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Nutrient absorption and yield of corn and soybeans planted in three row arrangements

Paul Logan Fulks

To the Graduate Council:

I am submitting herewith a thesis written by Paul Logan Fulks entitled "Nutrient absorption and yield of corn and soybeans planted in three row arrangements." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Frank F. Bell, Major Professor

We have read this thesis and recommend its acceptance:

W. L. Parks, L. N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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Frank F. Bell

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W L Parks

L N Skold

Accepted for the Council:

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Vice Chancellor
Graduate Studies and Research

NUTRIENT ABSORPTION AND YIELD OF CORN AND SOYBEANS PLANTED IN THREE ROW ARRANGEMENTS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Paul Logan Fulks

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ABSTRACT

The effect of different row arrangements on nutrient absorption and yield of corn and soybeans was investigated in 1972 on a Sequatchie loam soil at the Plant Science Farm, Knoxville, Tennessee.

Above ground plant samples taken at different times during the growing season were analyzed for their concentrations of nitrogen, phosphorus, potassium, calcium and magnesium. Generally the nutrient percentages in the above ground corn plants were high early in the season and decreased as the season progressed except for phosphorus which decreased until 77 days after planting, and then increased to day 110. After that time there was a decrease in percent phosphorus to the last sampling date. The nutrient percentages for all row arrangements followed the same pattern and generally no consistant trends were noted, except for the period from the tasseling to the ear filling stage of growth in the 12-24 inch row arrangement. The 12-24 inch row arrangement resulted in a higher percent of nitrogen, phosphorus, potassium, calcium, and magnesium during the tasseling and ear filling stage of growth.

Nitrogen, phosphorus, potassium, calcium and magnesium accumulation in pounds per acre increased up to 110 days after planting and then decreased.

In soybeans, nitrogen, phosphorus, potassium, calcium, and magnesium percentages were high in the early stages of growth. Percent of nitrogen and phosphorus generally decreased for the first 73 to 81

days after planting and then increased slightly. The percent potassium decreased throughout the season, and calcium and magnesium decreased for the first 73 days after planting and then leveled off. The amount of nitrogen, phosphorus, potassium, calcium and magnesium accumulated in the above ground soybean plant throughout the season.

The different row arrangements in corn produced significantly different yields. The 12-24 inch rows had the highest yields with the 12 inch rows next highest and the 36 inch rows the lowest.

Irregular soybean plant distribution and a large percent of lodging occurred in the 12 inch and the 12-24 inch row arrangement. This reduced the yield in these treatments and may have accounted for there being no significant differences in yield among the row arrangements in soybeans.

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CHAPTER I

INTRODUCTION

Previous studies have shown that row spacing may affect yield. The objective of this investigation was to determine the effect of row spacing on the yield, dry matter accumulation, percent and accumulation of nitrogen, phosphorus, potassium, and magnesium at different stages of growth for corn and soybeans. Dry weight of the above ground plants was considered as the total dry matter accumulation and per acre plant content of nutrient uptake was calculated from these values.

The relationship between nutrient accumulation and yield was examined.

CHAPTER II

REVIEW OF SELECTED LITERATURE

I. CORN

In 1921 Mooers (38) published the results of some Tennessee experiments in which he compared an equal number of plants per acre in row widths varying from 3 1/2 to 7 feet. Yields were appreciably higher from the 3 1/2 foot row widths. Mooers summarized his work as follows: "The general conclusion seems warranted, therefore, that the best results in practice will probably be obtained with a width of row which permits the satisfactory use of tillage implements but allows the determined number of plants to be as widely spaced as possible." Not only were row widths determined by the width of the horse, they were governed by the tillage implements, even after the advent of mechanized agriculture. The spacing of plants as widely apart as possible is what the narrow row widths and equidistant plant spacings have been achieving.

