FERTILIZER APPLICATIONS CORRELATED WITH GROWTH AND PRODUCTION OF PECAN TREES

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By

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FERTILIZER APPLICATIONS CORRELATED WITH

GROWTH AND PRODUCTION OF PECAN TREES

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INTRODUCTION

Pecan trees under Oklahoma conditions tend to be very erratic in production. The average annual production is very near twenty million pounds with a range from four million to forty million or slightly more per year. The tendency for alternate bearing of "native" or seedling trees is well recognized by growers and is a matter of great concern to them because; (1) annual income fluctuates extremely, and (2) it is usually very difficult to obtain the labor force needed to get an unusually large crop gathered before the "holidays" in order to take advantage of better prices offered at this time. Price also tends to vary inversely with production.

Much work has been done in Florida, Georgia, and other south-eastern states on the effects of plant food applications and cover crops (green-manured) on production, tree growth, and quality of nuts. Unfortunately for Oklahoma growers, this work has been done on varieties of known bearing habits. Approximately ninety per cent of Oklahoma's production is from seedling or "native" trees, which may be considered as each a differing variety from its neighbor.

Those essential elements used in the greatest amounts; nitrogen, phosphorus, and potassium (often designated the "major" elements) will be the only elements considered in this study. Trees selected for study were carefully chosen for freedom from any symptoms indicating "rosette" or zinc deficiency.

REVIEW OF LITERATURE

Atkinson (4) working with annual vegetable crops found a wide range in the adaptability of different crops in the correlation of yield to tissue tests. Tomatoes gave a close to predicted response with potatoes falling below tomatoes but above corn in this respect. Emmert (18) found tomatoes to require high nitrates at two different stages (phases) in their development. He also reported overcoming or depressing the effect of high nitrate by the use of 1,000 pounds of super-phosphate per acre.

Freeman (19) was able to show a direct correlation between nitrate and carotine in carrot. The supply of phosphorus and potassium showed no relationship to carotine. Thomas and Mack working with corn found a direct correlation of P2 O5 content of the leaf blade and yield. No relationship was observed between the content of nitrogen or potassium and yield. A depressing effect was noted on the uptake of calcium and magnesium when potassium was added with super-phosphate in comparison with super-phosphate alone.

Batjer and Degman (6) working with apple trees grown in solution reported an optimum response to nitrogen in a concentration of 60 p.p.m. and to potassium at 117 p.p.m.. However, in the case of potassium, actual deficiency symptoms other than reduced growth did not appear if the concentration of the solution was kept at as little as 10 p.p.m.. Boynton and Compton (11) have shown an inverse relation of nitrogen to potassium in apple. The statement is also made that the tree is capable of storing large amounts of nitrogen. They also found that leaf scorch due to potassium deficiency rarely appears if the potassium content of the leaf is above 1 percent in midsummer. Harley and Lindner (24) found that with apple trees growing in a heavy sod of crabgrass, the use of ammonium sulphate must allow for the strong competition of the grass with the tree for nutrients. Careful study indicated that the grass alone benefited from the first thirteen pounds of ammonium sulphate. Under these conditions of low nitrogen (and doubtless other nutrients), no nitrogen was stored above ground while the trees were dormant. Root samples did reveal the presence of nitrogen but no accurate determinations were made because of the variability of root sampling techniques. Knowlton (31) performed a unique experiment in which he fed one-fourth of the root spread area of several trees and observed the resulting response of the entire tree. No indication of cross transfer of nitrogen was found, nor was growth increased in other than those branches directly over the treated area. These results are in accord with data of Blackmon (9), Alben (3), and others. Roberts and Landau (39) studying apple trees growing in a soil very deficient in potassium made injections directly into the branches rather than additions of potassium carriers to the soil. Their conclusions were quite positive that the translocation and assimilation of potassium was dependent upon soluble iron in the vascular system of the tree. Tisue tests were employed to verify the visual changes observed.

Singh (44) cites depletion of nutrients during a heavy crop year coupled with poor vegetative growth as two of the main factors responsible for biennial bearing in apple trees. However, Wilcox, Hoy, and Palmer (52) were unable to find any significant difference in bearing habit due to any of a number of applications of varying amounts of nitrogen-phosphorus-potassium mixtures.

Hilgeman (25) did considerable work with grapefruit trees in the Salt River Valley in Arizona as regards their response to different forms of nitrogen carriers. He reports that the nitrate form is the one giving best response and that a well aeriated soil allowed for the more rapid uptake of nitrogen by the trees. Hilgeman also found that calcium nitrate was more readily absorbed than was urea, ammonium sulphate, or manure, in the order of their availability. The time of application giving best results varied and was found to be; February for calcium nitrate; December for urea and ammonium sulphate; and August for manure.

The effects from the manure were carried well into the second season. Jones, Bitters, and Finch (30), also working with grapefruit, found that fruits large enough to begin to show color did not take in nitrates, though the leaf analysis showed the leaves to have done so to a high degree, and the more immature fruits to have absorbed enough nitrates that they were entirely ruined for market.

Brown and Potter (13) working with tung trees in Louisiana growing in a potassium deficient soil, found that as little as twenty-four pounds per acre of K_2O added to the cover crop (lupine) increased the yield of tung by 13.6 pounds per tree (925 pounds per acre) and the yield of the cover crop by eighty seven percent. Such an addition of potassium also prevented appearance of leaf scorch of the type commonly associated with potassium deficiency. Additions of potassium also hastened maturity of the fruit. Loustalot and Lagasse (34) applied four and one-half pounds of ammonium nitrate to each of several seven year old tung trees beginning in December and continuing at monthly intervals until April. Tissue tests were made at monthly intervals to assist in tracing the movement of the fertilizer elements (nitrate and ammonium ions). The December application was found to give the best response because of having been able to move to the growing tips of the trees by the time growth was resumed in the spring. As late as June 26, the trees treated in December still contained higher percentages of total nitrogen in the leaves. No evidence was noted of the added nitrate resulting in earlier bloom. Sitton (43) applied varying amounts and compositions of mixed fertilizers to tung trees and noted the response over a four year period. He found the highest immediate yield to come from nitrates alone yet the highest ultimate yields came from the trees receiving the complete fertilizers. Increased yields were found to be associated with; (1) greater tree growth, (2) increased number of shoots, and (3) higher number of pistillate flowers per terminal bud. Oil content of the fruits was found to be depressed by high nitrates and increased by the additions of potassium. On the potassium deficient soils used in this experiment, even small amounts of nitrogen with no potassium gave very severe leaf scorch indicating potassium deficiency.

Bard (5) made a study of leaf samples from twenty-five species of trees growing on three soil types. Determinations were made for calcium, phosphorus, potassium, and nitrogen. Calcium was found to depend more on species than on soil type as shown by the almost constant content in the leaves regardless of the amount of calcium in the soil. The phosphorus content was found to vary inversly as the pH of the soil varied; the lower the pH, the higher the phosphorus content of the leaves. The potassium content increased with the increasing pH of the soil. Nitrogen content of all the species tested ranged from 1.11% to 3.5% and was in most cases found to be a limiting growth factor.

Chapman (15) in Malaya on rubber trees used applications of nitrogen (ammonium nitrate) and both crude and acidulated phosphates after concluding that potassium was in ample supply. He found the latex yield to be in direct proportion to the nitrogen content of the leaf and that ammonium sulphate tended to release "bound" or fixed phosphates in the soil. Chapman also concluded that phosphate applications immobilized the ammonium ($NH4$) ions in the soil and that additions of potassium depressed the phosphate content of the leaf.

Davidson (16) reports that nitrates applied in the fall were available in black walnuts for very early growth the following spring. Hostetter (27) after a fertilizer study on black walnuts states that limestone alone of all materials tested, was instrumental in producing better filled nuts. Cloudy weather during the filling period was also found to result in poorly filled nuts as was the application of nitrogenous materials to the soil.

McDaniels (36) in a study of walnuts, pecans, and hickorys in New York found that the mean average temperature was too low for nut development to be completed in the growing season in that area. He reports that no pecan does well enough for planting in that region and that Persian walnuts, black walnuts, and hickorys require a mean average temperature above 62 degrees F.. Better root systems were obtained on walnuts and hickorys by cutting the tap roots when the trees were very small. He states that nut trees grow better in neutral or slightly alkaline soils and cites drought and low light intensity as common causes of failure of nuts to fill properly.

