

To the Graduate Council:

I am submitting herewith a thesis written by Michael Blaine Donoho entitled "A Study of the Seasonal Trend of Several Nutrient Elements in Golden Delicious Apple Leaves in Tennessee Orchards to Determine the Ideal Time to Collect Leaf Samples for Foliar Analysis." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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We have read this thesis and
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Thesis
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A STUDY OF THE SEASONAL TREND OF SEVERAL NUTRIENT ELEMENTS
IN GOLDEN DELICIOUS APPLE LEAVES IN TENNESSEE ORCHARDS
TO DETERMINE THE IDEAL TIME TO COLLECT LEAF SAMPLES
FOR FOLIAR ANALYSIS

A Thesis
Presented for the
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Degree
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Michael Blaine Donoho

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ABSTRACT

Leaf samples from Golden Delicious apple trees were collected at nine dates throughout the growing season at four locations in Tennessee. The leaf samples were analyzed for percent N, P, K, Ca and Mg to determine the seasonal trends of these elements and to determine if a common period of relatively little nutrient change exists. N, P and K showed a general decrease in concentration throughout the season. Ca levels increased throughout the growing season, but Mg showed irregular changes. A period of minimal change in mineral composition of leaves with the exception of Mg was July 30 through August 27 for all locations. This would be the ideal time for collection of leaf samples for foliar analysis.

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CHAPTER I

INTRODUCTION

Plant or foliar analysis has a history of about 100 years. Early work in foliar analysis was primarily done in fruits with grapes being the most common. The point at which foliar analysis expanded from a research tool to a diagnostic tool to aid the grower varied greatly from area to area depending on when sufficient data was obtained to enable interpretation of results. Grower service programs were available as early as 1949 in some states. Currently about 16 states have a plant analysis service (8).

Foliar analysis is considered to be one of the most valuable techniques available to the horticultural scientist in determining the nutritional conditions necessary for optimum growth, yield and quality of a crop. Simply stated, foliar analysis utilizes the relationship that has been found to exist between the nutrient content of a leaf and the growth of that plant and/or the yield and quality of fruit it produces (3).

The nutrient element concentration in any plant part will change with time. The seasonal changes that occur in the leaf composition are such that analytical data may be misinterpreted if the sampling date is not taken into account.

The objective of this study is to determine the seasonal fluctuations of selected nutrient in Golden Delicious apple trees in four areas of Tennessee and to find a period of relatively little change in nutrient composition in leaf samples during this period.

CHAPTER II

LITERATURE REVIEW

In order to comprehend the leaf analysis approach to nutritional problems, it is necessary to have some knowledge of the principles involved.

Leaf analysis is based on the contention that: (a) the leaf is the principal site of plant metabolism; (b) that changes in nutrient supply are reflected in the composition of the leaf; (c) that these changes are more pronounced at certain stages of development than at others, and (d) that the concentration of nutrients in the leaf at specific growth stages are related to the performance of the crop (2).

A plant analysis interpretation is based on a comparison of the element concentration found in a particular plant part taken at a specific time with known desired values or ranges in concentrations. The interpretation is based on sufficiency ranges, the optimum element concentration range below which deficiency occurs and above which toxicity or imbalance occur. The elements studied and their sufficiency ranges for apples are given in Table 1 (8).

For tree crops, the development of leaf analysis as a diagnostic tool in preference to soil analysis appears to be related to the size and perennial nature of the plants. For example, it has been difficult to sample the soil of a mature

TABLE I
ELEMENTS AND THEIR SUFFICIENCY RANGES FOR APPLES

Element	Sufficiency Range
Nitrogen	2.0 - 3.0%
Phosphorus	0.15- 0.50%
Potassium	1.25 - 3.00%
Calcium	1.00 - 2.00%
Magnesium	0.20 - 0.50%

tree and determine whether or not adequate nutrient absorption has or will occur. Roots of many fruit trees typically grow to a depth of one and one-half to two meters or more, and extend laterally some six to 10 meters. Moreover, a tree occupying a soil for some 10 to 50 years or more is subject to many cultural abuses, the accumulation of which, sooner or later, brings about problems (3). The correlation between soil and leaf analysis has frequently been poor for most nutrient elements although such correlations do exist (3, 14).

Foliar analysis of deciduous fruit plants is based largely on total nutrient concentrations. Leaf nutrient concentration is controlled primarily by nutrient supply, but may be influenced by secondary external and internal factors. These factors are responsible for the variation in leaf nutrient concentration that sometimes occur between samples taken from a plant species growing on the same or different sites with similar soil fertility conditions. The extent to which these secondary factors influence leaf nutrient concentration should be known so that due allowance may be made for them when interpreting leaf analysis data (2, 4).

The position from which the leaf sample was taken will markedly affect the nutrient concentration of the sample (15). Potassium (K) was found to be higher in leaves from the middle and apex leaves of extension shoots, however, calcium (Ca), magnesium (Mg), iron and manganese were found to be highest

in the basal leaves of nonbearing spurs (6). Comparison between trees should be confined to samples of the same type. Mid-shoot leaves were found to be at least as sensitive in the total test as any other shoot leaves to changes in nutrient levels (5). Therefore, the contemporary practice is to analyze mid-shoot leaves in nutritional diagnostic work.

Studies have shown that for any given leaf position, there is an orderly and smooth change in nutrient content within the leaf with advancing season (7, 9, 10, 11, 12, 13, 15, 16, 18, 22). In addition, there is a time period during the season when the rate of change in the concentration of a given nutrient in leaves is minimal. A shorter time period exists when the concentration of all minerals in a leaf is changing very little (1, 7, 9, 10, 11, 12, 13, 16). This period is the ideal time to collect leaf samples since differences in a few days will not cause large differences in foliar analysis results. Time of day in collecting samples was not found to have any significant effect (13).

CHAPTER III

METHODS AND MATERIALS

The experiment was conducted in the Summer of 1975 at the University of Tennessee Plant and Soil Science Field Laboratory, Knox County (location A), at the Plateau Experiment Station, Cumberland County (location B), at Jack Flippen's orchard in Obion County (location C), and at R. B. Young's orchard in Hardeman County (location D).

Seven Golden Delicious trees were selected for foliar sampling at each of the four locations. The selected trees were 8 to 12 years of age and approximately at the same stage of growth and were treated the same at each location. The experimental design was a randomized complete block design using each individual tree as a replication.

Leaf samples consisting of at least 30 leaves per tree at each sampling date were taken approximately every two weeks from June 6 to September 24 (a total of nine sampling dates). The sample contained leaves from the mid point of the current season's elongation taken from the entire circumference of the tree in a band about four to six feet above ground level. The harvested samples were placed in labeled brown paper bags and dried in forced-air ovens at 70 C. The dried samples were ground in a Wiley mill using a 40-mesh screen and stored in air tight bottles until analyzed.

Ammonia nitrogen (N) was determined by adding 10 ml concentrated sulfuric acid to 0.2 g of dry weight sample and allowing it to predigest for four hours at room temperature. The mixture was then heated to 200 C for two hours. At the end of this period, 15 ml of 35 percent hydrogen peroxide were added and the mixture was reheated for 45 minutes after clearing. Following heating, the solution was cooled, placed in a 250 ml volumetric flask and brought to volume with deionized-distilled water. An aliquot from the 250 ml was placed in a Techicon Autoanalyzer and the concentration of N was determined from the phenolhypochlorite color reaction as described by Thomas et al. (21). Results are reported as percent N on a dry weight basis.

Concentrations of K, Ca, phosphorus (P) and Mg were determined by placing 0.5 g ground plant tissue in a porcelain crucible and ashing at 500 C for four hours. After cooling, 10 ml of 3N hydrochloric acid were added to the ashed sample. The solution was filtered using Whatman number 40 (ashless) filter paper into a 100 ml volumetric flask and brought to volume with deionized-distilled water. The K and Ca were determined using a Techicon III dual-channel flame photometer. The Mg was determined colormetrically by the magnesium blue reaction and P was determined by the ammonia vandate reaction. These procedures were described by Steckel et al. (20). Results are reported as percent K, P, Mg or Ca on a dry weight basis.

Procedures of the Statistical Analysis System (17) were employed for this experiment. Data were analyzed in two separate procedures. First, a combined analysis of variance was performed across locations to determine if there was a significant difference among locations. Upon finding a significant difference among locations, an analysis of variance was performed at each individual location. This was done to determine if the nutrient concentration was significantly different with changing sampling times. Means were separated by Duncan's New Multiple Range Test. The results from the Duncan's New Multiple Range Test were used to aid in determining the lines drawn to illustrate the seasonal trends of the elements studied.

CHAPTER IV

RESULTS AND DISCUSSION

Differences among sampling times and mineral concentrations were significant at the .01 percent level of probability for all locations except N at location B which was significant at the .05 percent level of probability and P at location D which showed no significant difference.

The seasonal trend for N was a general decline in nutrient levels throughout the growing season for all locations except location C where there was a slight increase early in the season. In midseason there was a period of relatively little decline (see figures on pages 13, 18, 23 and 28). These results agree with previously reported work (13, 16, 18).

At locations A and B the seasonal trend for P was a general decline as the season progressed with a relatively stable midseason period. These trends followed closely the patterns described by other workers (13, 16, 18). The seasonal trend at location C was to increase early in the season followed by a stable midseason period and then a rapid decline. Location D showed no change throughout the growing season (see figures on pages 14, 19, 24 and 29).

The seasonal trend for K was a general decline in nutrient levels throughout the season for all locations. Early in the growing season and at the latter part of the season the rate

of decline was great and there was a period of relatively little decline in midseason (see figures on pages 15, 20, 25 and 30). These results agree with previously reported work (13, 16, 18).

There was a general increase in Ca levels throughout the growing season. This increase was more pronounced early in the season (at all locations) and at the end of the season (at locations B and C). There was a stable midseason period for all locations (see figures on pages 16, 21, 26 and 30). These results followed closely the patterns described by other workers (13, 16, 8).

Seasonal changes for Mg were quite irregular and no single trend could be distinguished. There was a period of relatively little change in midseason and this period was much shorter (at locations B, C and D) than the stable period exhibited by other minerals (see figures on pages 17, 22, 27 and 32). These results also agree with previously reported work (13, 16, 18).

