6
+ - - -	17.7	36.4	44.7	36.1
+ + - -	15.5	34.4	39.6	50.5
+ + + -	15.7	23.1	48.9	55.4
- - - -	9.9	26.2	28.0	30.1
- + + +	11.9	31.4	40.0	44.4
- - + +	11.6	17.4	42.5	39.4
- - - +	16.5	17.8	29.1	41.0
Low K	10.6	28.9	32.1	28.0

Scion Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	21.1	15.8	19.5	11.0	1.99
+ - - -	24.4	19.3	17.3	33.0	20.2
+ + - -	26.1	16.7	23.0	11.8	22.6
+ + + -	30.9	16.2	17.6	16.3	23.5
- - - -	26.3	20.7	21.3	28.7	26.7
- + + +	36.1	17.7	23.0	12.8	16.2
- - + +	25.8	21.1	17.6	18.3	27.1
- - - +	31.5	29.0	20.6	20.3	15.0
Low K	41.0	15.7	16.4	34.3	36.2

Stock Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	28.3	18.5	15.8	10.8	20.7
+ - - -	27.3	16.3	17.3	14.2	24.5
+ + - -	28.8	24.2	21.7	18.8	24.0
+ + + -	26.9	24.0	12.6	9.1	26.6
- - - -	36.3	22.0	24.7	19.3	28.8
- + + +	31.0	23.2	19.4	19.5	19.4
- - + +	32.9	30.7	22.3	21.7	19.9
- - - +	26.9	25.0	31.5	21.5	25.4
Low K	27.6	29.4	30.9	23.0	25.0

Limbs

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	5.9	6.6	8.3	12.0	27.4
+ - - -	10.8	14.7	5.9	10.2	34.5
+ + - -	6.2	7.5	4.7	11.2	28.1
+ + + -	7.3	12.6	9.4	10.5	19.8
- - - -	1.7	5.6	7.3	8.3	16.6
- + + +	3.8	7.2	3.6	10.9	31.4
- - + +	4.0	3.3	7.4	12.6	23.0
- - - +	6.0	5.3	4.0	8.2	26.8
Low K	4.7	5.6	6.2	7.2	16.0

Old Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	19.8	23.2	12.8	6.1	22.2
+ - - -	17.7	11.7	13.2	5.7	15.1
+ + - -	21.2	15.2	9.7	7.1	17.9
+ + + -	18.3	16.9	9.8	6.5	25.0
- - - -	25.3	24.5	15.9	11.1	23.5
- + + +	16.5	18.9	10.8	9.8	21.8
- - + +	25.0	26.1	8.4	6.2	20.1
- - - +	18.0	21.4	14.0	7.8	24.1
Low K	15.1	18.5	13.0	6.2	16.2

New Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	1.8	2.1	1.5	2.4	9.7
+ - - -	2.1	1.5	1.5	0.6	5.8
+ + - -	2.1	2.1	1.3	0.8	7.5
+ + + -	1.5	2.2	1.6	2.4	5.1
- - - -	0.5	0.9	2.4	1.8	4.3
- + + +	0.6	1.6	1.2	2.5	11.3
- - + +	0.7	1.3	1.8	1.7	9.9
- - - +	1.0	1.4	0.8	1.1	8.6
Low K	0.8	1.9	1.3	1.4	6.5

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Appendix Table 17. Distribution of Magnesium in Peach Trees, Expressed as Per Cent of Total Amount in Tree Found in Various Tree Parts.