Proebsting (37) made observations and tests for five years with Bartlett pears and found that only those trees in the plots receiving nitrogen showed an increase over the check plots in yield. The plots receiving potassium and phosphorus, either alone or in combination, showed decreased yields in comparison with untreated plots. He reports that sixty pounds of phosphorus per tree did not change the content of phosphorus in the leaves, nor did fifty pounds of muriate of potash increase the potassium content of the leaves. He concludes that; (1) the phosphorus and potassium may have been localized in other than leaf tissue; or (2) that they may have been bound or fixed in the soil in forms unavailable to the tree.

Stephenson (45) offers the observation that plants not only vary in the amount of various nutrients required for good growth, but they differ in the amount of root system, degree of root ramification and depth penetrated. He states that filberts will grow well where walnuts fail because of boron deficiency.

Waltman (49) used sodium nitrate on strawberries growing at two locations In Kentucky; one high and the other low in available phosphate. In all cases the soluble phosphate in the crown of the plant tended to fluctuate less widely than did the soluble nitrate. Applications of nitrate resulted in much greater vegetative vigor, poorer fruit yields, and lower quality of fruit.

Waugh and Cullinan (52) present data from fertility studies with peaches to indicate that the nitrogen content of peach leaves varies less than the content of either phosphorus or potassium, regardless of the composition or amount of plant food added to the soil. In all cases reported in their study, the nitrogen content was above 3 percent.

Alben (1) in 1934 planted three varieties of pecans (Stuart, Success, and Schley) under cultural conditions to provide; (1) bermuda grass sod (2) winter legume cover crop, and (3) winter non-legume cover crop; with and without additional nitrogen for each plot. In the fall of 1948 leaf samples were taken for nitrogen analysis and the results correlated with yields. Highest yield in Stuart and Success was found with the highest nitrogen content of leaves which was 2.85% and 2.52% respectively. The highest yield from Schley was found in the plot having the second highest nitrogen content (2.50%) which was .16% less than the highest for the variety. The quality of nuts decreased for all varieties as the yield and nitrogen content increased.

Alben (2) cultivated, sprayed, and fertilized trees growing in both pasture and haymeadow and compared their performance to untreated trees in the same fields. The untreated trees bore crops of very low quality pecans one year in five while the treated trees bore crops of good quality nuts five years out of six. Leaf samples indicated that nitrogen, calcium, and magnesium (from the filler used in the fertilizer) were much higher in the treated trees while the content of phosphorus and potassium of the leaves from untreated trees was higher, and due to the poor growth made and the lack of nutrient loss in crop yield.

Alben (3) over a period of years collected samples of Stuart leaves (always in June) that were showing deficiency symptoms and analyzed them. He also grew Stuart trees in cultural solutions of differing concentrations to cause deficiencies to appear. These data are listed below.

Deficiency Experiment		Average	Average of 3000 Samples Lowest	Highest
Nitrogen	12,000	23,780	11,760	39,570
Phosphorus	980	1,560	1,300	2,010
Potassium	1,150	10,540	5,345	16,690
Calcium	4,300	17,210	10,500	25,200
Magnesium	784	5,290	2,880	11,000

The figures above are expressed for parts per million (p.p.m.) To convert to percentage, move the decimal four places to the left.

Alben also found that muriate of potash at rates of 50 and 100 pounds per tree did not result in increased amounts of potassium in the leaves unless super-phosphate was also applied in a like amount.

Billings (8) in Georgia lists three methods by which fertility can be maintained in a pecan orchard; (1) by sedimentation, (2) by the use of commercial fertilizers and, (3) the turning under of cover crops. He suggests planting four to nine trees on the fertile soils and fewer on the less fertile sites.

Blackmon (9) in Florida found that it required from five to six years to bring a neglected orchard back to full production by use of cover crops and as much as 2,000 pounds per acre of complete fertilizer applied to the cover crop. Blackmon grew pecan seedlings in sand culture and soil with and without boron and found that those receiving boron contained the lowest nitrogen but the greatest total weight.

Crane and Dodge (14) for a five year test selected eleven pairs of bearing size Schley trees for the following treatments; (1) pruning, (2) pruning and fertilizing with ammonium nitrate at a rate of fifteen pounds per tree year, and (3) check with no treatment. Pruning and fertilizing increased the number of pistillate blooms and the number of shoots over six inches long more significantly than did the pruning alone. No treatment was provided to allow for the use of ammonium nitrate without the pruning.

Finch (20) analyzed nuts of different grades of filling and reported that the poorer filled nuts contained the highest percentage of nitrogen. He advocates late fall or early winter applications of nitrogen at a level sufficient to allow for good spring growth but not high enough to carry into the late summer filling period.

Gossard (21) measured twig growth for previous and current year and compared growth rate and production in the three varieties Stuart, Success, and Schley. A direct correlation was found between twig growth and production.

Hammar (22) used radioactive phosphorus (P 32) in a study of phosphorus nutrition of pecans. Five months after applying the material to the soil, he was able to detect the radioactive ions in the leaves. The radioactive phosphorus was inserted in holes bored into the branches and was found twelve days later in the leaves. Foliar applications of the same material gave no evidence of having been absorbed into the leaves. No significant lateral movement of phosphorus within the tree's trunk was noted.

Hammar and Hunter (23) took weekly samples of pecans during the kernel development period and analyzed shucks, shells, and kernels separately. It was found that before kernel development began 92.5% of the dry weight of the shuck and shell had formed. On September 15, 96% of the protein, 82% of the oil, 85% of the dry weight, and 84% of the ash had formed as compared to the mature kernel. The potassium content of the shuck comprised 73% of the mineral elements in the mature nut and 54% of the ash of the shuck.

Hunter (28) conducted a comparative test of cultivation to mulching with fertilizers used under both cultural systems. After four years, the influence of fertilizer on yield had not yet reached the significant level. The increased yield of the trees in the cultivated plots over the mulched plots was highly significant.

Hunter and Hammar (29) caution against too heavy a reliance on yield figures from field test trials. The reason given being that the loss from insects, disease and animals make it almost impossible to calculate results with any degree of accuracy. This test was made on fourteen-year old trees of the Moore variety using 1200 pounds per year of 6-8-4 analysis fertilizer for three years and changing to 1,000 pounds per acre per year of 4-8-4 for the next seven years. The fertilizer applications were made at different times of the year but no significant difference was noted as to the best time to make fertilizer applications. However, the best filled nuts were obtained from those trees fertilized while dormant. The plots receiving nitrogen alone kept pace in yield with those receiving complete fertilizer for the first four years but after this rapidly declined until by the tenth year this plot (nitrogen only) was producing but 40% of the yield of the plot receiving complete fertilizer. No foliar analysis data were offered.

Lewis and Hunter (32) took samples of nuts and their supporting shoots at four sampling dates; July 15, August 15, September 15, and October 3 (harvest). During the filling period it was found that the hut increased in units of mineral content while actually showing a decrease in percentage of mineral in the kernel due to the rapid accumulation of carbohydrates. At this time the shoot analysis showed rapid depletion of all minerals. Calcium was found largely in the shell; potassium mostly in the shuck, and phosphorus and nitrogen were mainly in the kernel.

Loustalot (33) made determinations of photosynthetic rates and rates of transpiration of pecan leaves treated with heavy applications of Bordeaux and arsenate sprays. Even with a coating of residue thick enough to obscure the green color of the leaves, no significant difference in the rate of photosynthesis or transpiration was noted. Fluctuations actually observed were attricuted to changes in light intensity and other meteorlogical variations.

Lutz and Hardy (35) found that the photosynthetic activity of pecan leaves increased with increased vigor of the tree as shown by the darker leaf color when nitrogen was applied. Foliage diseases greatly decreased the effectiveness of the leaves even when not severe enough to cause defoliation. The fact that healthy foliage remains on the tree until removed by frost indicates that measures be taken to retain foliage as long as possible in order to have thrifty trees.

Roberts (38) was able to find no correlation of the results from rapid tissue tests (on both leaf and petiole samples) and standard laboratory complete analysis results. He was unable to find nitrates in the xylem from the bole of the pecan at the time for growth to resume in the spring. He did find, however, nitrates in the roots after fertilization with nitrogen (ammonium nitrate) which indicated that not all the nitrate was reduced in the roots.

Sharpe and Gammon (41) tested sampling techniques and tree variation in uniformly treated plots and duplicated their tests so that they were able to subject their results to an analysis of variance. Trees within uniformly treated plots were found to vary as to calcium, potassium, and phosphorus content of the foliage at a highly significant level.

Breazeale (12) working with corn and other plants maintained at very low moisture supply reached the conclusion that plants could take up nutrients independently of water absorption and that if moisture were available to the deeper roots, the plant could even excrete moisture from the roots in the desicated soil and so continue to extract nutrients though the soil was much below the wilting point.