The physiological bases for these changes have been studied by Emmert (5) and Smith (19). The downward trends in N, P and K that occur in Spring are due to rapid increases in leaf dry weight which cause the nutrients, initially present in high concentrations, to be diluted. Thus, nutrient concentrations decrease, even though absolute amounts show a general net increase. Conversely, the upward trend in Ca that

occurs in Spring is due to this nutrient, initially present in low concentrations, accumulating more rapidly than leaf dry weight. The late Summer drop in leaf K is generally ascribed to competition between leaves and fruits for newly absorbed K.

There is a time period during the season when the rate of change in the concentration of a given nutrient in leaves is minimal. A shorter time period exists when the concentrations of all minerals in a leaf is changing very little (1, 7, 9, 10, 11, 12, 13, 16). This period is the ideal time to collect leaf samples since differences in a few days will not cause large differences in foliar analysis results. This time period for location A (see Figures 1-5) for all elements combined is July 30 through August 27. If Mg is not considered because of its irregular patterns, at locations B, C, and D then the period to sample is longer and more uniform among elements and across locations. The ideal sampling time for location B (see Figures 6-10) is July 27 through August 27. This time period for locations C (see Figures 11-15) and D (see Figures 16-20) is July 30 through August 27. Thus a uniform ideal time period to sample across all locations would be July 30 through August 27.

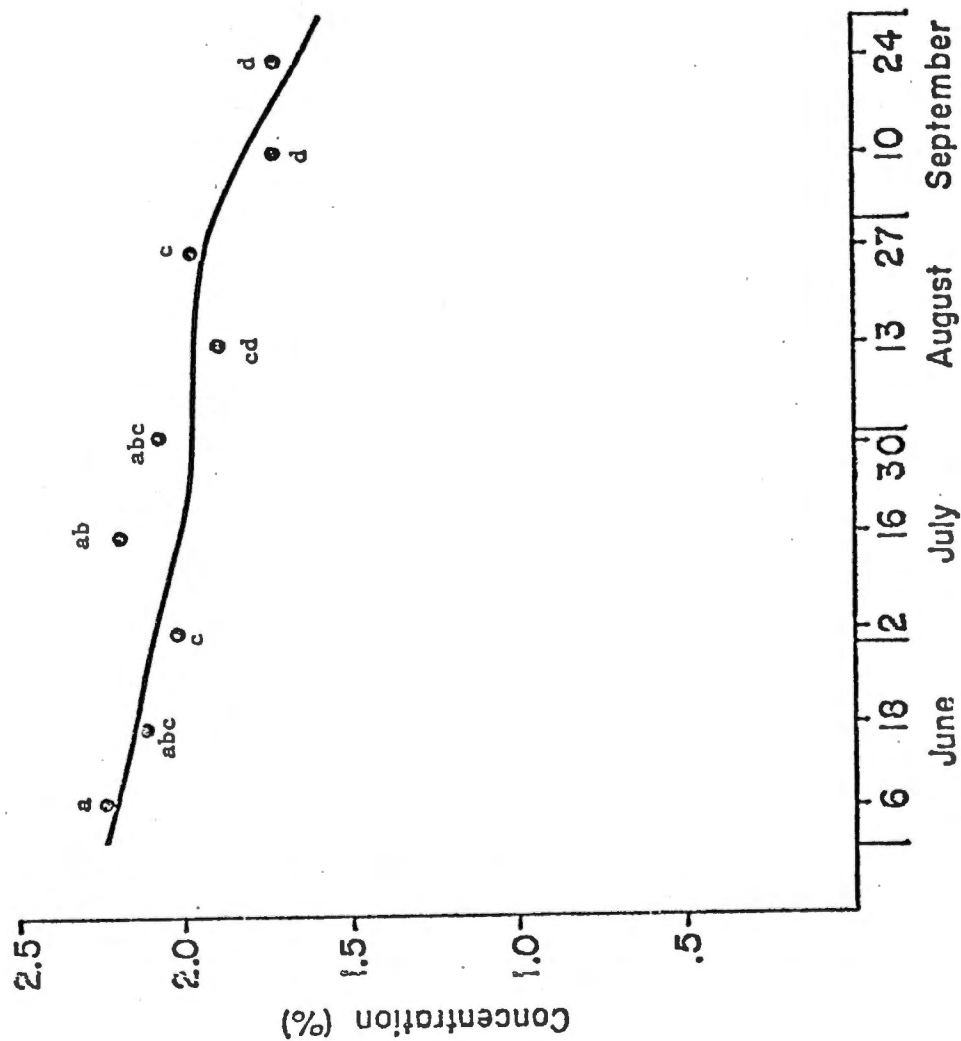


Figure 1. Seasonal trend in concentration of N at location A. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

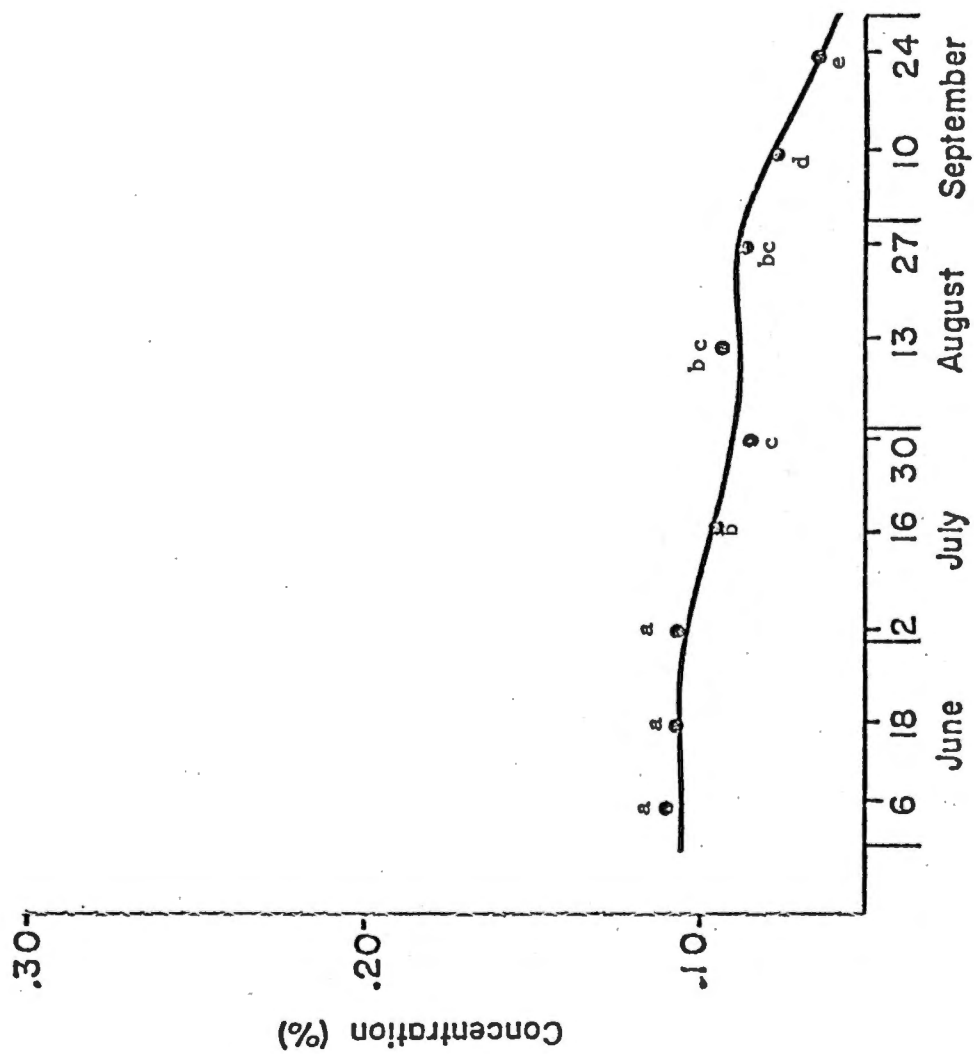


Figure 2. Seasonal trend in concentration of P at location A. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

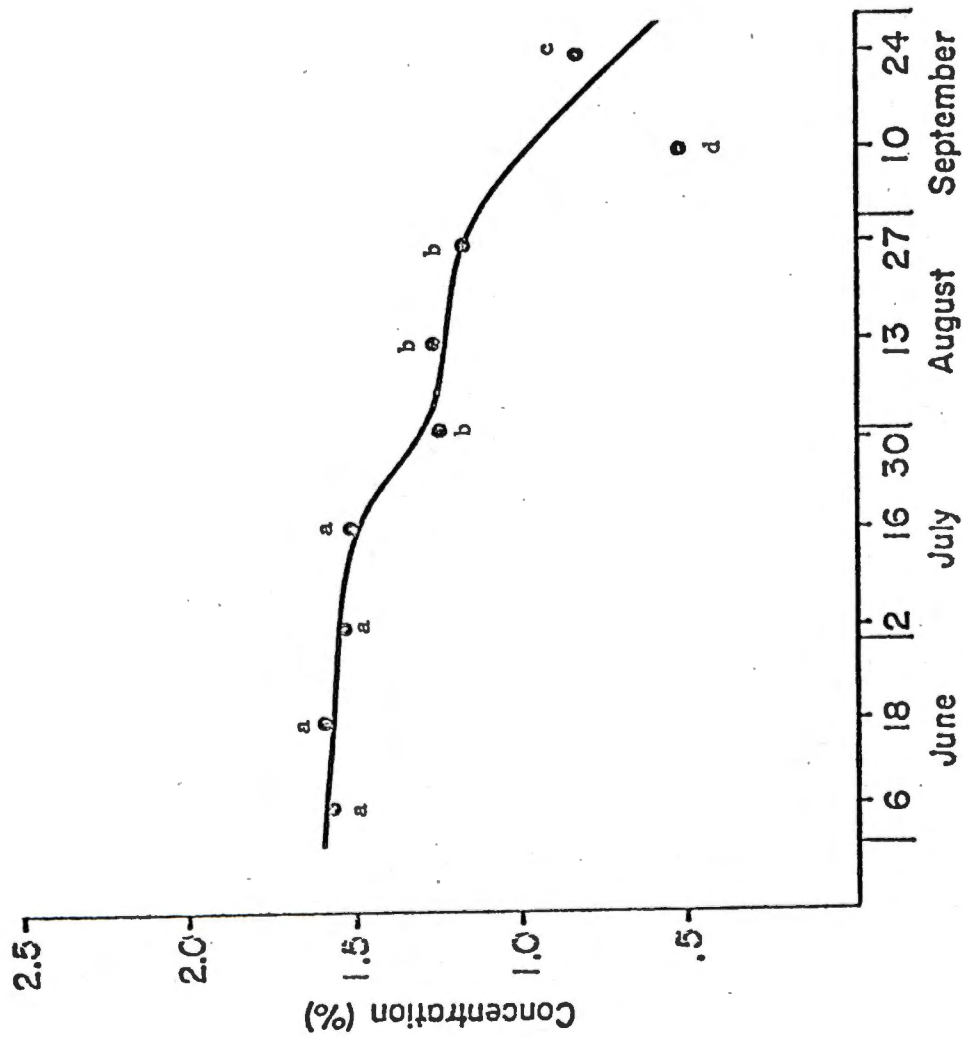


Figure 3. Seasonal trend in concentration of K at location A. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