Leaves

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	47.4	56.7	55.2	55.5
+ - - -	43.8	53.2	58.9	51.5
+ + - -	40.8	62.1	55.1	50.4
+ + + -	34.7	51.6	57.9	57.2
- - - -	40.5	55.4	46.1	52.1
- + + +	45.6	57.1	62.3	56.6
- - + +	45.2	50.3	58.6	46.8
- - - +	46.3	44.8	51.7	55.8
Low K	41.9	60.4	56.2	51.7

Scion Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	13.7	10.3	12.9	10.6	22.5
+ - - -	16.2	14.0	9.7	17.3	21.1
+ + - -	18.3	12.3	12.9	9.5	21.0
+ + + -	27.8	15.1	10.5	12.0	22.3
- - - -	22.8	17.8	20.2	18.5	28.2
- + + +	19.4	13.8	9.4	10.4	15.9
- - + +	15.5	15.9	13.0	16.1	20.0
- - - +	17.0	24.0	12.3	15.4	14.3
Low K	22.8	11.4	8.5	20.1	27.2

Stock Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	12.9	11.9	6.6	5.6	12.8
+ - - -	11.2	8.2	5.2	6.4	11.6
+ + - -	10.4	9.7	7.9	8.0	14.9
+ + + -	10.4	11.4	4.5	4.6	17.0
- - - -	11.6	6.7	7.6	7.2	16.1
- + + +	10.6	10.9	6.6	8.4	9.5
- - + +	12.8	13.1	6.4	9.6	8.7
- - - +	8.1	12.2	9.7	9.8	9.9
Low K	11.6	12.3	8.9	10.0	21.0

Limbs

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	7.6	4.9	5.2	9.5	14.9
+ - - -	12.2	7.8	8.2	10.6	30.3
+ + - -	8.3	4.4	5.1	10.7	19.7
+ + + -	9.4	6.8	6.7	7.1	12.3
- - - -	4.5	5.5	7.4	8.1	15.4
- + + +	9.2	5.3	6.4	5.2	23.7
- - + +	8.1	3.7	7.0	8.9	13.8
- - - +	10.4	5.6	7.3	6.8	23.4
Low K	8.3	4.1	9.1	6.4	13.8

Old Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	13.3	12.9	11.8	10.9	31.2
+ - - -	10.9	11.3	11.3	9.7	19.6
+ + - -	15.0	8.3	11.7	13.1	30.3
+ + + -	12.1	11.9	15.0	10.6	35.2
- - - -	12.6	12.8	14.9	10.0	27.8
- + + +	10.6	9.4	9.6	11.5	27.8
- - + +	11.7	14.6	9.8	12.2	34.0
- - - +	11.4	11.1	14.7	7.9	33.8
Low K	9.1	8.6	12.8	8.8	27.6

New Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	5.0	3.3	8.3	7.8	18.5
+ - - -	5.7	5.4	6.6	4.4	17.3
+ + - -	7.2	3.1	7.1	8.2	14.0
+ + + -	5.5	3.2	5.4	8.4	13.2
- - - -	7.9	1.7	3.8	4.0	12.5
- + + +	5.5	3.4	5.7	7.9	23.0
- - + +	6.8	2.4	5.2	6.3	23.5
- - - +	6.7	2.1	4.3	4.2	18.6
Low K	6.3	3.2	4.7	2.8	10.4

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Appendix Table 18. Distribution of Potassium in Peach Trees, Expressed as Per Cent of Total Amount in Tree Found in Various Tree Parts.

Leaves

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	47.1	44.7	56.3	64.0
+ - - -	45.5	40.2	48.3	38.6
+ + - -	39.6	52.8	49.6	51.6
+ + + -	36.5	41.2	56.7	66.7
- - - -	35.2	27.2	25.7	36.1
- - - -	32.3	44.7	54.5	57.1
- - + +	35.2	20.8	50.5	53.1
- - - +	35.2	22.5	31.9	51.6
Low K	34.6	34.7	30.2	42.0

Scion Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	9.9	9.4	9.0	6.4	16.2
+ - - -	11.4	17.6	10.8	18.6	15.7
+ + - -	12.1	11.3	11.5	8.1	16.7
+ + + -	16.3	10.7	9.0	7.7	23.1
- - - -	21.0	20.7	22.0	19.2	16.7
- - - -	20.1	9.7	11.1	7.4	13.8
- - + +	16.1	21.6	12.1	10.5	17.2
- - - +	13.0	27.0	16.9	19.6	10.4
Low K	27.0	15.6	12.4	21.9	20.0