Drake, Vengris, Colby (17) by use of plant analysis were able to show that different species of forage plants were able to extract from the soil widely varying amounts of a nutrient element when that element was at a critically low level. Hoagland and Arnon (26) cite petioles as an especially likely tissue to use for potassium determinations. They remark also that failure to achieve a correlation of tissue tests with plant behaviour is often due to failure to consider ecological factors in conjunction with the results of the tests. Schultz (40) despairs of use of visual symptoms alone in diagnosis of nutrient deficiencies in plants.

Shear, Crane, and Meyers (42) emphasize that leaf analysis is an integration of all circumstances that influence the availability of the salts in the soil. Leaf analysis is the only means by which cultural solution experiments can be directly related to field experiments. The function (they state) of leaf analysis is to determine the direction and extent of nutrient embalance within the plant. Thomas and Mac (48) do not advocate the use of visual symptoms in diagnosing a deficiency; only as an indication that a deficiency does exist.

Thomas (47) reports that the upteke of a nutrient element is not always in direct proportion to the external concentration and that less error is to be found in standard laboratory total analysis than in "quick tests" for soluble nutrients.

Wear and White (51) in a study of clay-fraction absorption, or fixing of potassium offer the suggestion that the potassium is sandwiched between the layers of the clay crystal and fixed there by drying. Sodium, Magnesium, and calcium are able to completely replace the potassium so fixed.

METHODS AND PROCEDURE

Four native pecan trees in the college grove at Stillwater, Oklahoma were selected for treatment and observation in March of 1949. The tree numbers and treatments are as follows; tree 29 has received annual applications of ammonium nitrate in the amount of one pound per inch diameter; tree 89 has received annual applications of ammo-phos (16-20-0) in the amount of two pounds per inch diameter; tree 90 has served as an unfertilized check tree; and tree 714 which had only one application of fifty pounds of ammo-phos and fifty pounds of twenty-five percent potash (manure salts). All cultural operations were conducted without regard to test trees. Winter cover crops of rye and vetch have been grown every year and incorporated into the soil in the spring.

In the Bixby, Oklahoma, area four trees of San Saba Improved and four of Moore were selected from orchards owned by Mr. R. C. Walker for observation. The only treatments were to trees 3 and 4 which received one application of 100 pounds of twenty-five percent potash in August of 1949.

Yearly yield records have been kept in so far as possible. Twig samples have been taken at three periods during the dormant season; December, January, and March. After leafing out in the spring, leaf samples are taken at thirty day intervals until leaf drop in the fall. The individual samples are composed of approximately 200 leaves (both blade and petiole) gathered from all portions of the tree to insure a uniform sample. The samples have been delivered to the laboratory the same day they were gathered.

Leaf blades and petioles were oven dried at 60 degrees C. until dry enough to grind without difficulty. They were ground in a Wiley mill fine enough to pass an 80 mesh screen and further dried at 105 degrees C. until constant weight was attained.

Ash was determined by the following procedure; 6.0 grams of pecan leaf or twig tissue was placed in a previously weighed platinum dish and placed in a muffle furnace at 550 degrees C. for twelve to sixteen hours. The dish plus sample ash were placed in a desiccator and cooled sufficiently to permit weighing serious convection effects. The samples were then weighed rapidly and the ash weight determined by difference. The ash was then quantitatively transferred to a beaker and the soluble contents brought into solution by the addition of 5 milliliters of hydrochloric acid followed by approximately 50 ml. of water. The beaker was then placed on a steam plate and the contents evaporated to dryness to dehydrate the silica. Ten ml. of hydrochloric acid and 30 ml. of water were then added and the hot solution filtered into a 200 ml. flask. The beaker and the precipitate on the filter were then washed repeatedly with small amounts of distilled water. The solution was mixed thoroughly and diluted to 200 ml. with distilled water and mixed again. This solution was then used for the determination of phosphorus and potassium. Phosphorus was determined by the precipitation as the ammonium phospho molybdate, essentially prescribed by the Association of Agricultural Chemists; the quantity of the precipitate being determined titrametrically after the addition of an excess of a standard base.

Potassium was determined by flame photometry with the Perkin-Elmer flame photometer Model 52-C. Lithium nitrate was used as internal standard and the instrument was calibrated against a standard solution prepared from potassium acid phthalate obtained from the Bureau of Standards. Frequent checks were made during each series of measurements to assure that the instrument was operating correctly.

Nitrogen determinations were made by the Macro-Kjeldahl analysis as stipulated by the Association of Agricultural Chemists. Two or three gram samples were used, depending on the nitrogen content.

On March 11, 1949, eighty-seven trees on the west side of Cow Creek were selected for the study of the effects of ammonium nitrate and ammo-phos on growth as well as yield. The trees were divided into two plats; the first containing fifty-five trees and the second thirty-two. Both natives and varieties were included in this performance test. Checks were selected from native trees growing in an open cultivated field under a system of no management except those cultural operations necessary for the growing of feed crops which were raised every year in the area. The test trees were calipered at a height of roughly four feed and three inches from the ground (breast height). The first group (fifty-five) of trees received a yearly application of ammonium nitrate equal to 1 pound per inch of diameter of the trunk and the second group group of trees (thirty-two) were given two pounds per inch of trunk in the form of ammo-phos. Time of application was in the dormant season, usually in January or February.

The vetch cover crop was turned under in May and two or three cultivations were made for weed control during the summer. Sheep were also grazed in the area to assist in weed control. Other than the fertilizer applied, all trees received identical cultural treatment.

No tissue tests were made on the eighty-seven trees in this test. Growth increment as measured by the increase in diameter and increased yields of the trees were to be used to evaluate the test.

PRESENTATION OF DATA

Summarization of treatments and yield response of all sample trees is as follows:

Stillwater Grove

Tree No. 29:

1949: Medium heavy crop

1950: Light crop set

1951: 31.0 pounds

1952: Very light crop set; none harvested due to freezing.

Treatment: Cultivation, vetch cover crop.

March 24, 1949 - 17 pounds of ammonium nitrate (33% N)

January 27, 1950-17 pounds of ammonium nitrate.

January 17, 1951-18.7 pounds of ammonium nitrate.

February 7, 1952-18.7 pounds of ammonium nitrate.

Tree No. 89:

1949: Medium heavy crop

1950: No crop

1951: No crop

1952: Light crop set; none harvested due to freezing.

Treatment: Cultivation, vetch cover crop

March 25, 1949 - 26 pounds of ammo-phos (16-20-0)

January 28, 1950-27 pounds of ammo-phos

January 17, 1951-29.8 pounds of ammo-phos

February 7, 1952-29.8 pounds of ammo-phos

Tree No. 90:

1949: Medium heavy crop

1950: Medium crop

1951: 89.5 pounds

1952: Very light crop set; none harvested due to freezing.

Treatment; Cultivation, vetch cover crop

No fertilizer

Tree No. 714:

1949: Light crop

1950: No crop

1951: 2.0 pounds

1952: No crop set

Treatment: No cultivation. Top soil removed from around tree

1949: August 18,; 50 pounds ammo-phos and 50 pounds of 25% potash (manure salts)

1950: No fertilizer

1951: No fertilizer

1952: No fertilizer

Walker Orchard South of Bixby

San Saba Improved

Tree No. 1:

1948: No crop

1949: Heavy crop

1950: No crop

1951: 166 pounds

1952: Light crop set; none harvested due to freezing.

Treatment: No fertilizer

Tree No. 2:

1948: Approximately 200 pounds of pecans

1949: No crop

1950: Medium crop set: no accurate figures reported.

1951: 140 pounds of pecans

1952: Light crop set; none harvested due to freezing.

Treatment: cultivation with wheat cover crop that was pastured.

No fertilizer applied.

Tree No. 3:

1948: No data

1949: Medium crop

1950: Light crop

1951: 108 pounds

1952: Light crop set; none harvested due to freezing.

Treatment; August 10, 1949 - applied 100 pounds of 25% potash.

Cultivated with wheat cover crop which was pastured.

Tree No. 4:

1948: No data

1949: No crop

1950: Light crop

1951: 146 pounds

1952: Light crop set; none harvested due to freezing.

Treatment: August 10, 1949 - applied 100 pounds of 25% potash.

Cultivated with wheat cover crop which was pastured.

Walker Orchard North of Bixby

Moore Variety

Tree No. 8:

1948: No data

1949: Light crop

1950: Light crop

1951: No data

1952: Light crop set; none harvested due to freezing.

—All trees in this north grove have been cultivated with pastured wheat cover crop without any fertilizer applications being made at any time.