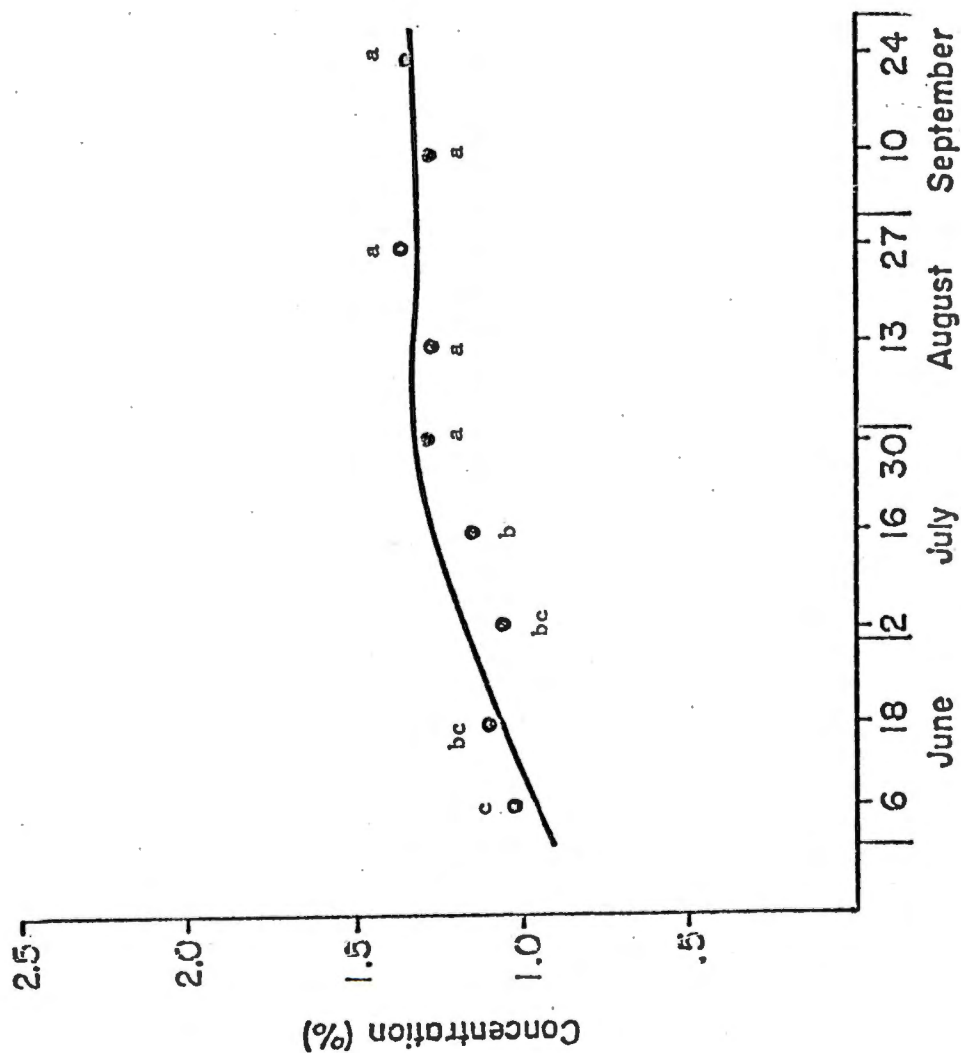


Figure 4. Seasonal trend in concentration of Ca at location A. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

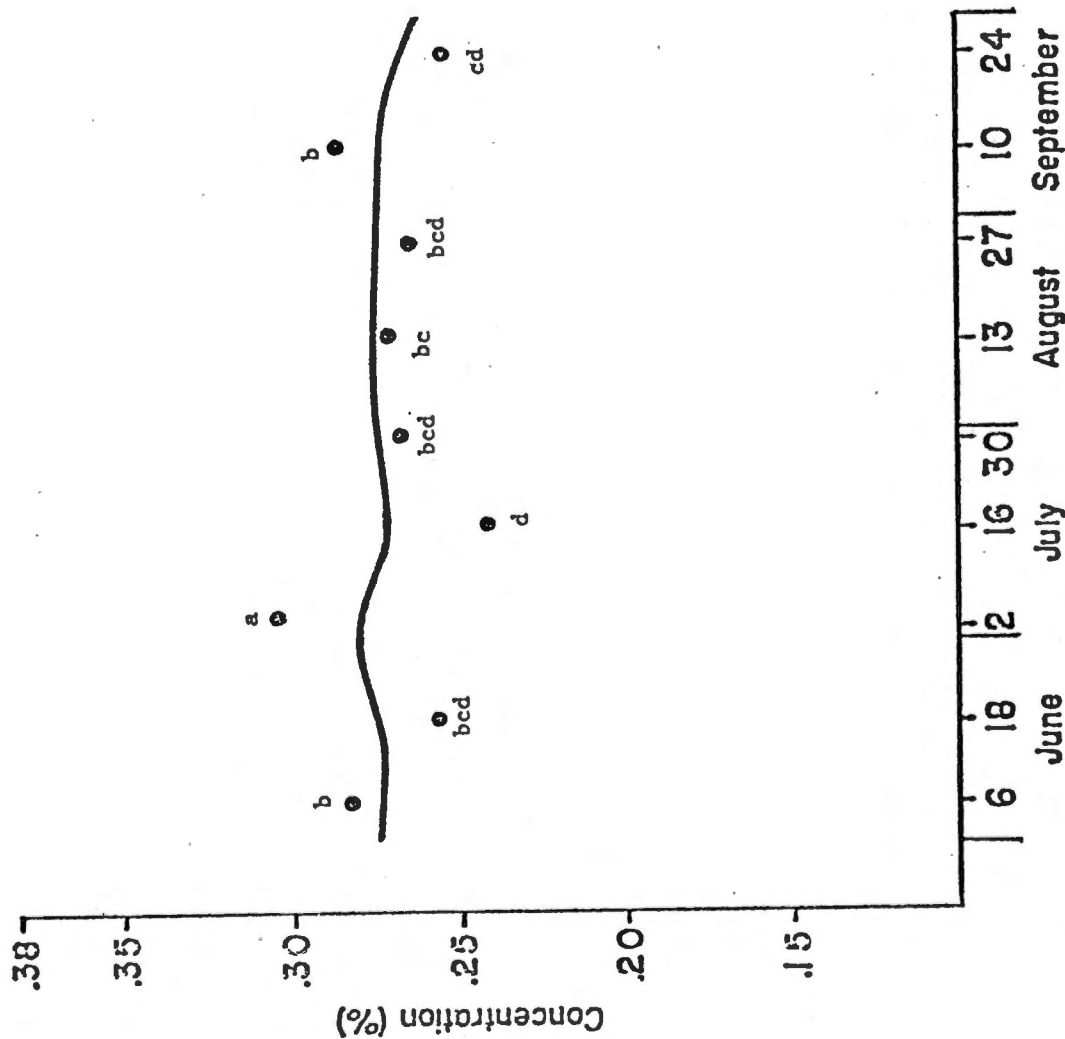


Figure 5. Seasonal trend in concentration of Mg at location A. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

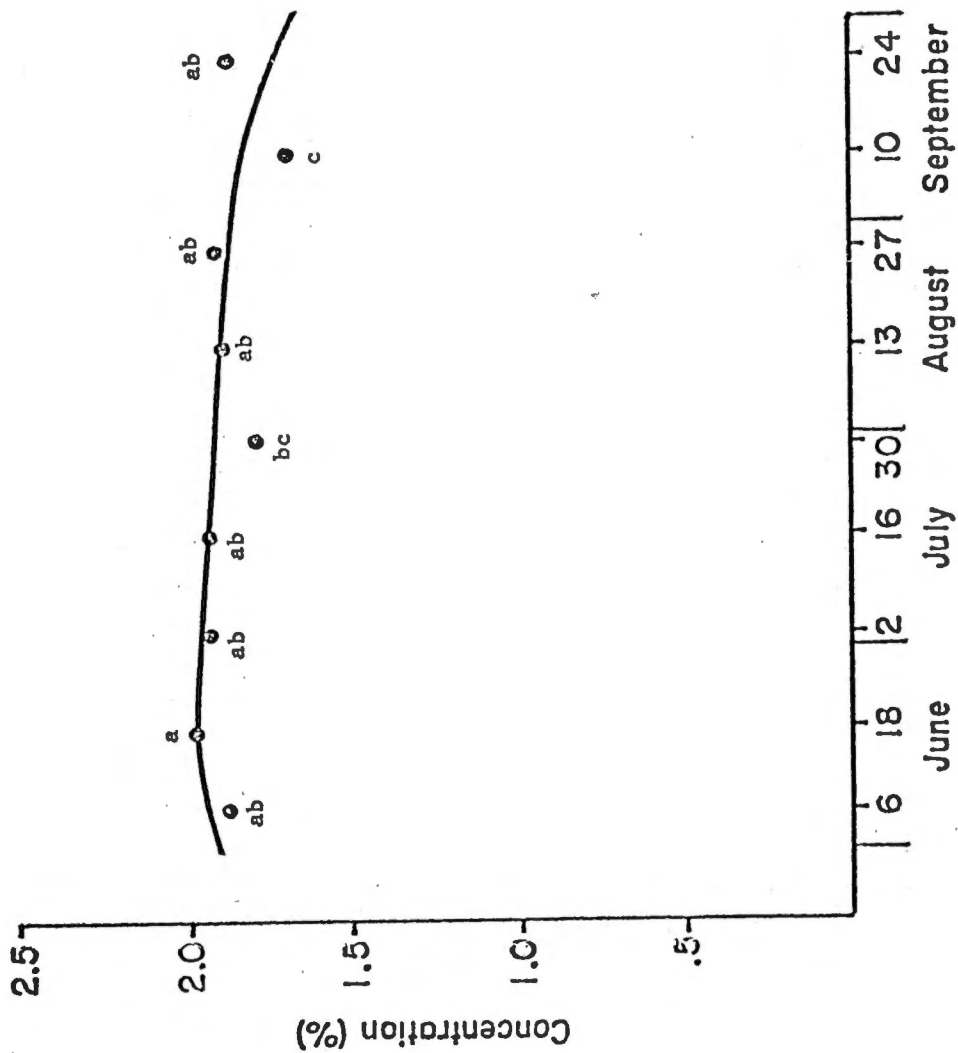


Figure 6. Seasonal trend in concentration of N at location B. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