Stock Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	6.7	7.4	6.3	4.2	10.7
+ - - -	6.3	5.9	6.4	8.3	10.9
+ + - -	5.8	8.0	9.6	7.3	14.3
+ + + -	6.1	8.9	4.4	3.8	14.8
- - - -	11.1	8.1	10.9	11.5	16.7
- - - -	7.8	9.0	6.2	7.2	9.2
- - + +	9.0	13.2	7.2	7.3	7.8
- - - +	8.1	9.0	12.7	6.6	14.8
Low K	9.4	9.2	17.7	9.1	15.0

Limbs

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	6.0	6.1	5.6	6.0	14.0
+ - - -	10.0	12.2	11.3	11.1	19.9
+ + - -	8.9	8.3	5.7	9.5	17.9
+ + + -	8.7	11.4	6.5	6.0	10.1
- - - -	3.2	9.6	11.0	8.5	10.2
- + + +	8.9	8.6	6.7	4.7	19.2
- - + +	7.2	5.2	8.5	7.4	9.8
- - - +	11.0	10.6	8.3	6.2	16.8
Low K	9.6	10.0	11.0	7.6	15.6

Old Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	16.5	25.2	14.6	8.7	29.5
+ - - -	12.9	19.1	16.0	14.9	29.7
+ + - -	14.2	15.3	16.9	15.7	29.5
+ + + -	14.1	21.5	14.8	9.2	34.6
- - - -	18.1	31.0	25.1	17.6	34.3
- + + +	20.4	20.7	15.9	13.8	27.7
- - + +	21.3	34.9	12.8	14.4	23.1
- - - +	18.4	27.3	22.5	10.1	34.1
Low K	14.8	25.2	22.1	14.5	30.3

New Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	13.7	7.3	8.3	10.7	29.3
+ - - -	13.8	4.9	7.1	8.3	23.8
+ + - -	19.4	4.2	6.6	7.8	21.6
+ + + -	18.3	6.3	8.5	6.5	17.4
- - - -	11.4	3.2	5.3	7.0	22.0
- + + +	10.5	7.3	7.6	9.7	30.1
- - + +	11.1	4.3	8.7	7.2	36.9
- - - +	9.2	3.5	7.8	5.9	23.8
Low K	4.5	5.2	6.7	4.9	21.1

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Appendix Table 19. Distribution of Phosphorus in Peach Trees, Expressed as Per Cent of Total Amount in Tree Found in Various Tree Parts.

Leaves

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	32.5	28.4	30.5	36.1
+ - - -	35.5	36.5	36.8	35.4
+ + - -	32.4	33.3	30.5	35.7
+ + + -	28.9	29.7	32.1	38.0
- - - -	27.5	31.3	34.5	38.7
- + + +	33.4	31.5	33.8	37.7
- - + +	32.5	25.1	40.5	33.1
- - - +	37.1	26.6	28.5	36.1
Low K	28.4	38.7	40.7	36.7

Scion Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	11.2	15.1	18.0	12.8	14.9
+ - - -	16.5	14.9	15.5	10.1	16.4
+ + - -	12.3	17.0	17.3	7.1	15.2
+ + + -	13.6	11.8	16.9	12.9	18.5
- - - -	17.0	17.6	10.2	16.2	14.4
- + + +	13.8	17.1	19.2	12.0	9.1
- - + +	13.3	14.6	14.4	15.3	12.2
- - - +	12.2	13.7	10.4	17.3	7.3
Low K	16.4	13.6	8.3	15.3	15.3

Stock Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	9.6	10.4	10.4	8.8	8.8
+ - - -	9.3	7.6	9.2	10.6	8.7
+ + - -	10.1	12.7	14.7	8.6	11.7
+ + + -	9.7	7.6	7.5	6.4	12.7
- - - -	10.8	7.7	13.9	8.0	14.1
- + + +	7.1	11.9	11.0	11.0	7.5
- - + +	3.8	14.0	11.2	10.4	7.7
- - - +	6.3	12.2	9.7	9.9	12.4
Low K	11.9	7.3	11.8	11.1	13.4