Tree No. 9:

1948: No data

1949: Light crop

1950: Light crop

1951: No data

1952: Light crop set; none harvested due to freezing.

Tree No. 10:

1948: No data

1949: No crop

1950: Light crop

1951: No data

1952: Light crop set; none harvested due to freezing.

Tree No. 11:

1948: No data

1949: No crop

1950: Light crop

1951: No data

1952: Light crop set; none harvested due to freezing.

The graphs numbered one through nine represent the results of the tissue tests performed on the sample trees. Those portions of the graphs dated in black are from leaf tissue and those in red are from twig tissue.

Chart One is a total of all the monthly tests on leaf samples from the trees in the Stillwater grove and is to be compared with graphs one, two, and three. Chart Two is the total of the leaf tests for the San Saba Improved Variety from the Walker Orchards at Bixby and is to be compared with graphs four, five, and six. Chart Three is for the Moore variety at Bixby and is to be compared with graphs seven, eight, and nine.

Chart One - Average of 12 Samples

Tree	N	Phos.	Potass.
29	2.479	.1560	1.11
89	2.762	.1862	1.20
90	2.381	.1852	.95
714	1.671	.1816	.803

Chart Two

Tree	N	Phos.	Pot.
1	2.072	.2183	1.12
2	2.168	.1872	1.066
3	2.386	.1692	1.0016
4	2.269	.1520	1.094

Chart Three

Tree	N	Phos.	Pot.
8	2.468	.1785	1.055
9	2.281	.2007	1.146
10	2.375	.2026	1.165
11	2.377	.2057	1.178

Chart four is the summary of the growth records for the fifty-five trees in the Stillwater grove which were given ammonium nitrate.

Chart Four

Variety	Number of trees	Average total diameter increase for four growing seasons
Burkett	7	2.457 inches
Early Bird	8	2.225 inches
Tissue Paper	3	2.3 inches
Love	2	1.7 inches
Native	35	1.89 (Five best growers averaged 3.4 inches)

Chart five is the summary of the growth records for the group of thirty-two trees in the Stillwater grove which received yearly applications of ammo-phos (16-20-0).

Chart Five

Variety	Number of trees	Average total diameter increase for four growing seasons
Love	9	2.2 inches
Burkett	2	1.55 inches
Stuart	1	2.2 Inches
Native	19	2.005 (Five best growers averaged 2.72 inches)

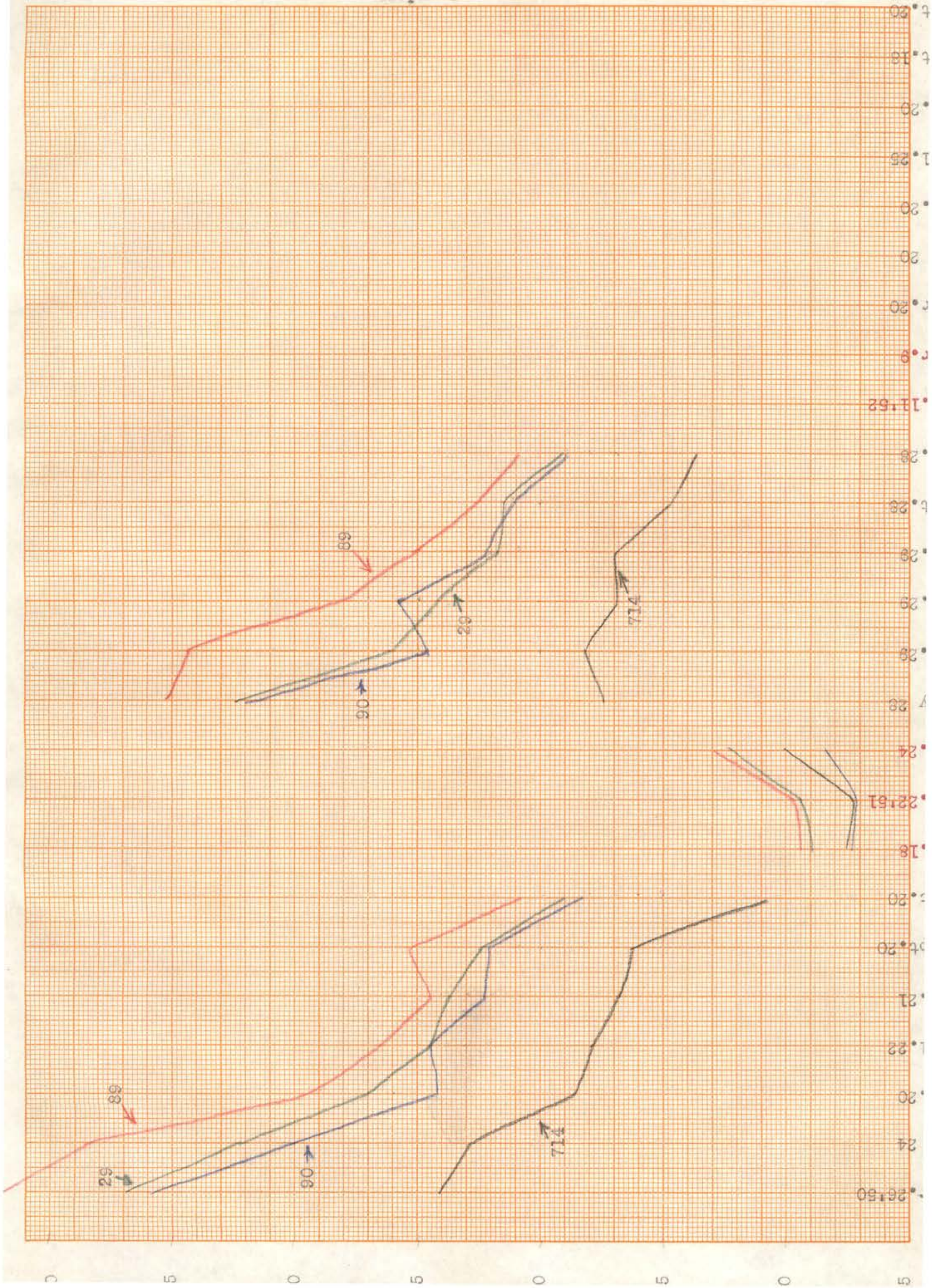
Chart six is a record of the growth made by the check trees located outside, but adjacent to, the native grove at Stillwater. These trees have had more than ample room to grow without competition with each other.

Chart Six

Variety	Number of trees	Average total diameter increase for four growing seasons
Native	6	3.31 inches