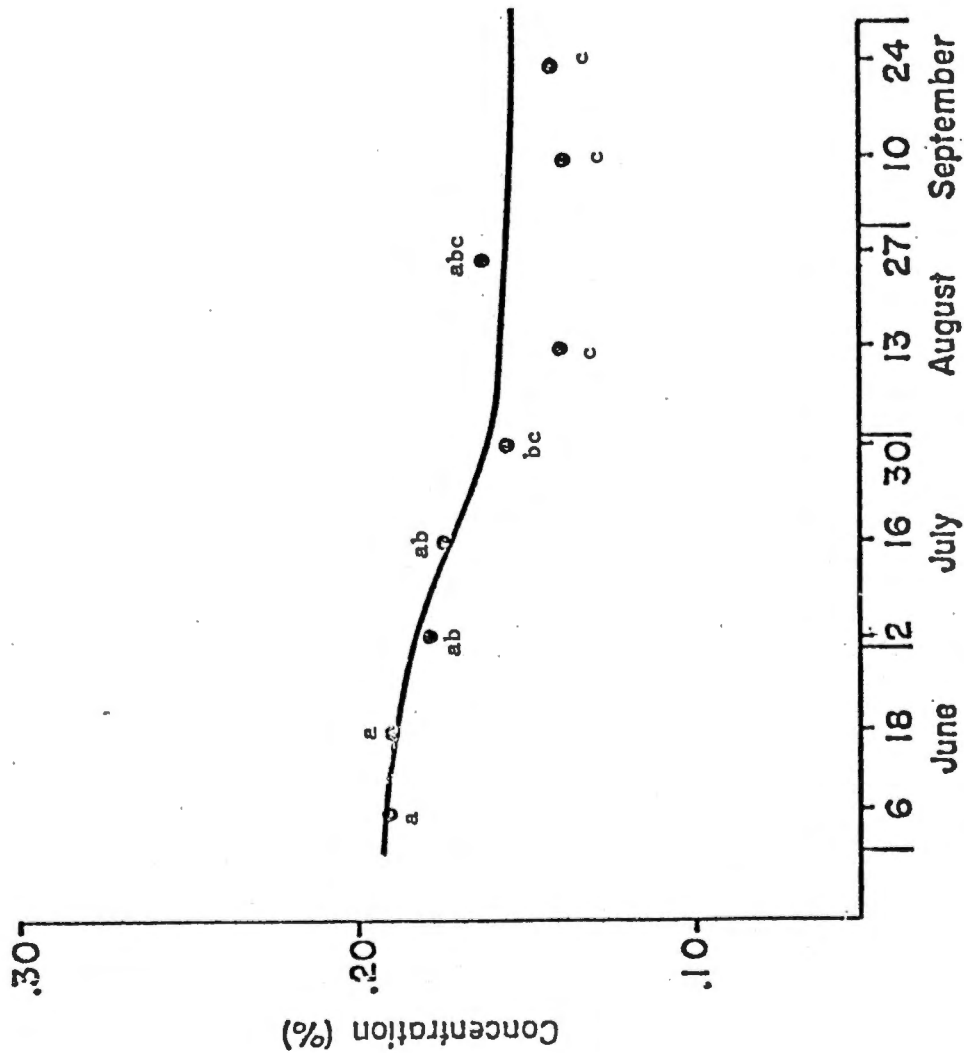


Figure 7. Seasonal trend in concentration of P at location B. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

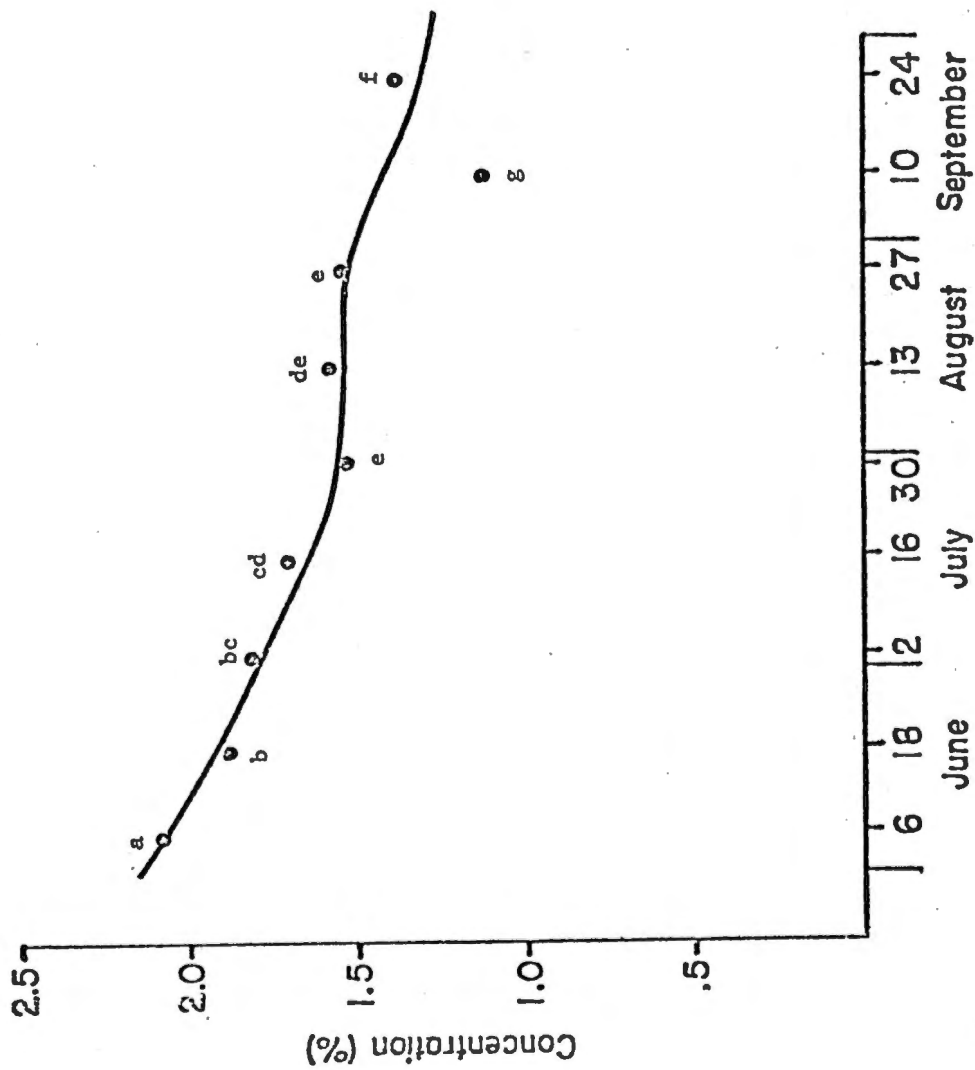


Figure 8. Seasonal trend in concentration of K at location B. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

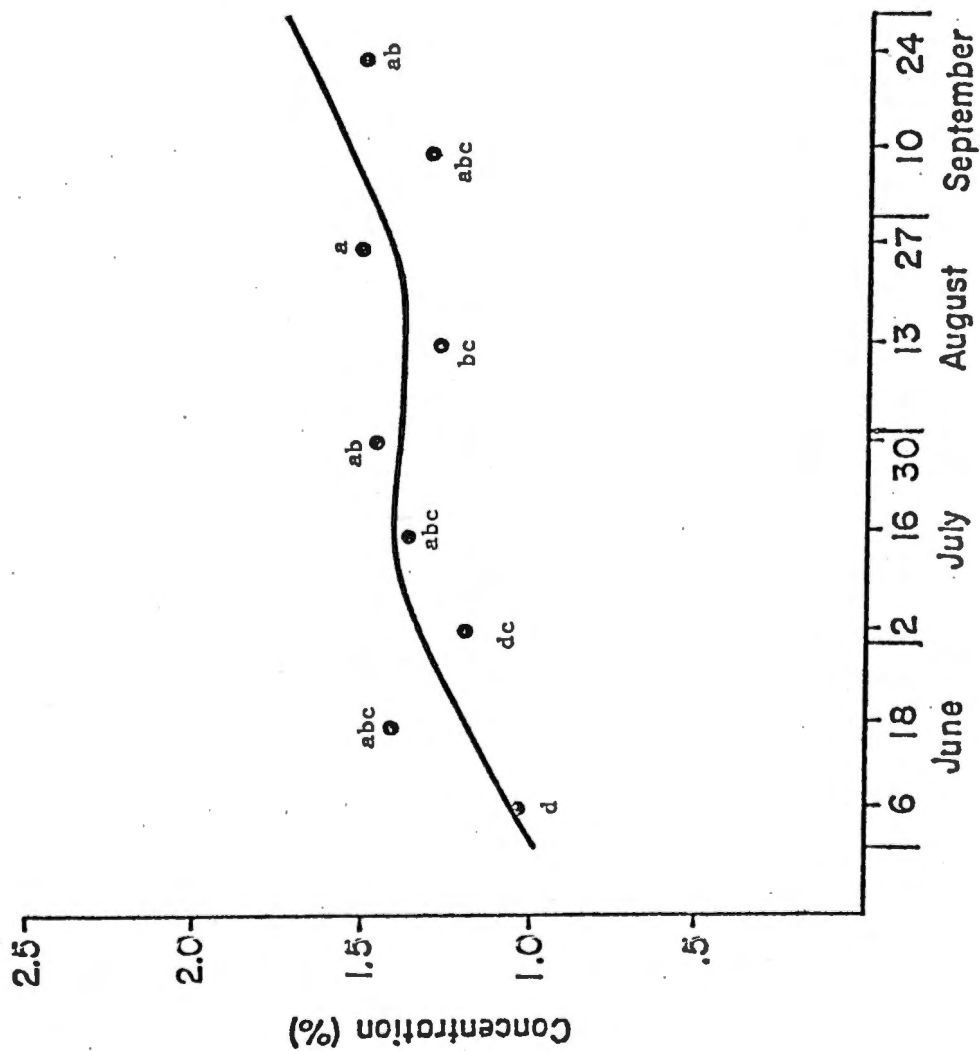


Figure 9. Seasonal trend in concentration of Ca at location B. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