The published reports on narrow-row plantings of corn have shown that yield increased as the row widths decreased (8, 10, 11, 16, 29, 30 34, 38, 55, 61, 62). A few reports, however, have shown no differences in yield due to narrow row spacings (18, 35, 40, 43, 54). Brown et al. (8) reported that corn grain yield is a product of grain per plant and plant population. Therefore, studies of the effects of plant population on yield are necessary for a wide range of conditions. The trends toward higher fertilizer rates, higher plant populations and higher yielding cultivars require periodic reexamination of plant population and spacing geometry. Colville (11) reported that corn grown in 20 inch or 30 inch rows had fewer barren plants and heavier ears, than those grown in 40 inch row widths. He also reported an increase in yield of 16.1 percent by row spacings of 20 inches as compared to 40 inches and a 9.7 percent increase for 30 inch rows as compared to 40 inch rows. Lutz et al. (34) doing work in the Southeast reported an increase in yield with 16, 24 and 32 inch row widths as compared to 40 inch row widths and 10 to 40 inch row widths. Work done in Georgia by Brown et al. (8) showed that corn yielded more grain in 20.1 inch rows than in 40.2 inch rows. Fulton (16) reported that the highest yields were obtained where high soil moisture levels were combined with high populations and narrow rows. However, Stickler (53) reported superior yields with narrow rows even when moisture was limited. Extensive research was done in Indiana over a period of 11 years at different locations under a wide range of conditions, with row widths of 20.1, 29.9, and 40.1 inches. Grain yields increased an average of 7.3 percent with rows 20.1 inches wide and 4.4 percent with rows 29.9 inches wide in comparison to rows 40.1 inches wide (55). After reviewing the literature and doing research Colville (11) concluded that, "We can expect 5 percent increase in yield by narrowing to 30 inch rows and likely another 5 percent by moving to 20 inch rows."

This increase in yield for narrow rows is attributed to a reduction to interplant competition for mositure, nutrients, and light. Such plantings also shade the ground earlier in the season and thus reduce weed growth and soil moisture loss (29, 44). Hoff and Mederske (29) theorized that an equidistant planting pattern reduced competition between roots of adjacent plants for water and nutrients and thereby increased grain yield.

In radiation studies Abertin et al. (2) reported that net radiation was greatest where rows were narrower. A higher inception of light has been reported by plants grown in 21 inch rows than in 32 inch rows or 42 inch rows (13, 53, 63). Water use efficiency seems to be related to high light interception and is higher in 21 inch rows than in 32 inch rows or 42 inch rows (62). Denmead et al. (13) suggested that spacing rows narrower than 40 inches could increase the energy available for photosynthesis by 15 to 20 percent. The efficiency with which a foliage canopy intercepts solar radiation limits photosynthesis and dry matter production (61).

Maximum yields also depend on an adequate and balanced supply of essential nutrients. The mineral nutrition of corn plants appears to influence grain yields mainly by affecting (a) the leaf area produced early in the growing season and (b) length of time the leaves remain alive and functioning during grain formation (21). Grain yield is primarily a function of leaf area and leaf area is a function of the nutrient status of the plant (24). Shear, Crane and Meyers (50) indicated that if all other factors were constant, plant growth was a function of nutrient intensity and balance. A number of investigators have found a positive correlation between the percent, nitrogen, phosphorus, and potassium and in corn leaves at silking time and yield of grain (24, 39). The chemical composition of the leaves at silking time can indicate which nutrient elements are deficient and which deficiencies have resulted or will result in a reduced leaf area and thereby a reduction in grain yield (24). Hanway (23) reported that the time of sampling and position of the leaves on the plant or the plant part sampled appears to be less critical near silking time than at any other time when diagnosing the nutrient status of the plant. The importance of plant analysis in plant nutrition rests upon the fact that it can give a picture of nutrient concentrations within the growing plant (58).

The accumulation of dry matter in corn tends to follow the characteristic sigmoid-shaped curve (3). Many have reported that the rate of dry matter accumulation was slow initially, but increased as more and more leaves emerged, increasing the leaf area exposed to sunlight. Dry matter accumulation followed the same pattern in each of the different plant parts, beginning first with the leaves and leaf sheaths, then the stalk and tassel, followed by the husks, shank and cob, and finally the grain (22). Syre (48) found that the maximum rate of dry matter production occurred during tasseling and silking and after growth in height had ceased. Hanway (24) reported this period of ear filling as being the "critical period." Most of the dry matter produced during this period was transferred to the grain. Hanway (23) and others (7, 48) reported that the trend for nitrogen accumulation was similar to that for dry matter production and the greatest rate of nitrogen accumulation occurred at the same time as the greatest dry matter production. The percent nitrogen present in the whole plant decreases as the age of the plant increases (4, 7, 23, 29, 47). This is an example of the dilution effect as reported by others.

Phosphorus accumulation was reported to be similar in many ways to nitrogen accumulation. The maximum amounts were present at the same time as was the nitrogen, but the total amount per plant increased to the end of the season. This was attributed to the large amount of phosphorus which moved into the grain (23, 47, 48). Percent phosphorus tended to reach a maximum about the middle of the season and then to decrease as the plant matured (7, 39, 47, 48).