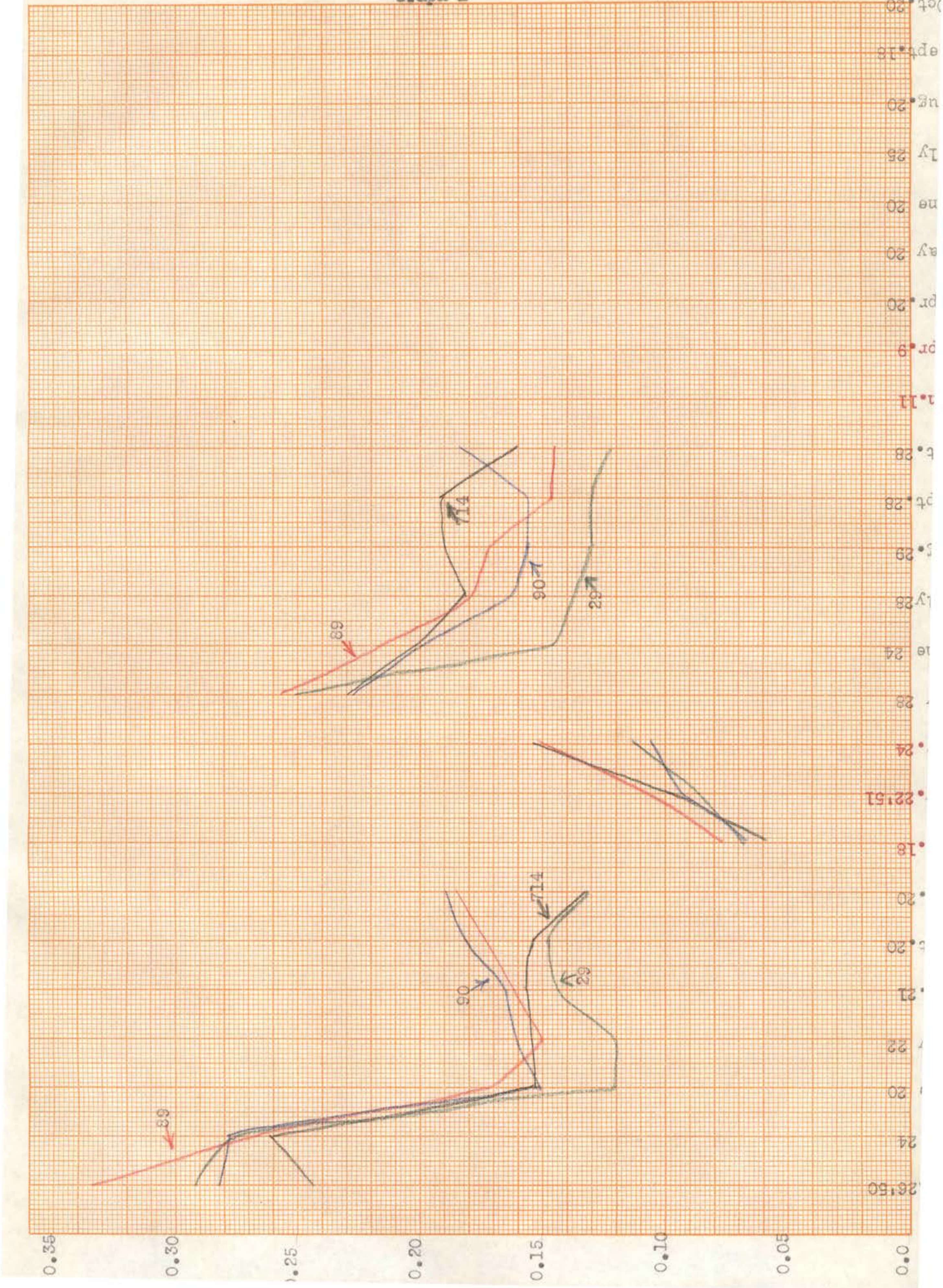
Stillwater Grove
% Nitrogen

Graph I



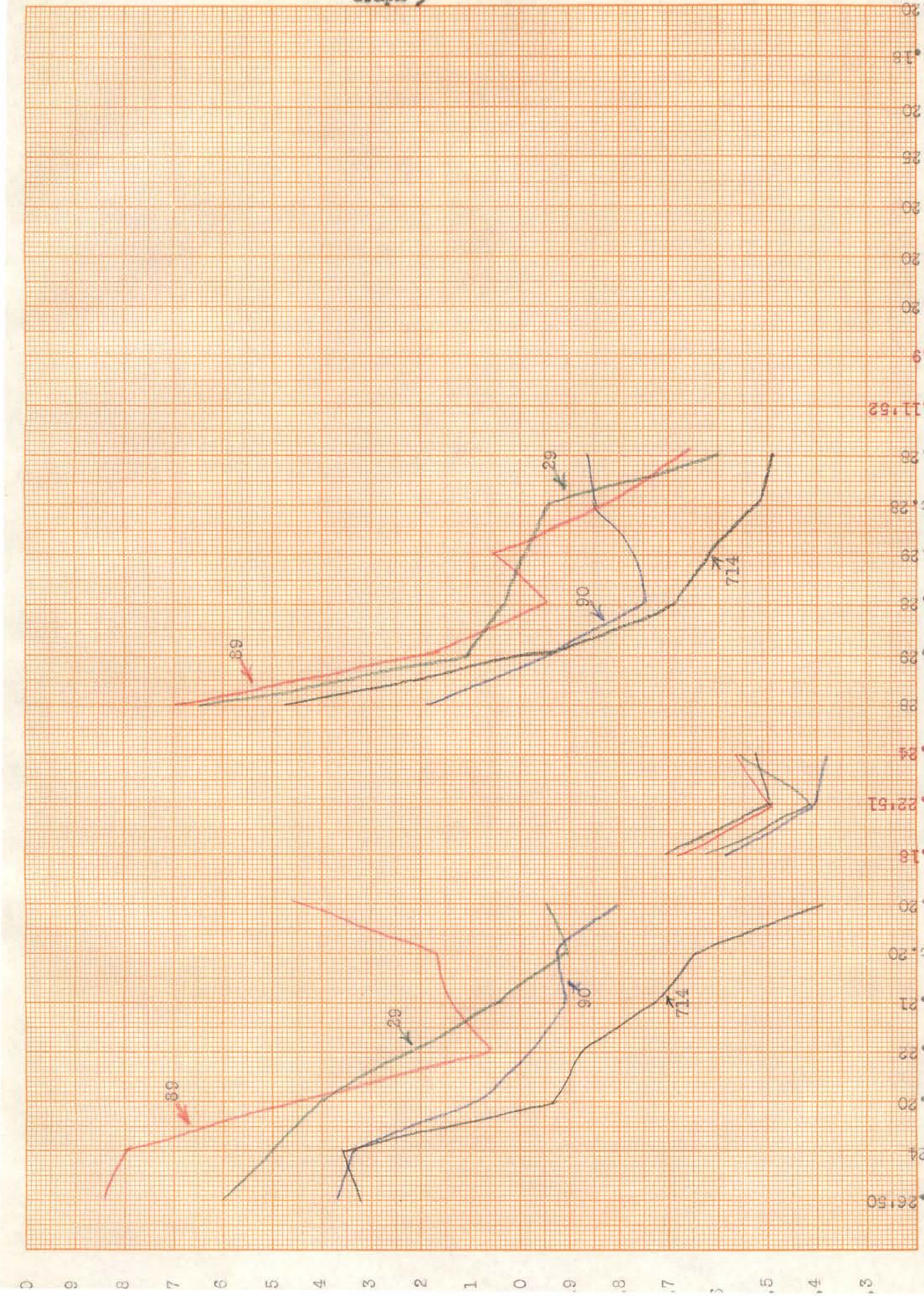
Stillwater ...
% Phosphorus

Graph 2



% Potassium

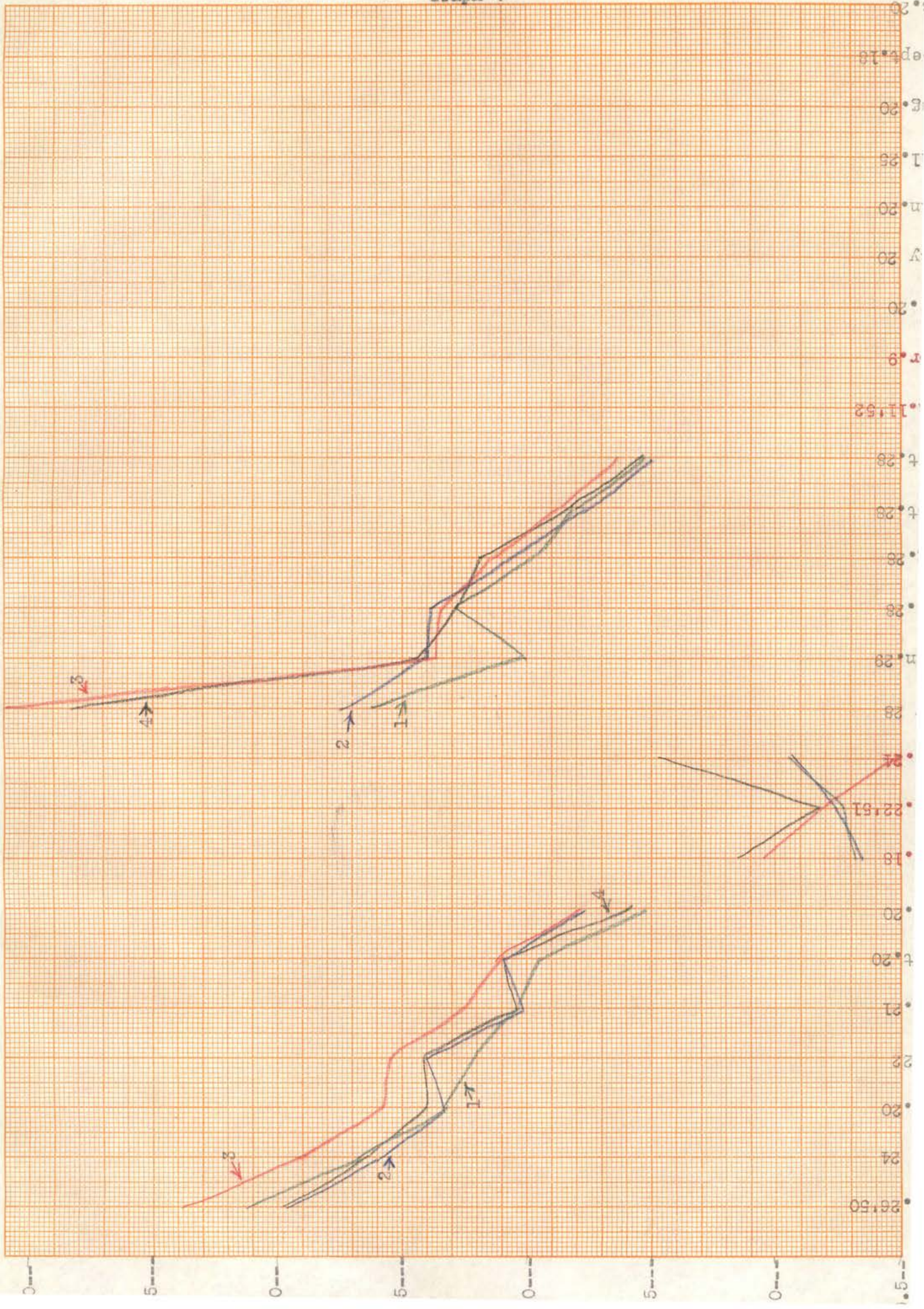
Graph 3



Bixby-Jan Data Improved

% Nitrogen

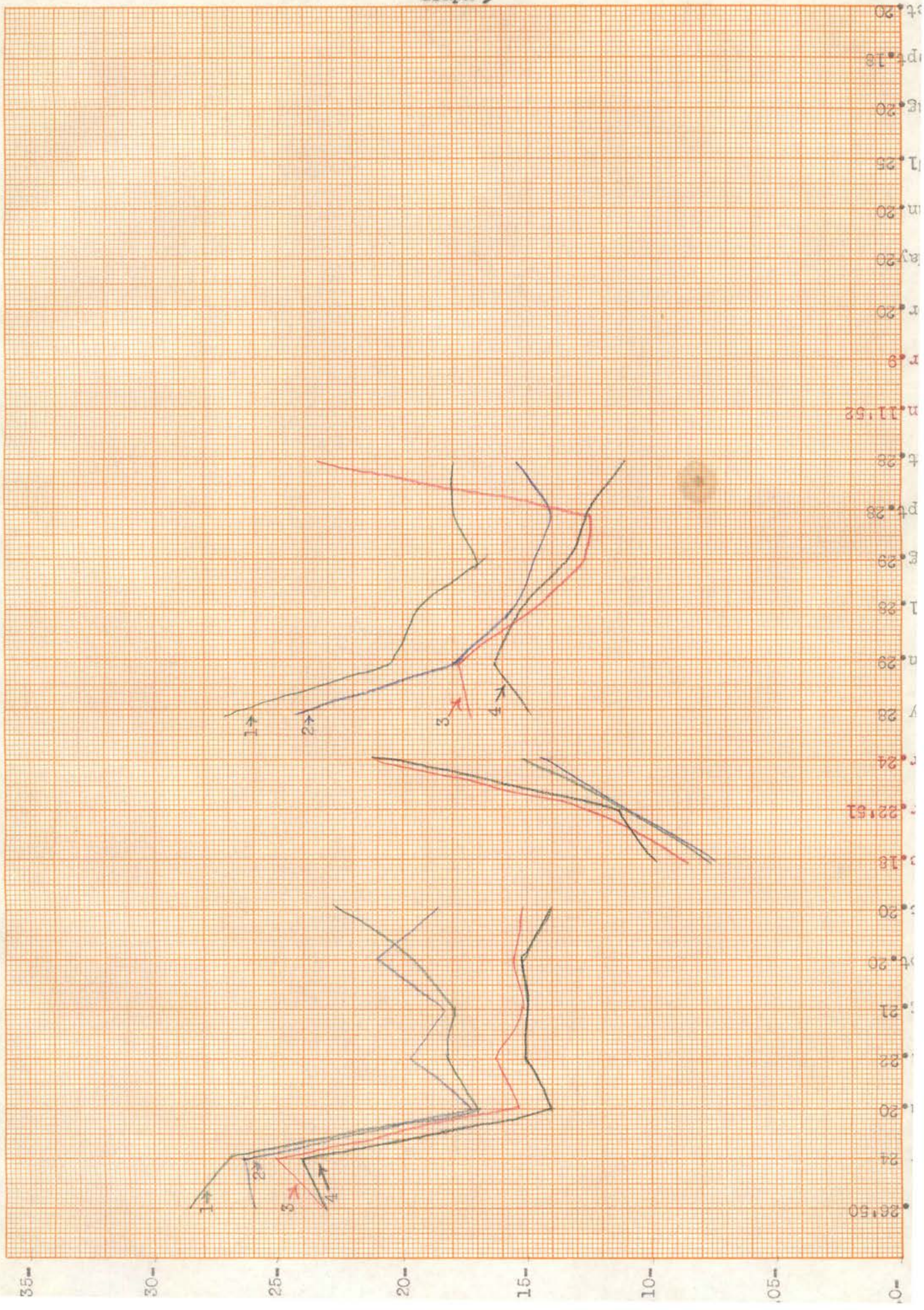
Graph 4



Bixby-San Saba Variety

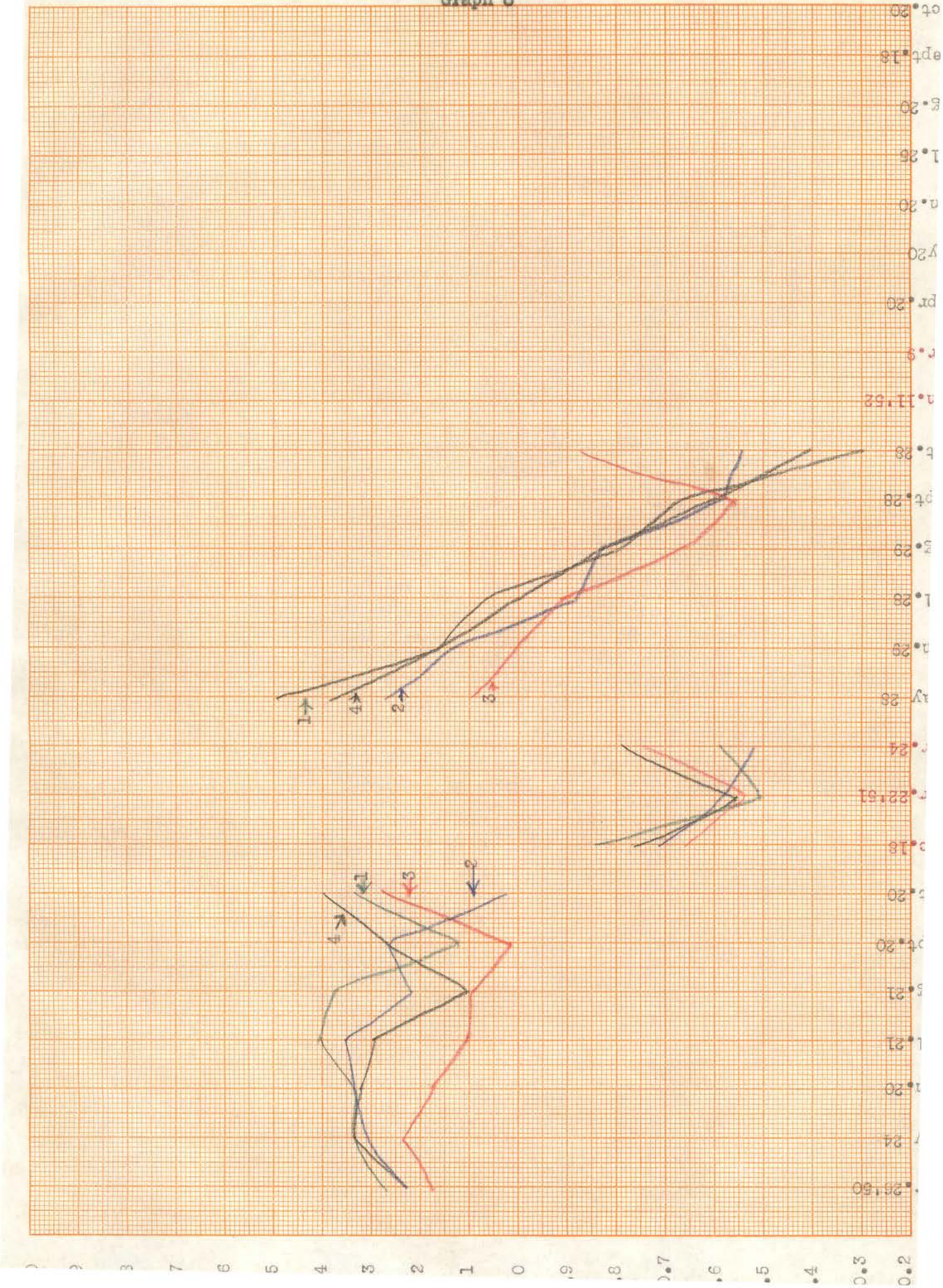
% Phosphorus

Graph 5



% Potassium

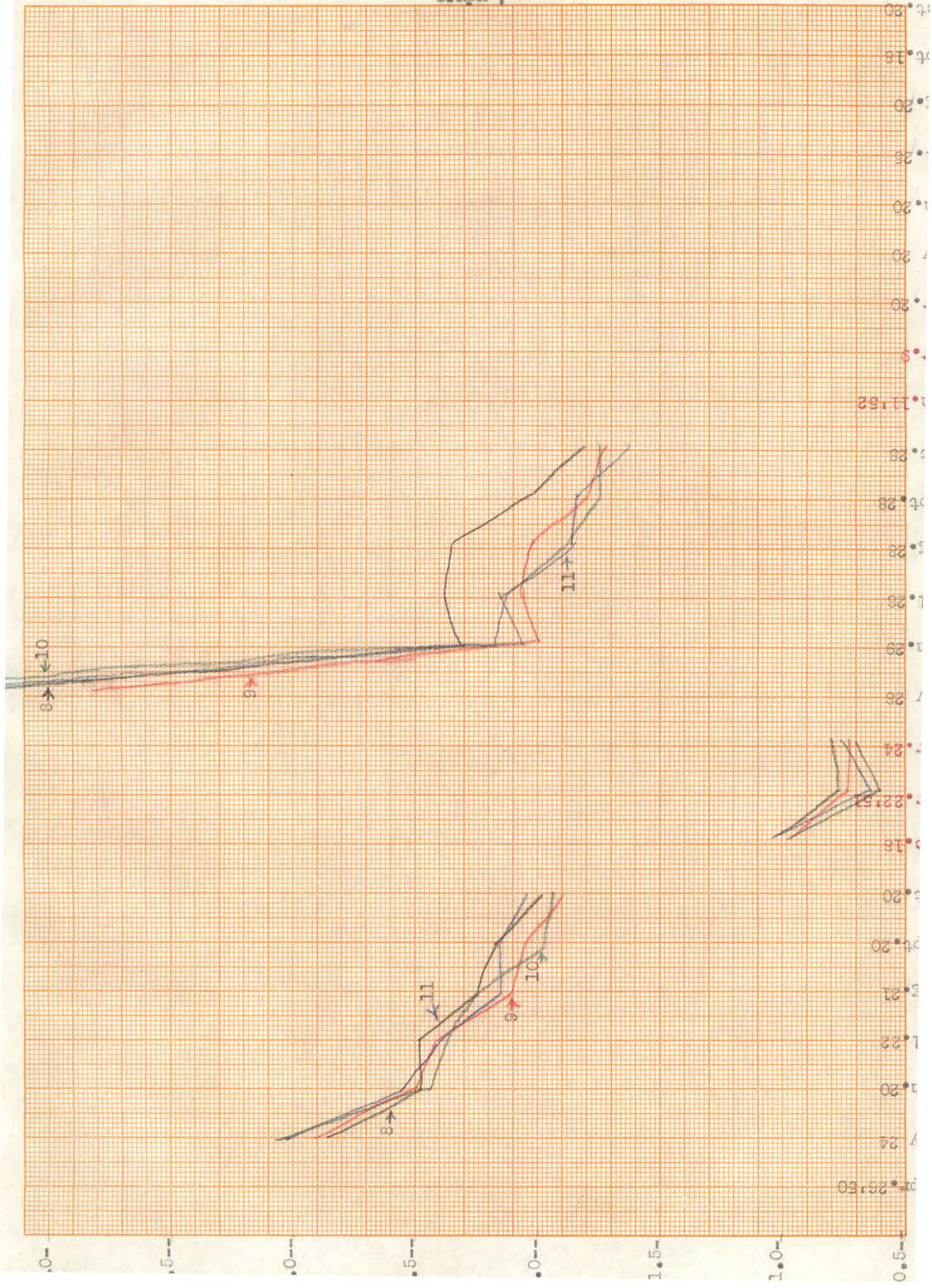
Graph 6



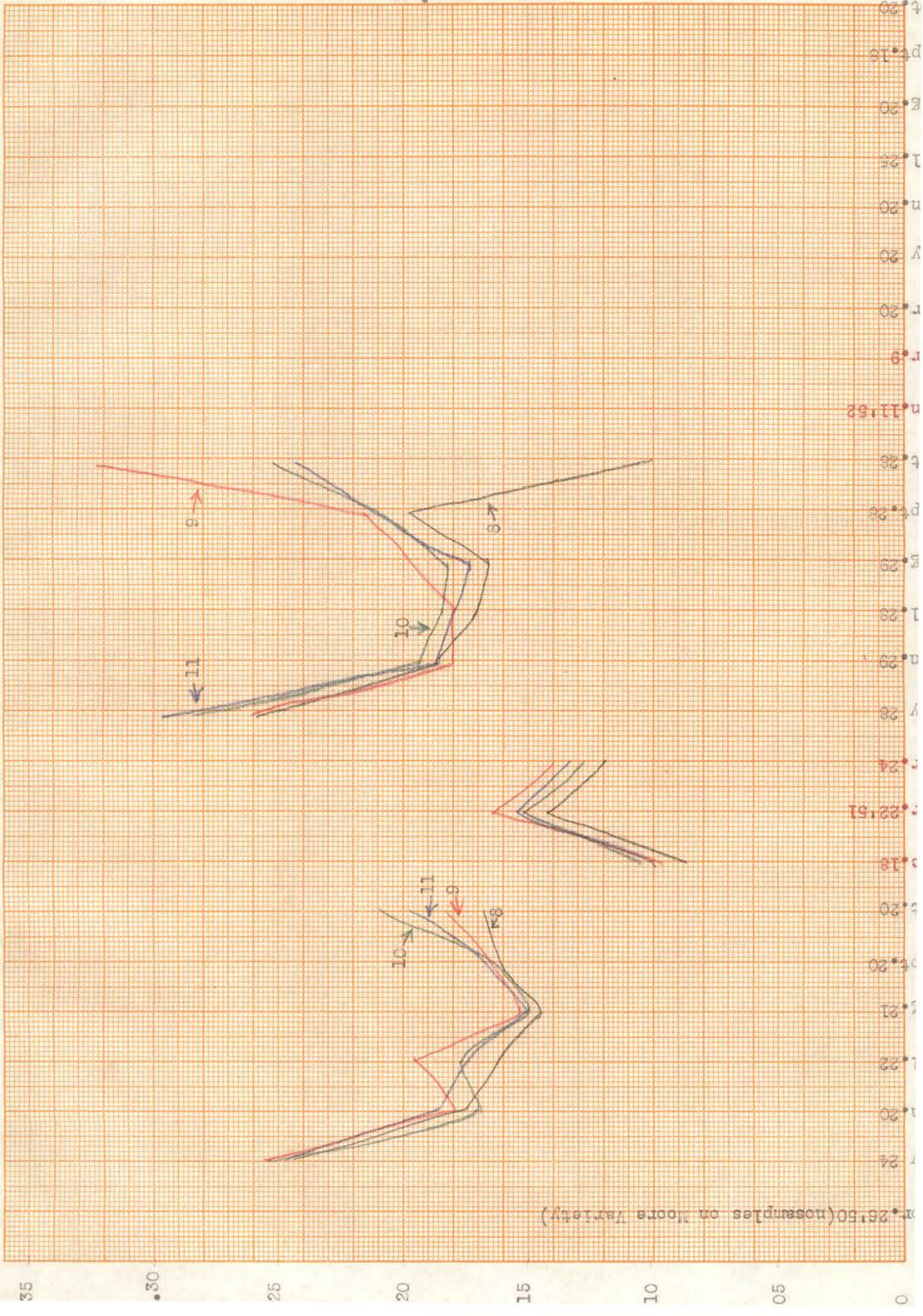
Bixby-Moore Variety

% Nitrogen

Graph 7



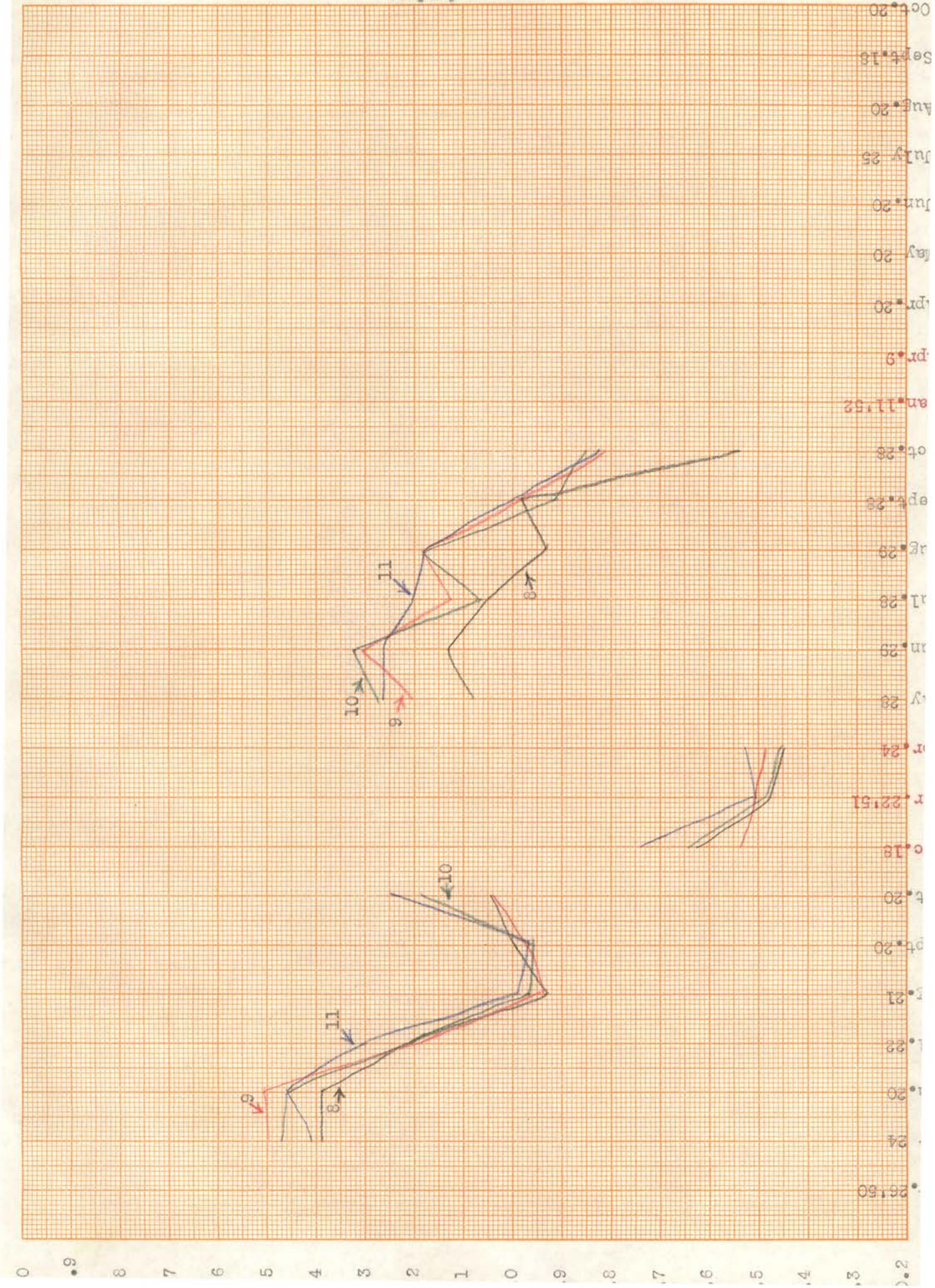
Bixby-Moore Variety
% Phosphorus
Graph 8



Bixby-Moore Variety

% Potassium

Graph 9



DISCUSSION

Charts one, two, and three were prepared for comparing the amounts of nitrogen, phosphorus, and potassium for natives (chart one), San Saba Improved (chart two), and Moore (chart three). The range in seedlings from highest to lowest is 2.762 to 2.381 percent for nitrogen, .1862 to .1560 percent for phosphorus, and 1.20 to .95 percent for potassium. For San Saba Improved the ranges are 2.386 to 2.072 percent for nitrogen, .2183 to .1520 percent for phosphorus, and 1.12 to 1.0016 percent for potassium. The ranges for Moore were 2.468 to 2.281 percent for nitrogen, .2037 to .1785 percent for phosphorus, and 1.178 to 1.055 percent for potassium.

By establishing the averages given on charts one, two, and three on the corresponding graphs for each tree and nutrient, it was possible to determine the time of year when the nutrients in leaves of each tree reached and average level. July fifteenth was the most frequent date by odds of 9:1. This is the time of year when nitrogen content of the leaves tends to stabilize for a short time and follows rapid spring growth and maturity of the leaves in size.