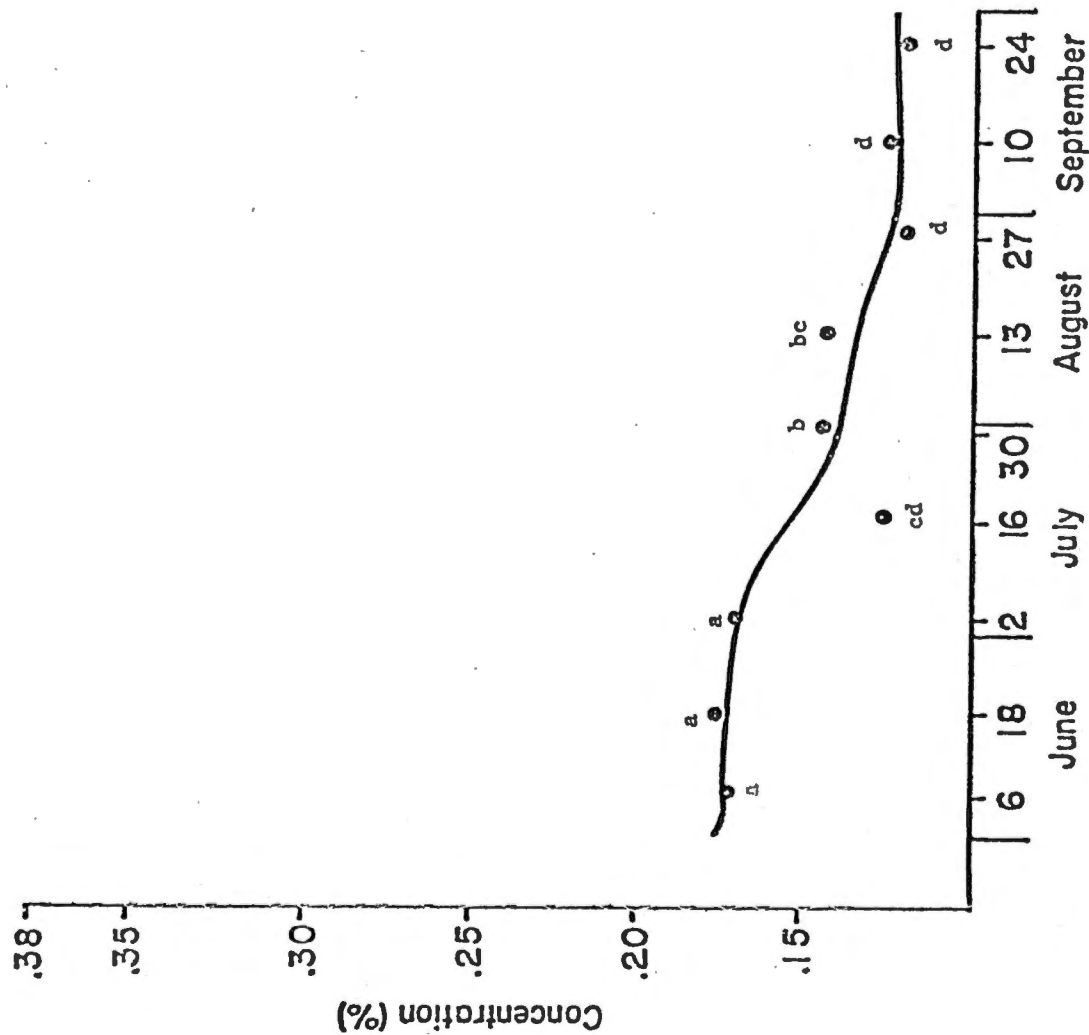


Figure 10. Seasonal trend in concentration of Mg at location B. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

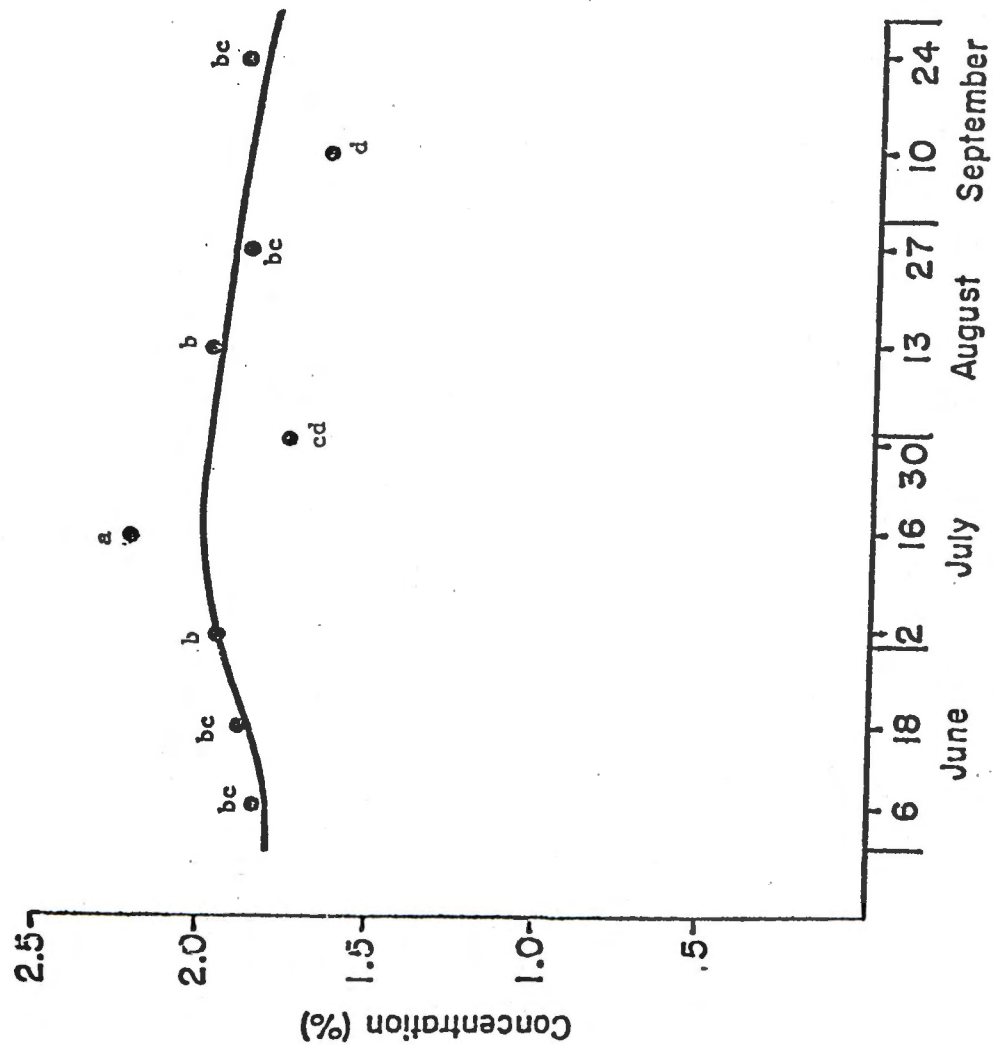


Figure 11. Seasonal trend in concentration of N at location C. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