Limbs

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	5.0	6.9	7.6	10.3	7.6
+ - - -	9.0	13.7	11.4	15.6	23.3
+ + - -	8.9	10.6	7.1	13.2	17.5
+ + + -	8.4	14.1	9.3	9.5	9.1
- - - -	4.4	11.7	12.1	11.5	16.1
- + + +	9.5	9.0	9.0	8.2	14.0
- - + +	9.8	6.4	10.6	10.4	7.8
- - - +	12.2	13.7	9.8	10.3	12.1
Low K	9.1	10.2	12.6	13.2	17.4

Old Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	29.3	30.7	20.5	16.6	35.7
+ - - -	20.1	20.0	16.2	20.9	29.6
+ + - -	23.3	18.2	20.0	21.7	31.8
+ + + -	24.8	25.7	21.8	18.9	37.4
- - - -	32.3	27.4	22.1	18.0	34.4
- + + +	28.3	[illegible]	15.7	16.7	35.0
- - + +	33.0	35.1	14.7	19.3	35.7
- - - +	23.4	24.7	26.1	16.7	45.1
Low K	25.3	24.9	19.5	16.4	36.4

New Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	12.2	10.5	13.0	15.3	33.0
+ - - -	9.4	7.4	10.9	9.2	22.0
+ + - -	13.0	8.2	10.3	13.7	23.8
+ + + -	14.6	11.0	12.2	14.2	22.2
- - - -	7.9	3.6	7.2	7.5	21.0
- + + +	7.7	8.4	11.2	14.2	34.4
- - + +	7.5	4.7	8.5	11.4	36.6
- - - +	8.6	4.1	7.4	9.7	23.0
Low K	8.8	5.2	7.0	7.2	17.5

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Appendix Table 20. Distribution of Nitrogen in Peach Trees, Expressed as Per Cent of Total Amount in Tree Found in Various Tree Parts.

Leaves

Treatment	June 1	July 1	Aug. 1	Sept. 1
	%	%	%	%
+ + + +	46.9	35.4	41.5	42.9
+ - - -	50.7	48.5	43.0	38.1
+ + - -	48.3	47.0	38.8	33.7
+ + + -	43.0	36.0	43.3	45.1
- - - -	38.0	45.4	38.9	37.4
- + + +	43.3	43.2	42.6	41.9
- - + +	42.0	32.9	51.2	50.6
- - - +	46.4	43.9	39.9	40.4
Low K	40.2	47.1	46.3	40.0

Scion Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	10.0	10.1	10.8	8.3	12.3
+ - - -	11.5	13.4	10.9	11.4	14.6
+ + - -	11.1	11.5	13.0	5.7	15.1
+ + + -	15.6	10.2	10.3	9.3	18.7
- - - -	12.9	12.6	9.6	12.2	18.0
- + + +	12.6	13.1	11.5	7.7	9.6
- - + +	11.8	11.6	11.8	9.4	14.4
- - - +	12.6	14.4	11.2	15.7	7.6
Low K	16.4	10.0	7.6	15.1	20.3

Stock Trunk

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	9.5	8.4	7.9	7.2	11.1
+ - - -	9.7	5.9	6.5	6.6	9.9
+ + - -	8.6	8.0	8.9	8.2	12.9
+ + + -	9.2	9.1	5.8	5.2	12.4
- - - -	15.2	5.9	10.8	7.1	12.8
- + + +	9.1	8.4	7.6	8.7	9.2
- - + +	10.3	12.2	7.7	8.6	8.7
- - - +	7.7	8.2	8.8	7.5	14.5
Low K	10.7	9.2	9.4	7.4	12.8

Limbs

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	5.9	3.9	4.8	7.9	10.3
+ - - -	5.8	7.9	7.6	10.3	18.1
+ + - -	5.5	5.9	4.9	8.7	13.2
+ + + -	6.2	8.3	6.1	6.9	7.6
- - - -	2.8	7.6	7.8	8.7	13.6
- + + +	5.6	5.9	6.3	6.1	12.6
- - + +	5.1	4.0	6.7	7.3	7.2
- - - +	7.4	8.1	6.8	8.1	11.0
Low K	6.5	6.2	8.4	9.5	18.3