Potassium accumulation reached a high earlier in the season than did nitrogen or phosphorus. The maximum rate of accumulation also occurred earlier in the season. Potassium was not transferred from the plant to the grain in large quantities and was lost from the plant at the end of the season. It has been theorized that potassium is lost by loss of leaves, leaching from the leaves by rainwater and loss from the roots (23, 39, 47, 48). The percent potassium in the plant decreased from the first to the last of the season as did nitrogen (4, 7, 14, 23).

The accumulation of calcium in the plant increased to a maximum at maturity with a small loss occurring at the end of the season. The calcium percentage decreased as age of the plant increased (4, 23, 39, 47).

Magnesium accumulation increased throughout the season with no losses recorded at maturity (4, 23, 39). Sayre (47) reported that percent magnesium in corn increases, then levels off and decreases at the last of the season.

Nelson (39) reported that whole corn plants would accumulate in the grain and stover 142 lb. of nitrogen, 29 lb. of phosphorus, and 100 lb. of potassium per acre. Ohlrogge (41) published data showing that a mature corn crop yielding 150 bu/A would contain in the grain and stover 200 lb. of nitrogen, 35 lb. of phosphorus, and 195 lb. of potassium per acre. Sayre (47) reported values similar to those of Nelson's and also stated that the uptake of calcium was 10.7 lb. per acre and magnesium 12.3 lb. per acre.

II. SOYBEANS

Pendleton (44) reported that not only did decreased row spacing increase yields in corn but that soybeans gave greater yield increases than did corn in Illinois. In the North Central States, research results with soybeans show yields increased from 10 to 20 percent by narrowing rows (12, 45). Research from both the North Central States and Southern soybean producing states indicates that the importance of row spacing seems to diminish from North to South. Hartwig (6) reported in research from Mississippi and North Carolina that no yield advantage could be expected from narrow row widths in the South. Although some research in the Southeast has not indicated any advantage for close row spacing, Thurlow (57) published results of some experiments done at Auburn in which he indicated that with changing varieties and increased double cropping, which caused delayed planting, closer rows have resulted in increased yields even in the South. Thurlow indicated that the highest yields could be expected from 13 inch rows. However, the average of seven late plantings indicated the greatest yield increases came from reducing row widths from 36 to 30 inches. Leffel and Barber (32) found that yield was highest at the row width of two feet in the South at late planting dates.

Early studies by Wiggans (60) in New York revealed that soybeans planted in 8 inch rows produced highest yields. Reiss and Sherwood (39) in Illinois found that soybean performance was best in 24 inch row spacing. McClelland (37) of Arkansas reported that soybeans yielded more in a 36 inch row width than in a 8 inch row width. Lehmar and Lambert (33) in Minnesota reported that seed yields were significantly higher at the 20 inch row spacing than at the 40 inch spacing. They also found that as spacing between rows was increased, the number of branches increased. Wiggans (60) in New York found that as the arrangement of plants on a given area approached a uniform distribution, the yield increased. Holding other factors constant, the narrower the distance between rows, the greater the yield.

Some workers have reported no yield differences for different row spacings (9, 28, 40). Caviness (9) reported no yield advantage to an irregular row spacing in Arkansas. Timmons et al. (56) reported studies done in 1964 and 1965 in which neither row spacing nor plant population influenced evapotranspiration, but they did find that the highest water use efficiencies were obtained from low populations in 8 inch rows.

Dry weight was shown by Weber et al. (59) to be highly correlated with increasing leaf area index. They reported that those plant population arrangement combinations favoring a rapid attainment of high

LAI (high plant population and narrow row spacing) were those also having the greatest dry weight accumulation. The maximum seed yield occurred at less than maximum LAI and at generally lower populations and narrower row spacing, highest seed yield occurred in 10 inch rows with low plant populations. Shibles and Weber (51, 52) reported that dry matter production was a function of percent solar radiation interception, regardless of planting patterns, but that seed yield was not correlated with total dry matter produced or solar radiation intercepted. They stated that a high population or close plant spacing tended to result in lower seed yields. While high interception during the seed formation stage is required for the highest seed yields, conditions resulting in high seasonal interception may not result in the greatest seed yield.

Shaw and Weber (49) reported that yield was positively correlated with both the amount of leaf area and the volume of canopy above the compensation point. Yao and Shaw (63) have reported that a large proportion of the incident visible light was intercepted at the outer periphery of the canopy, resulting in low light intensity within the canopy and leading to low photosynthesis rates in the lower leaves.

Many have reported that dry matter production was progressive in soybeans, reaching a maximum rate during the beginning of bean formation (20, 25, 27, 42). Two changes took place in dry matter accumulation during the season: (a) highest rate of dry matter accumulation occurred at approximately the same time the plants reached their maximum height, and (b) dry weight dropped at the end of the season because of leaf drop.