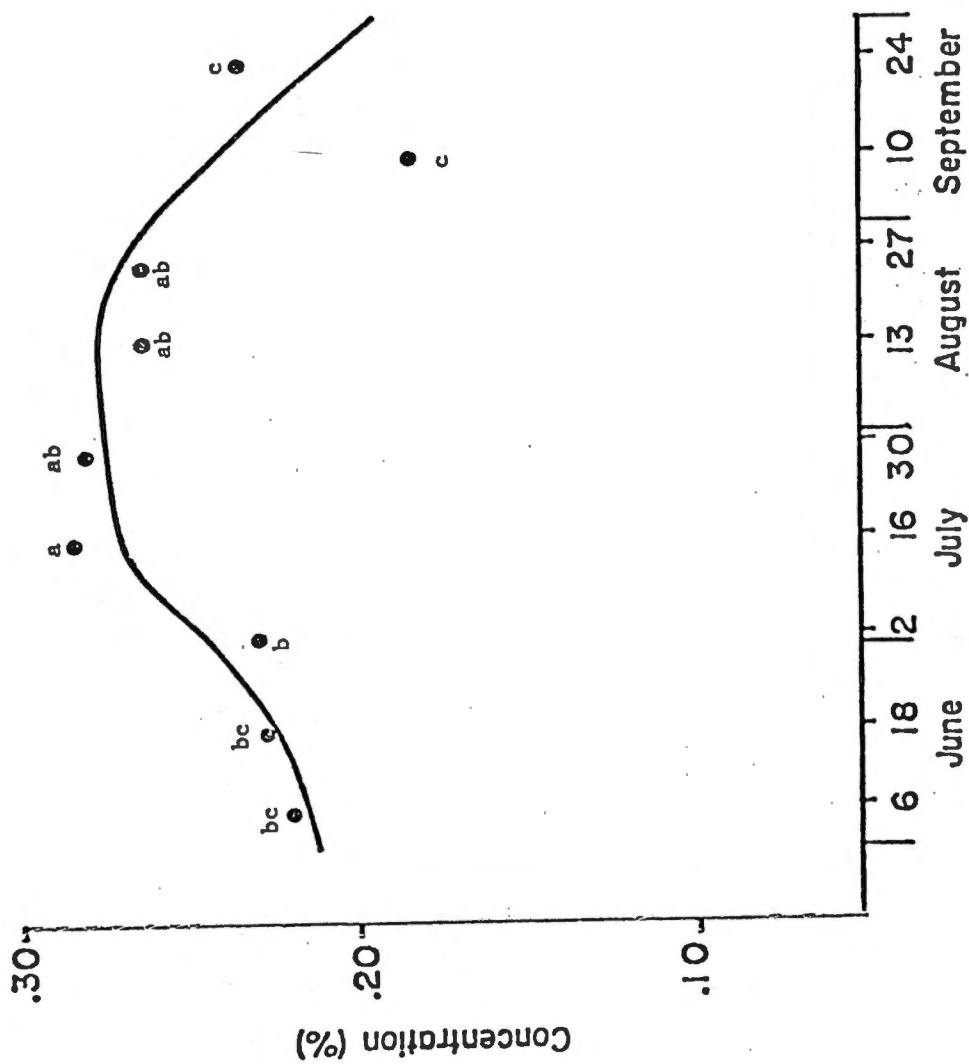


Figure 12. Seasonal trend in concentration of P at location C. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

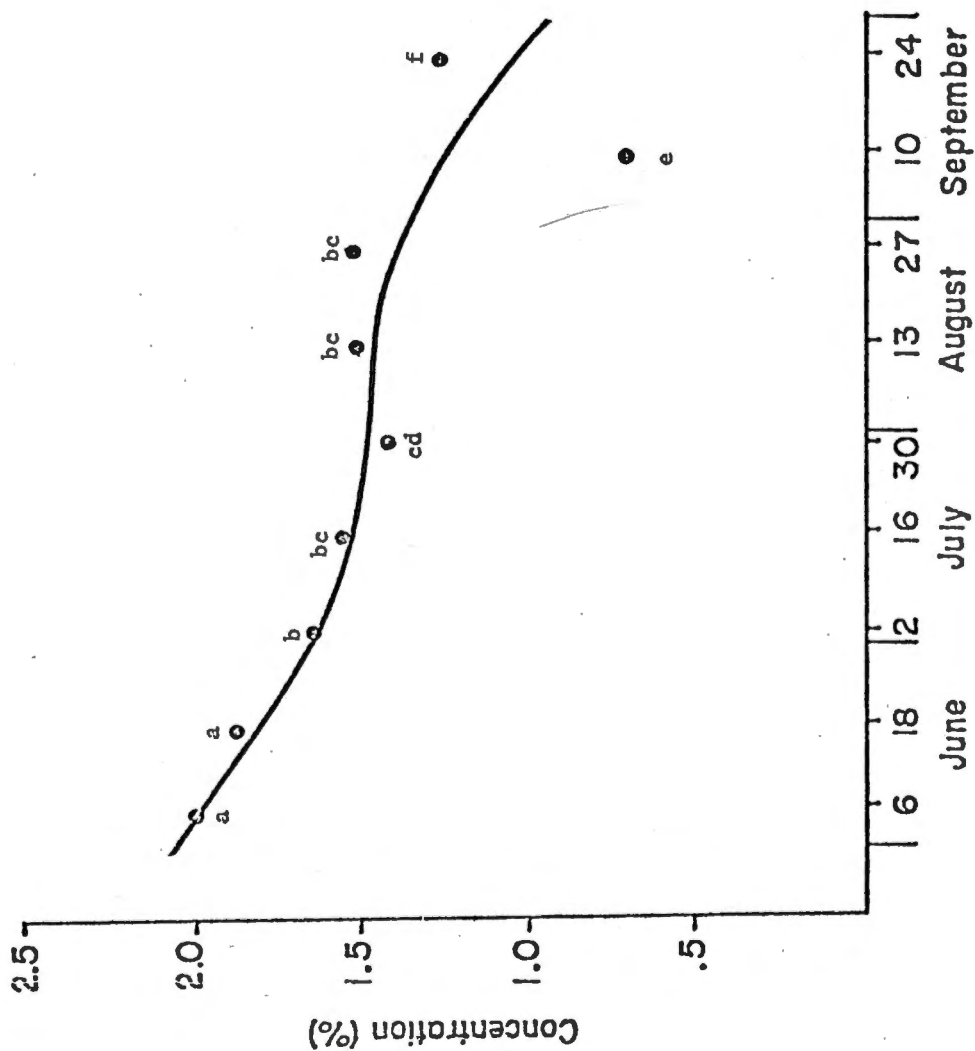


Figure 13. Seasonal trend in concentration of K at location C. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

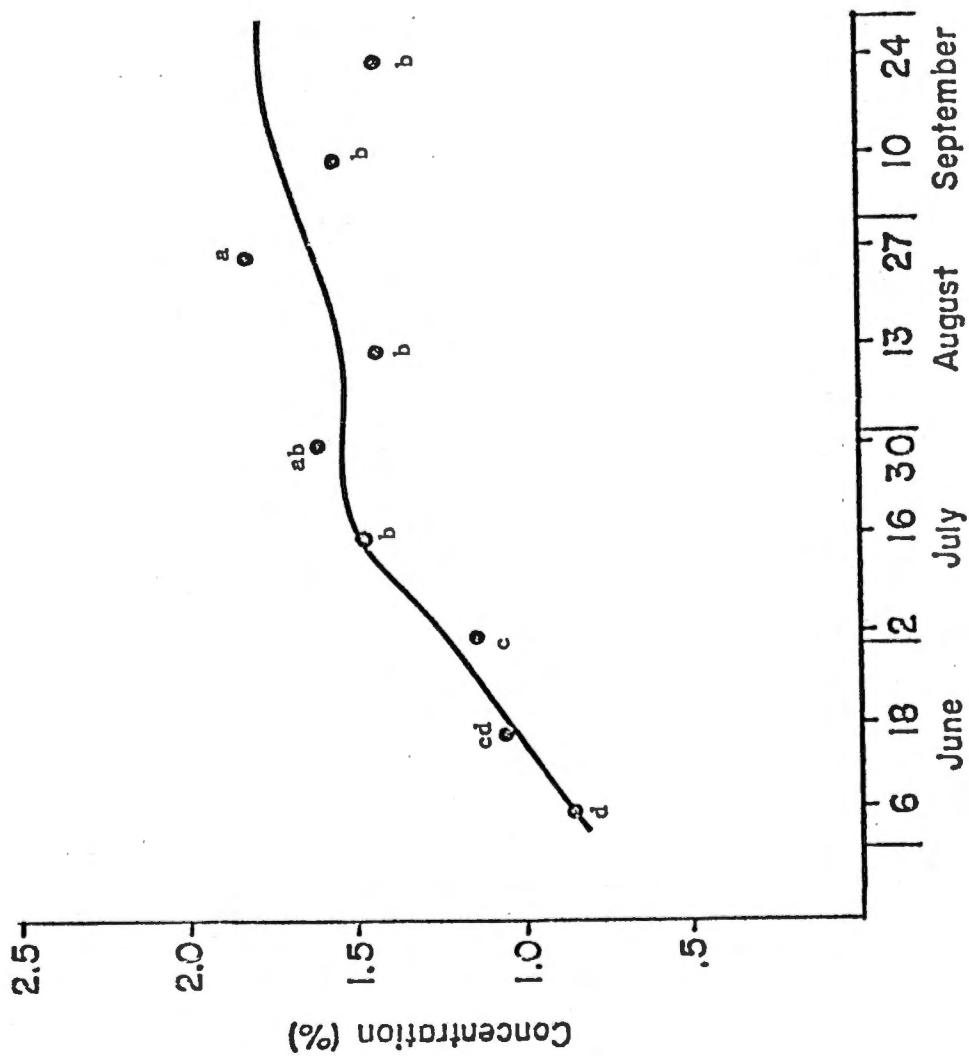


Figure 14. Seasonal trend in concentration of Ca at location C. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