Old Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	22.9	28.1	17.9	15.2	35.7
+ - - -	16.3	16.4	17.9	18.6	31.9
+ + - -	19.4	17.3	18.5	24.0	35.2
+ + + -	18.8	21.4	18.6	17.4	39.3
- - - -	25.9	23.5	22.5	19.4	35.6
- + + +	23.7	19.3	16.2	19.6	35.1
- - + +	24.7	34.3	12.4	17.2	36.2
- - - +	20.5	20.9	22.4	15.6	44.5
Low K	20.0	20.8	18.4	17.0	28.4

New Roots

Treatment	June 1	July 1	Aug. 1	Sept. 1	Dec. 18
	%	%	%	%	%
+ + + +	6.8	14.0	16.9	18.5	30.6
+ - - -	5.9	7.9	14.0	15.0	25.5
+ + - -	7.1	10.9	15.9	19.7	23.6
+ + + -	7.1	14.9	15.8	16.1	22.0
- - - -	5.1	5.1	10.4	15.0	19.9
- + + +	5.6	9.9	15.7	16.0	33.4
- - + +	5.9	5.0	10.1	16.8	33.5
- - - +	5.3	4.5	10.8	12.6	22.4
Low K	6.2	6.7	9.7	11.0	20.2

[redacted]

Appendix Table 21. Per Cent of Calcium in Leaves From Trees in Fertilizer Plots. (Dry Weight Basis).

Treatment	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		%	%	%	%	%	%	%
Straw mulch	J	1.85	2.09	2.56	1.55	1.90	1.54	2.97
	K	1.68	1.94	2.52	1.45	2.17	1.37	2.86
5 lbs. Super phosphate	J	1.72	1.89	2.49	1.00	2.17	1.76	2.47
	K	1.81	2.12	2.01	1.45	2.10	1.37	2.20
KCl 1 lb. plus straw	J	1.72	1.65	2.08	1.30	1.87	1.21	2.14
	K	1.65	2.01	2.62	1.45	2.05	1.21	2.58
KCl 1 lb.	J	1.70	1.73	2.14	1.36	2.27	1.21	2.20
	K	1.76	2.12	2.51	1.57	1.72	1.37	2.47
KCl 1 lb. ≁ 5 lbs. Super p.	J	1.75	1.85	2.50	1.40	1.72	1.65	2.75
	K	1.68	2.01	2.56	1.40	2.22	1.26	2.69
Check	J	1.68	2.13	2.58	1.45	2.02	1.54	2.86
	K	1.76	1.90	2.55	1.50	2.10	1.43	2.86
KCl ½ lb.	L	1.89	2.20	2.61	1.65	1.90	1.54	2.58
	M	1.72	2.15	2.82	1.45	1.95	1.21	2.58
KCl 1 lb.	L	1.78	2.05	2.43	1.50	1.90	1.43	2.36
	M	1.71	2.16	2.51	1.50	2.17	1.10	2.69
KCl 2 lbs.	L	1.74	1.96	2.35	1.40	1.90	1.54	2.20
	M	1.75	1.92	2.54	1.72	1.65	1.21	2.36
KCl 4 lbs.	L	1.91	2.06	2.33	1.57	2.05	1.21	2.75
	M	1.82	2.37	2.71	1.75	1.75	0.99	1.81
2 lbs. Amm. nitrate	L	1.71	2.00	2.34	1.35	2.10	1.26	2.75
	M	1.81	2.26	2.70	1.65	2.15	1.37	3.41
Check	L	1.72	2.17	2.51	1.35	2.25	1.43	2.75
	M	1.35	2.26	2.56	1.54	2.20	1.54	3.30

[redacted]

Appendix Table 22. Per Cent of Magnesium in Leaves From Trees in Fertilizer Plots. (Dry Weight Basis).