A range of 2.3 to 2.5 percent nitrogen was found in the leaves of the most productive trees. These figures are lower than those established by Alben (1) from tests performed in Louisiana.

Measurements of trees over a four year period, some receiving nitrogen alone and others receiving nitrogen plus phosphate, did not indicate any significant growth increase for the phosphorus (nitrogen being equal in both treatments). These results agree with those of Hunter (28).

The leaf analyses indicated no increase in the amount of potassium as a result of fertilizing with this element. This may have been due to the small amount applied, to a high fixing capacity of the soil, or the potash may have been stored in other than leaf tissue.

Because of its low degree of variability and its failure to appear in the leaves after application to the soil, determination of potash is of no particular value in determining production or growth of pecan trees. Phosphorus being found in even less amounts and varying even more in content of the leaves than does potash, is of no consequence. Nitrogen, which is found in much greater amounts than either phosphorus or potash and subject to a wide range of fluctuation can very well be used as an index of production and growth.

Chemical analysis may well be used during the growing season (preferably mid-July) for an index of production. Optimum nitrogen should be between 2.3 and 2.5 percent of the dry weight of the leaf. When nitrogen falls below 2.3 percent, the amount of growth is not enough to make the tree highly productive. If the nitrogen is above 2.5 percent, secondary growth and nut shedding prevent production even though growth is made.