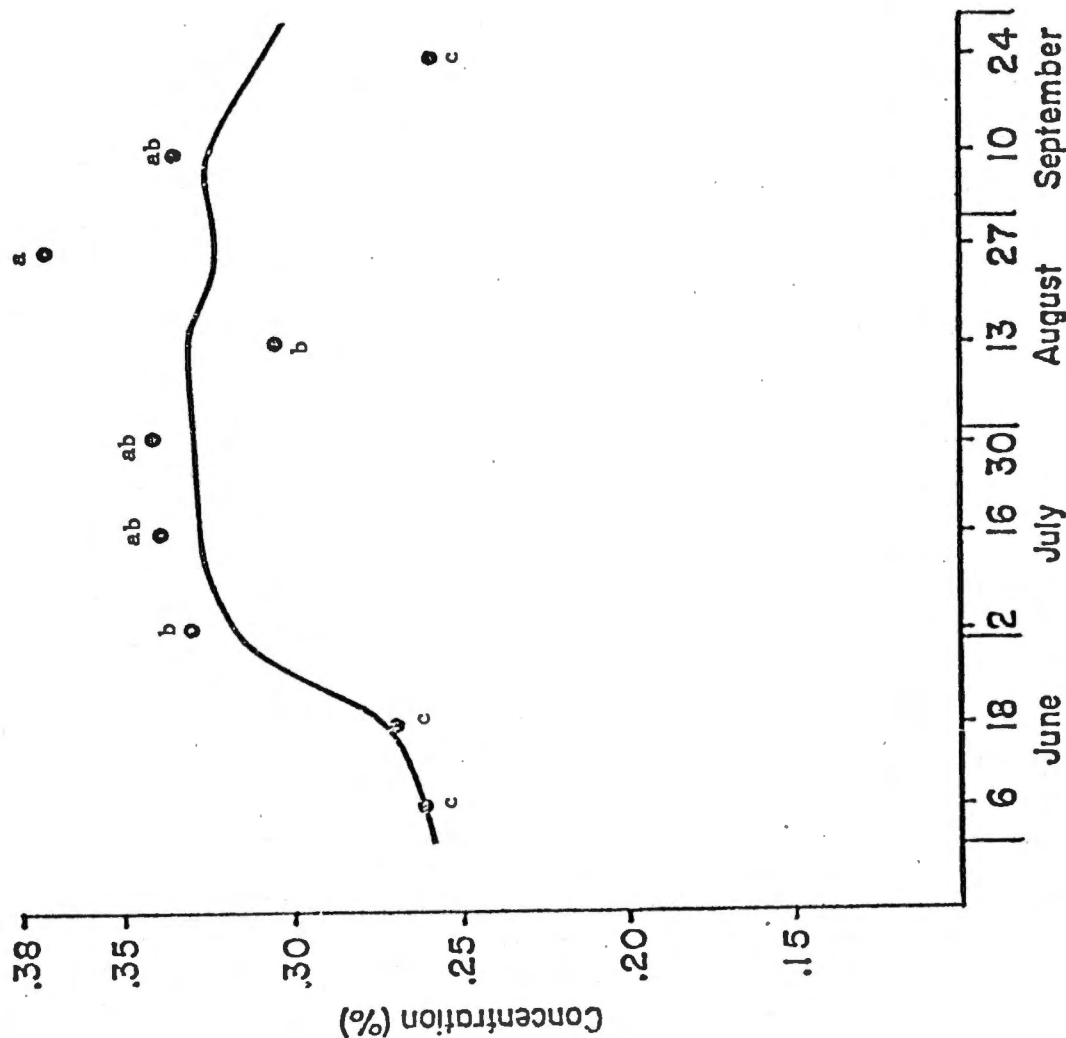


Figure 15. Seasonal trend in concentration of Mg at location C. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

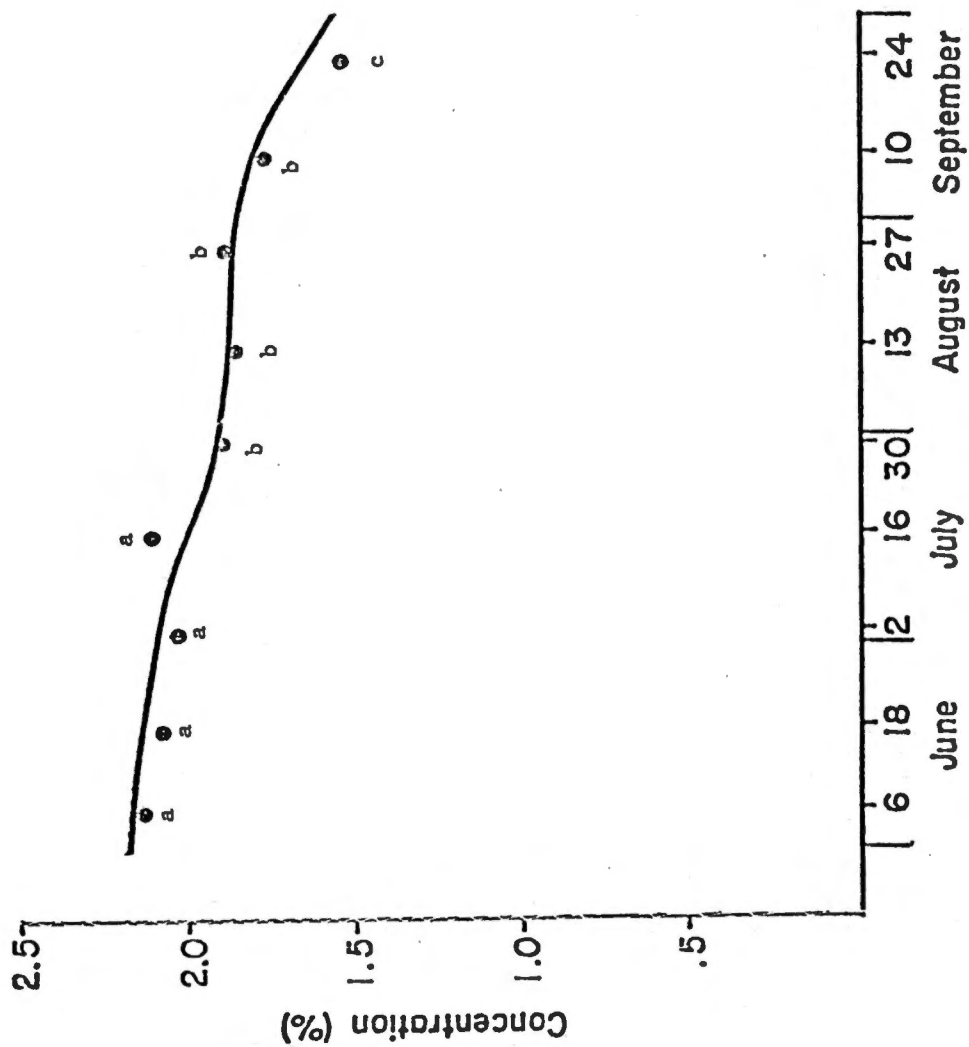


Figure 16. Seasonal trend in concentration of N at location D. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

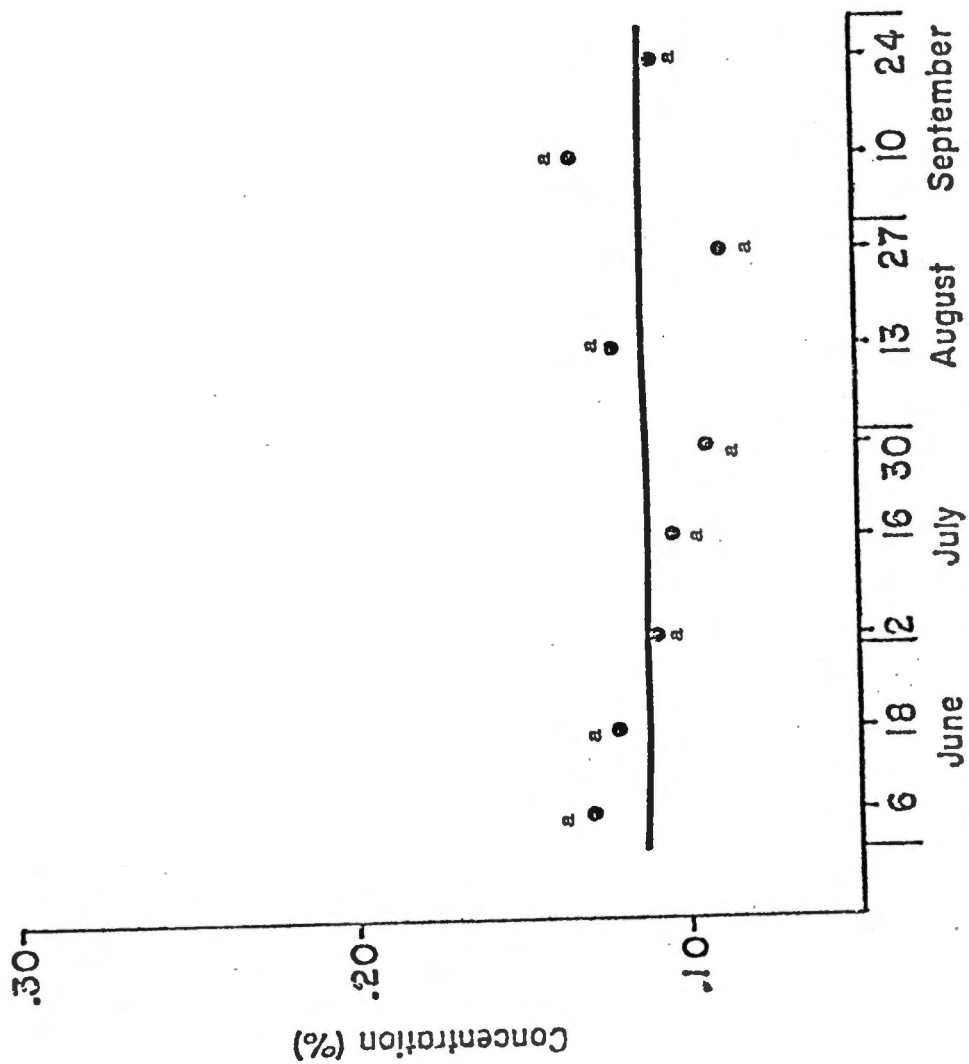


Figure 17. Seasonal trend in concentration of P at location D. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