Treatment	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		%	%	%	%	%	%	%
Straw mulch	J	0.57	0.51	0.62	0.33	0.53		
Do	K	0.55	0.48	0.62	0.36	0.43		
5 lbs. Super phosphate	J	0.45	0.44	0.59	0.30	0.50		
Do	K	0.45	0.48	0.59	0.43	0.43		
KCl 1 lb. plus straw	J	0.57	0.48	0.64	0.40	0.46		
Do	K	0.53	0.40	0.55	0.36	0.40		
KCl 1 lb.	J	0.55	0.44	0.62	0.36	0.46		
Do	K	0.50	0.51	0.64	0.40	0.36		
KCl 1 lb. ≠ 5 lbs. Super p.	J	0.60	0.56	0.57	0.40	0.43		
Do	K	0.50	0.51	0.62	0.36	0.40		
Check	J	0.53	0.44	0.62	0.40	0.40		
Do	K	0.53	0.51	0.66	0.43	0.43		
KCl ½ lb.	L	0.55	0.55	0.71	0.43	0.46		
Do	M	0.48	0.52	0.44	0.40	0.50		
KCl 1 lb.	L	0.53	0.55	0.68	0.43	0.50		
Do	M	0.55	0.66	0.69	0.46	0.46		
KCl 2 lbs.	L	0.57	0.55	0.66	0.40	0.36		
Do	M	0.60	0.48	0.69	0.62	0.43		
KCl 4 lbs.	L	0.55	0.55	0.68	0.27	0.40		
Do	M	0.45	0.46	0.60	0.32	0.33		
2 lbs. Am. nitrate	L	0.53	0.61	0.71	0.43	0.50		
Do	M	0.48	0.52	0.71	0.43	0.50		
Check	L	0.45	0.55	0.68	0.43	0.46		
Do	M	0.40	0.42	0.65	0.59	0.50		

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Appendix Table 23. Per Cent of Potassium in Leaves From Trees in Fertilizer Plots. (Dry Weight Basis).

Treatment	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		%	%	%	%	%	%	%
Straw mulch	J	1.13	1.28	1.47	1.45	1.45	1.43	1.48
Do	K	1.25	1.56	1.73	1.85	1.92	1.81	1.92
5 lbs. Super phosphate	J	1.16	1.33	1.59	1.10	1.25	1.26	1.26
Do	K	1.44	1.57	1.97	1.32	1.55	1.65	1.48
KCl 1 lb. plus straw	J	0.80	1.11	1.58	2.05	2.22	2.25	2.03
Do	K	1.25	1.44	1.74	2.02	2.25	2.42	2.25
KCl 1 lb.	J	1.40	1.59	2.08	1.67	1.92	2.20	1.92
Do	K	1.46	1.46	1.73	1.57	1.60	2.14	2.09
KCl 1 lb. ≠ 5 lbs. Super p.	J	0.91	1.34	1.58	1.40	1.82	1.92	1.87
Do	K	1.44	1.55	1.64	1.80	2.02	2.36	2.14
Check	J	1.58	1.61	1.87	1.55	1.57	1.54	1.76
Do	K	1.31	1.63	1.73	1.27	1.45	1.48	1.48
KCl ½ lb.	L	1.46	1.35	1.68	1.25	1.50	1.87	1.76
Do	M	1.35	1.44	1.84	1.40	1.62	1.54	1.65
KCl 1 lb.	L	1.57	1.39	1.80	1.50	1.70	2.25	1.92
Do	M	1.34	1.19	1.40	1.52	1.92	2.14	2.09
KCl 2 lbs.	L	1.20	1.45	1.59	1.97	2.17	2.75	2.42
Do	M	1.80	1.67	2.12	2.00	1.98	2.42	2.25
KCl 4 lbs.	L	1.28	1.40	1.78	2.35	2.45	2.91	2.64
Do	M	1.56	1.87	2.20	2.31	2.40	2.97	2.69
2 lbs. Am. nitrate	L	1.49	1.38	1.79	1.27	1.80	1.48	1.54
Do	M	1.51	1.51	1.76	1.22	1.70	1.54	1.59
Check	L	1.25	1.36	1.59	1.12	1.32	1.48	1.48
Do	M	1.31	--	1.36	1.27	1.35	1.59	1.54

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Appendix Table 54. Per Cent of Phosphorus in Leaves From Trees in Fertilizer Plots. (Dry Weight Basis).