SUMMARY AND CONCLUSIONS

Graph one (Stillwater grove - nitrogen) indicates a response to nitrates by both tree 29 and 89 with tree 90 being below those two and above 714 in nitrogen content of the leaves. Decline in nitrogen is generally a gradual decrease throughout the season with no leveling off period such as shown by phosphorus and potassium.

A comparison of graph one with graphs four and seven shows a greater range in nitrogen content between individual native trees than between individual trees of the same variety.

Tree 89 was highest of trees on graph one for nitrogen, phosphorus, and potash. Chart one has been made to show the relative status of the trees in the Stillwater group as regards average nutrients found in the tissue tests. Tree 29 was the second highest in nitrogen and potassium but was lowest of the group for phosphorus. The depletion of phosphorus in this case was apparently caused by the continued use of nitrates alone. Such results are in accordance with the findings of Hunter and Hammar (29) and Sitton (45). Tree 90 (unfertilized check) cannot be compared with tree 714 because of the earth having been removed from about it with serious damage to the feeder roots.

Chart one on being compared with graphs one, two and three shows the best time for taking one representative sample to be in the month of July.

Chart two compared to graphs four, five, and six shows no increase in potassium for trees 3 and 4 which received 100 pounds each of twenty-five percent potash in 1949. The increase in nitrogen for these two mentioned trees may be explained by; (1) stimulation of azotobacters by the potash applied, or (2) the accumulation of the potassium in other than leaf tissue.

Conclusions arrived at after this study were;

(1) There is a wider range in nutrient levels between native trees than between a like number of trees of one variety.

(2) About July fifteenth is the best time during the year to take a single representative sample.

(3) The most productive trees have a nitrogen content range of from 2.3 to 2.5 percent average in the leaves.

(4) Nitrogen applied alone tends to reflect in the leaf sample as an increase in nitrogen and a decrease in phosphorus compared to the check trees.

(5) Nitrogen and phosphorus applied together reflect in the leaf sample as an increase in both elements compared to the check trees.

(6) For a period of four growing seasons, nitrogen alone has produced as much growth as has nitrogen and phosphorus applied together (nitrogen being equal).

(7) No correlation can be drawn between the analysis of twigs and the subsequent growth and mineral matter content of the leaves.

(8) Applications of potassium have not increased the potassium content of the leaves.

(9) No final conclusions can be formulated at this time on the effects of fertilizer treatments on alternate bearing because; (1) of incomplete yield records of the variety trees at Bixby, (2) unseasonable freezes two of the four years of the test have made harvest of some of the trees impossible, and (3) the results of some of the treatments are but now becoming apparent.

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