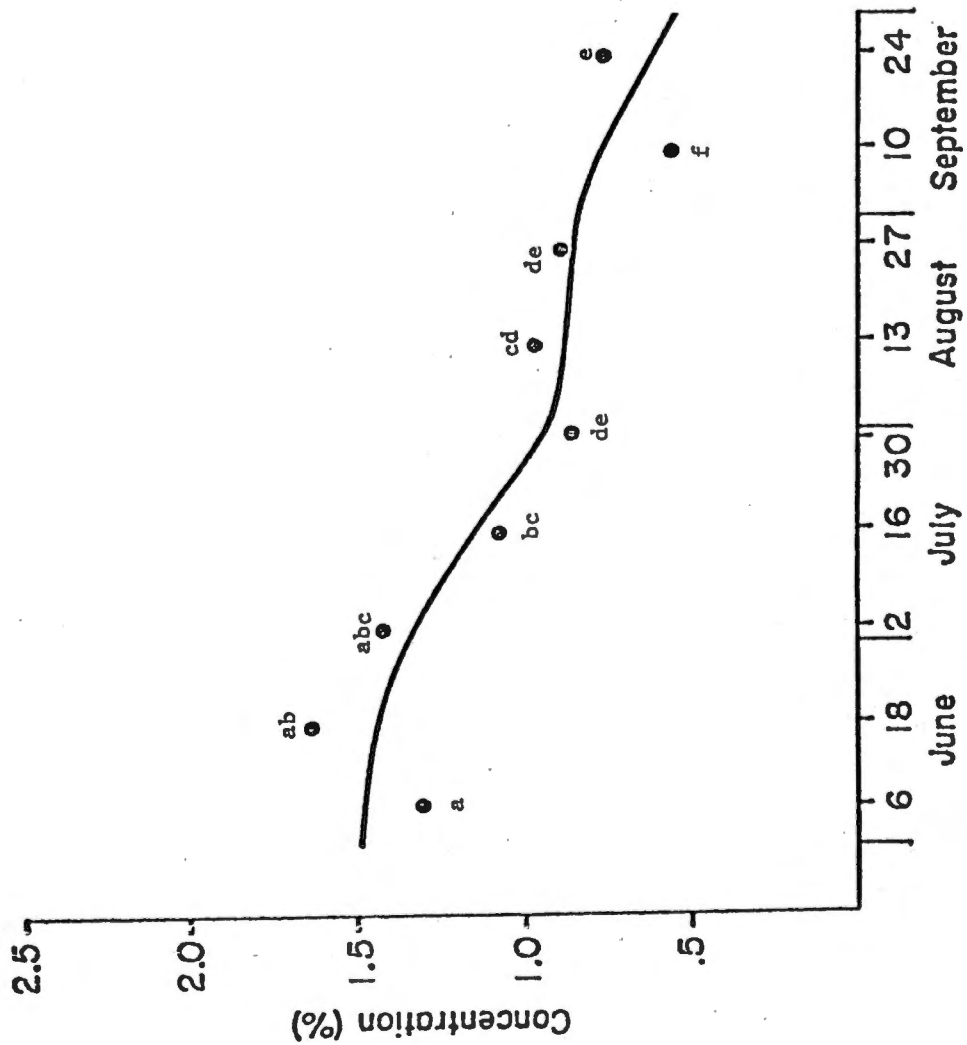


Figure 18. Seasonal trend in concentration of K at location D. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

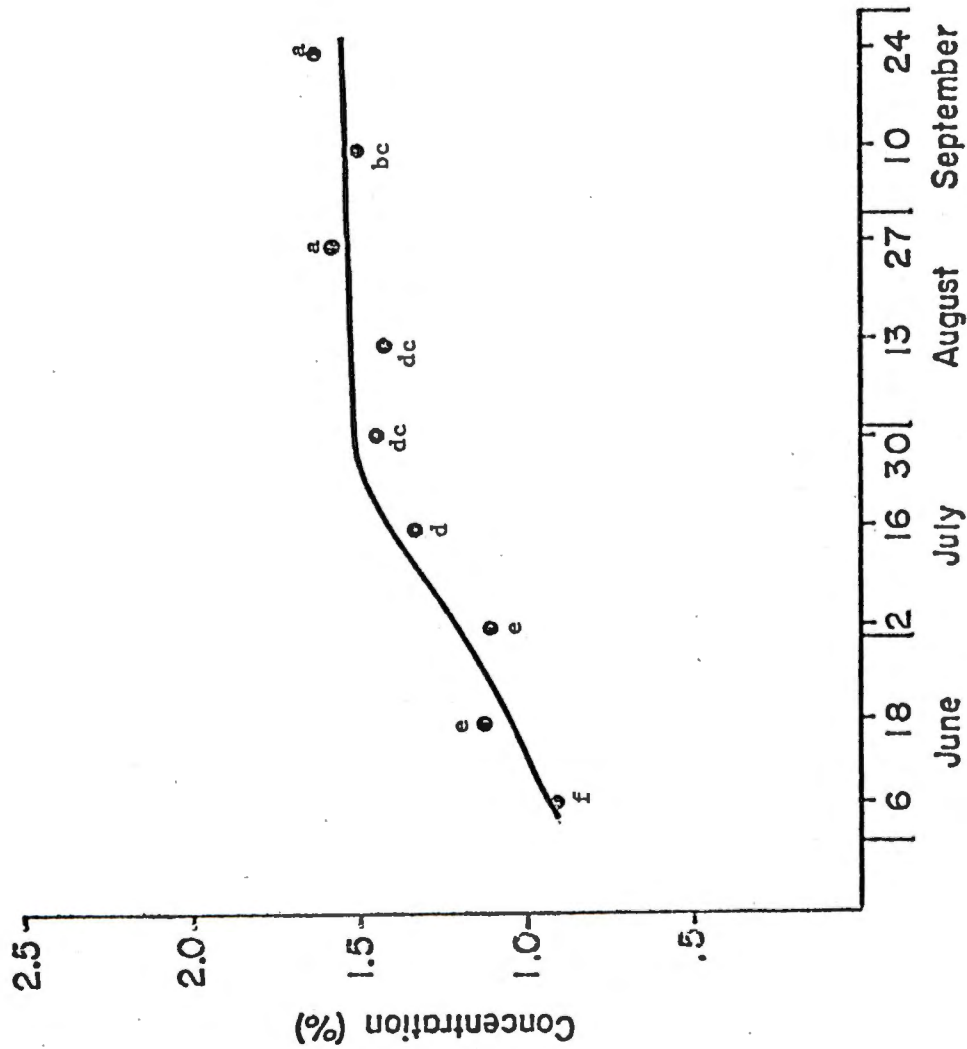


Figure 19. Seasonal trend in concentration of Ca at location D. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

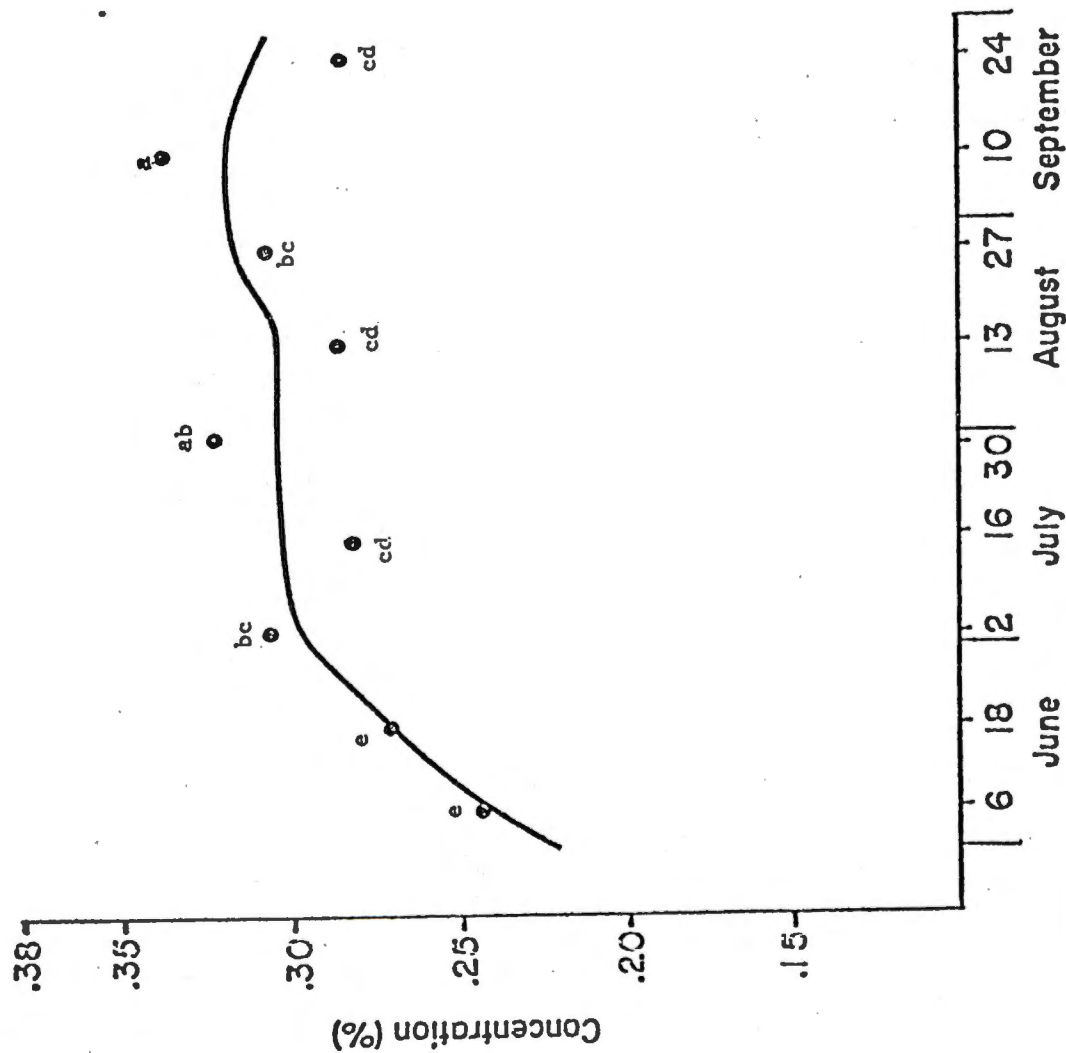


Figure 20. Seasonal trend in concentration of Mg at location D. Each point is the mean concentration for each sampling date. Within each date, values followed by different letters are significantly different at the 0.05 level of probability.

CHAPTER V

SUMMARY

A study of the seasonal trend of several nutrient elements in Golden Delicious apple leaves in Tennessee orchards was conducted in the summer of 1975 to determine the ideal time to collect leaf samples for foliar analysis.

Leaf samples were analyzed for percent of N, P, K, Ca and Mg. N, P and K showed a general decrease in concentration throughout the season with a relatively stable midseason period. Ca levels increased throughout the growing season and also showed a midseason period of relatively little change. Seasonal changes for Mg were irregular. There was a period of relatively little change in midseason but this period was much shorter than the stable period exhibited by the other minerals.

There is a time period during the season when the rate of change in concentration of a given nutrient in leaves is minimal. A shorter time period exists when the concentration of all minerals in a leaf is changing very little. This period is the ideal time to collect leaf samples since differences in a few days will not cause large differences in foliar analysis results. The results from this experiment indicate that the ideal time period to collect leaf samples at all locations studied for analysis of N, P, K, and Ca

would be July 30 through August 27. No uniformity existed for Mg.

The ideal sampling time reported is from a one year study. Further investigation is required to warrant recommendations.

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LITERATURE CITED

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VITA

Michael Blaine Donoho was born June 30, 1952 in Nashville, Tennessee. He was graduated from Portland High School in 1969. He received the Bachelor of Science degree from the University of Tennessee in 1973. He received the Master of Science degree with a major in Plant and Soil Science from the University of Tennessee in 1976.