Nutrient percentage and nutrient accumulation are important in soybeans as in any other plant. Hanway and Weber (21) reported that the percent nitrogen in the plant decreased from the seedling stage until pod fill began and then increased until bean harvest. Harper (25) found that percent nitrogen decreased from the first of the season until midbloom and then leveled off until bean harvest. Hammond et al. (20) and Henderson and Kamprath (27) reported that percent nitrogen was initially high but decreased throughout the season.

Nitrogen accumulation has been reported by many (6, 21, 27) to increase until harvest. The peak period of uptake coincides with the period of pod set and initial filling (25). The accumulation of nitrogen was also reported by Henderson and Kamprath (27) to continue after the pods and seeds were formed, which indicated that the plant continued to fix nitrogen during that period.

Phosphorus uptake patterns were similar to nitrogen uptake over the season with the peak uptake occurring during the period of pod set and initial pod fill (21). Henderson and Kamprath (27) stated that this indicated a rapid accumulation of phosphorus in the seeds and pods. The percent phosphorus in the plant has been reported to increase initially, then decrease slowly until early bloom and then increase until maturity (6, 21, 25, 27).

Hanway and Weber (21) and Henderson and Kamprath (27) published results showing the percent potassium in the whole plant was the highest at the first of the season after which time there was a continuous decrease in the vegetative portion except for a brief increase about the start of leaf fall. Although the accumulation of potassium was not as uniform as other elements, it was very similar to nitrogen and phosphorus, the period of greatest uptake being the same pod filling stage. The potassium accumulation, however, did decline during the last growth stages (21, 25).

The percent calcium increased sharply for the first 30 days, then decreased rapidly and then remained relatively constant till the plant reached maturity (21, 25). Hammond et al. (20) reported the accumulation of calcium to increase at relatively constant rates until pod fill began after which time there was a small decrease in calcium. Others reported these same trends (6, 21, 25).

Harper (25) reported that the percent magnesium remained almost constant throughout the season. Hammond et al. (20) and Henderson and Kamprath (27) published results showing the accumulation of magnesium continues until maturity. Increasing rates of accumulation occurred from 45 days after emergence to the end of the season (25).

Hammond et al. (20) and Borst and Thatcher (6) reported that the soybean plant accumulated 180 and 140 lb. of nitrogen, 17 and 12.8 lb. of phosphorus, 55 and 37.6 lb. of potassium, 103 and 75 lb. of calcium and 69 and 39 lb. of magnesium per acre, respectively. In more recent work Henderson and Kamprath (27) reported soybean accumulations of 222.1 lb. of nitrogen, 14.5 lb. of phosphorus, 108 lb. of potassium, 54.7 lb. of calcium, and 26.8 lb. of magnesium per acre. Ohlrogge (42) reported nitrogen and phosphorus values comparable to these and a potassium value of 80 lb. per acre.

CHAPTER III

MATERIAL AND METHODS

I. GENERAL

The experiment reported here was conducted on a Sequatchie loam located at the Knoxville Plant Science Farm during the 1972 growing season.

A conventional seedbed was prepared by plowing, disking, and harrowing.

The three treatments of 36 inch, alternating 12-24 inch, and 12 inch row widths were arranged in a randomized complete block design with four replications. Plots were 35 feet in length and 36 feet wide. Half of each plot was used for plant sampling throughout the season and the other half was used for grain harvest.

Soil tests were taken prior to planting. Results of the soil tests indicated pH levels varying from 6.2 to 6.7; therefore no lime was applied. The level of soil phosphorus and potassium varied from low to medium.

The experimental plots were irrigated through the season when rain did not supply adequate moisture.

The test crops were corn and soybeans.

II. CORN

Ammonium nitrate at the rate of 400 pounds per acre and a 6-12-12 fertilizer mixture at the rate of 500 pounds per acre were broadcast on the corn plots and disked in. Tennessee 606 corn was seeded to 150 percent of desired stand on May 18 and thinned to 17,424 plants per acre at the seedling stage.

Atrazine at the rate of two pounds of active ingredient per acre was applied on May 26 for weed control.

III. COLLECTION OF FIELD DATA FOR CORN

Whole plant (above ground) samples were taken on June 27, July 12, July 19, July 27, August 3, August 10, August 21, September 5, and September 19. Thus the plant samples were taken 40, 55, 62, 70, 77, 84, 95, 110, and 124 days after planting. Sampling procedure consisted of taking all of the above ground tissue from two groups of three plants randomly selected from each plot. The whole stalk samples were then washed free of soil, cut up by hand, placed in labeled cloth bags, and dried in forced-air ovens at 70°C. The dried samples were weighed and one plant of every three was ground in a Wiley mill using a 40 mesh screen, and stored in glass bottles until analyzed.