Treatment	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		%	%	%	%	%	%	%
Straw mulch	J	0.25	0.24	0.19	0.28	0.19	0.25	0.21
Do	K	0.21	0.23	0.23	0.28	0.18	0.24	0.16
5 lbs. Super phosphate	J	0.20	0.24	0.21	0.30	0.18	0.22	0.20
Do	K	0.23	0.25	0.21	0.28	0.21	0.22	0.18
KCl 1 lb. plus straw	J	0.29	0.23	0.25	0.29	0.20	0.24	0.20
Do	K	0.22	0.19	0.22	0.30	0.18	0.24	0.17
KCl 1 lb.	J	0.22	0.21	0.31	0.27	0.17	0.22	0.19
Do	K	0.24	0.24	0.22	0.28	0.18	0.24	0.19
KCl 1 lb. ≠ 5 lbs. Super p.	J	0.24	0.26	0.18	0.28	0.19	0.24	0.21
Do	K	0.21	0.20	0.18	0.29	0.19	0.25	0.17
Check	J	0.23	0.21	0.19	0.27	0.17	0.23	0.20
Do	K	0.22	0.24	0.21	0.28	0.18	0.24	0.19
KCl ½ lb.	L	0.22	0.21	0.21	0.28	0.18	0.22	0.20
Do	M	0.27	0.22	0.21	0.30	0.18	0.23	0.18
KCl 1 lb.	L	0.22	0.22	0.23	0.26	0.19	0.22	0.19
Do	M	0.21	0.22	0.19	0.27	0.17	0.24	0.17
KCl 2 lbs.	L	0.25	0.20	0.20	0.28	0.18	0.22	0.19
Do	M	0.22	0.18	0.21	0.27	0.19	0.22	0.17
KCl 4 lbs.	L	0.24	0.21	0.20	0.27	0.19	0.22	0.17
Do	M	0.24	0.25	0.20	0.25	0.16	0.22	0.16
2 lbs. Am. nitrate	L	0.25	0.19	0.20	0.26	0.16	0.24	0.16
Do	[illegible]	0.23	0.23	0.20	0.30	0.16	0.25	0.19
Check	L	0.24	0.22	0.20	0.29	0.18	0.22	0.20
Do	M	0.22	0.25	0.19	0.28	0.17	0.24	0.19

[redacted]

Appendix Table 25. Per Cent of Nitrogen in Leaves from Trees in Fertilizer Plots. (Dry Weight Basis).

Treatment	Block	Aug. 14, 1947	Sept. 12, 1947	Oct. 17, 1947	June 25, 1948	Sept. 10, 1948	June 25, 1949	Sept. 15, 1949
		%	%	%	%	%	%	%
Straw mulch	J	3.52	3.63	3.17	4.46	3.43	3.72	3.03
Do	K	3.74	3.56	3.65	4.23	2.92	3.67	3.23
5 lbs. Super phosphate	J	3.81	3.35	3.20	4.41	3.17	3.43	3.03
Do	K	4.09	3.58	3.39	4.35	3.15	3.80	3.05
KCl 1 lb. plus straw	J	4.23	3.54	3.17	3.97	3.17	3.54	3.04
Do	K	3.50	3.41	3.62	4.15	3.00	3.43	2.92
KCl 1 lb.	J	3.60	3.25	3.17	4.29	2.81	3.58	3.14
Do	K	3.64	3.34	3.43	4.26	3.26	3.63	2.98
KCl 1 lb. + 5 lbs. Super p.	J	3.77	3.80	3.28	4.51	3.57	3.64	3.22
Do	K	3.99	3.55	3.24	4.45	3.02	3.63	2.89
Check	J	3.93	3.16	3.50	4.43	3.44	3.72	2.91
Do	K	3.56	3.85	3.42	4.29	2.85	3.72	3.04
KCl ½ lb.	L	3.76	3.81	3.56	4.29	3.13	3.60	3.12
Do	M	3.58	3.55	3.49	4.33	3.50	3.81	3.10
KCl 1 lb.	L	3.81	3.51	3.54	4.30	3.27	3.48	3.16
Do	M	3.51	3.37	3.57	4.21	3.17	3.90	3.27
KCl 2 lbs.	L	4.21	4.01	3.46	4.35	3.27	3.53	3.05
Do	M	4.03	3.15	3.52	4.01	3.15	3.89	2.87
KCl 4 lbs.	L	3.74	3.60	3.52	4.12	3.15	3.60	2.80
Do	M	3.79	3.45	3.75	4.25	3.35	3.67	3.03
2 lbs. Am. nitrate	L	3.91	3.86	3.54	4.49	3.40	3.54	3.04
Do	M	3.91	3.65	3.60	4.25	3.01	3.94	2.92
Check	L	3.18	3.51	3.63	4.30	2.96	3.49	3.09
Do	M	3.85	3.56	3.54	3.90	2.95	3.70	3.15

[redacted]

Appendix table 56. Mineral Composition of Leaves from Potassium Spray Plots. (Dry weight basis).

Spray Treatment	September 11, 1947 Lowest leaf from 5 inch terminal before spraying					September 11, 1947 Leaves washed after spraying					September 11, 1947 Leaves unwashed after spraying				
	Ca %	Mg %	K %	P %	N %	Ca %	Mg %	K %	P %	N %	Ca %	Mg %	K %	P %	N %
Check	1.78	.44	1.33	.25	3.64	1.78	.44	1.33	.25	3.64	1.78	.44	1.33	.25	3.64
Potassium Nitrate	1.79	.41	1.46	.19	3.52	1.89	.40	2.12	.24	3.56	2.05	.44	2.16	.20	3.70
Potassium Chloride	1.95	.48	1.51	.20	3.78	1.89	.44	2.06	.20	3.44	1.96	.46	2.18	.20	3.49
Potassium Phosphate	2.01	.41	1.38	.26	3.68	1.96	.44	2.11	.34	3.51	1.98	.44	2.03	.34	3.47
Potassium Tartrate	1.61	.41	1.47	.25	3.75	1.87	.40	1.94	.17	3.53	1.87	.40	2.09	.20	3.43

Spray Treatment	October 17, 1947 Lowest leaf from 5 inch terminal				
	Ca %	Mg %	K %	P %	N %
Check	1.72	.45	1.51	.30	3.49
Potassium Nitrate	1.70	.42	1.95	.23	3.39
Potassium Chloride	1.80	.41	1.76	.24	3.32
Potassium Phosphate	1.86	.39	1.75	.28	3.31
Potassium Tartrate	--	.36	1.95	.23	3.42

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Appendix Table 27. Mineral Composition of Twigs from Potassium Spray Plots. (Dry weight basis)

Spray Treatment	September 11, 1947 (Before Spraying)					October 17, 1947					April 3, 1948				
	Ca %	Mg %	K %	P %	N %	Ca %	Mg %	K %	P %	N %	Ca %	Mg %	K %	P %	N %
Check	2.28	.11	.47	.16	2.04	1.91	.11	.54	.16	1.87	1.57	.10	.87	.23	2.46
Potassium Nitrate	2.26	.11	.51	.17	1.94	1.78	.11	.55	.16	2.00	1.57	.12	.92	.24	2.38
Potassium Chloride	2.26	.11	.48	.15	2.09	1.75	.11	.59	.16	1.94	1.41	.14	.97	.25	2.62
Potassium Phosphate	2.19	.11	.48	.17	2.01	1.65	.10	.58	.17	1.83	1.62	.14	.97	.25	2.30
Potassium Tartrate	2.27	.10	.49	.16	1.95	1.91	.12	.56	.17	1.96	1.54	.14	.97	.24	2.47

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