At maturity all plots were harvested for grain by hand. Grain yields were reported as bushels of shelled corn per acre containing 15.5 percent moisture.

IV. SOYBEANS

The soybean plots received P_20 and K_20_5 as a 0-20-20 fertilizer mixture at the rate of 200 pounds per acre. The fertilizer was broadcast and disked in before planting.

York soybeans were treated with molybdenum, inoculated and seeded on May 19. Soil crusting resulted in a poor stand of soybeans. The plots were therefore replanted on June 2. Two plots which had very poor stands were spot planted on June 14. The soybeans were seeded to obtain a population of 12 plants per foot of row in the 36 inch row widths, six plants per foot of row in the 12-24 inch rows and 4 plants per foot of row in the 12 inch rows. As seeds per foot of row decreased with the 12-24 and 12 inch rows so did emergence. The poor stand resulting from crusting reduced the stand in the narrower rows by about 30 percent. Because of the soybeans' ability to overcome poor initital stands by filling in all space given them, the stand was considered adequate.

To control weeds, the plots were hand hoed three times during the season.

V. COLLECTION OF FIELD DATA FOR SOYBEANS

Whole plant (above ground) samples were taken on July 14, July 20, July 28, August 4, August 14, August 22, September 6, and September 22. Thus plant samples were obtained 42, 48, 56, 63, 73, 81, 96, and 112 days after planting. The sampling procedure consisted of taking all the above ground tissue from two three-foot sections of rows randomly selected from each plot.

The whole plant samples were washed free of soil. Samples were then placed in labeled cloth 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 glass bottles until analyzed.

At maturity all plots were harvested with a plot combine and grain yields were determined by converting field plot weights to bushels per acre at 13 percent moisture.

VI. LABORATORY PROCEDURE AND ANALYSES

All tissue samples were analyzed for nitrogen concentration by the procedure of Gehrke, Ussary, and Kaiser (17) as modified by Ashburn and Parks (1) for the Technicon Autoanalyzer. The digestion procedure is outlined in the Appendix, page 63. The nitrogen concentration was then determined colormetrically by the Technicon Autoanalyzer. The Technicon procedure for nitrogen is outlined in the Appendix, page 64.

A modification of the wet oxidation procedure as outlined by Gieseking, Snider, and Getz (19) (Appendix, page 66) was used for digesting all samples for potassium, calcium, magnesium, and phosphorus. Concentrations of these nutrients were determined on the digestate using the Technicon Autoanalyzer. Potassium and calcium were determined by flame while phosphorus and magnesium were determined colormetrically. The Technicon procedure is outlined in the Appendix, page 67.

Laboratory analyses were converted to percent concentration in the plant for each element. Grams of each nutrient accumulated in the whole plant (above ground) were determined by multiplying the percentage of each nutrient by the dry weight of the sample. Total uptake per acre in the above ground portion of the plant was then determined by multiplying the uptake per sample by the percent of acre that the sample represented and converting their value to pounds per acre.

VII. STATISTICAL ANALYSES

Yield data were analyzed by simple analysis of variance. When differences were detected, significant means were separated by Duncan's Multiple Range Test at the 0.05 probability level.

The percent nitrogen, phosphorus, potassium, calcium and magnesium in the different treatments were compared using the Duncan's Multiple Range Test at the 0.05 probability level.

CHAPTER IV

RESULTS AND DISCUSSION

I. NUTRIENT CONTENT OF CORN

The data for the percent nitrogen, phosphorus, potassium, calcium, and magnesium in corn are given in the Appendix, Table 3.

Nitrogen

The data for percent nitrogen at the different sampling dates are given in Figure 1. The percentage of nitrogen in the plant decreased with the age of the plant. This drop of percent nitrogen with the age of corn has also been noted by Sayer (47), Benne et al. (4), Hanaway (23), and Bromfield (7).

The data in Figure 1 indicate that as the season progressed the percent nitrogen present in the plant of the different treatments changed, so that by 95 days after planting (hereafter, days after planting will be referred to only as day) the 12-24 inch rows had a significantly higher percent nitrogen than the 12 inch and 36 inch row widths.[1] The difference that occurred in percent nitrogen present in the plants of the 12-24 inch rows between day 84 and day 110 is obvious when viewed in Figure 1.

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[1]When further comparisons are made on the data presented, significant will refer to differences at the 0.05 level of probability.

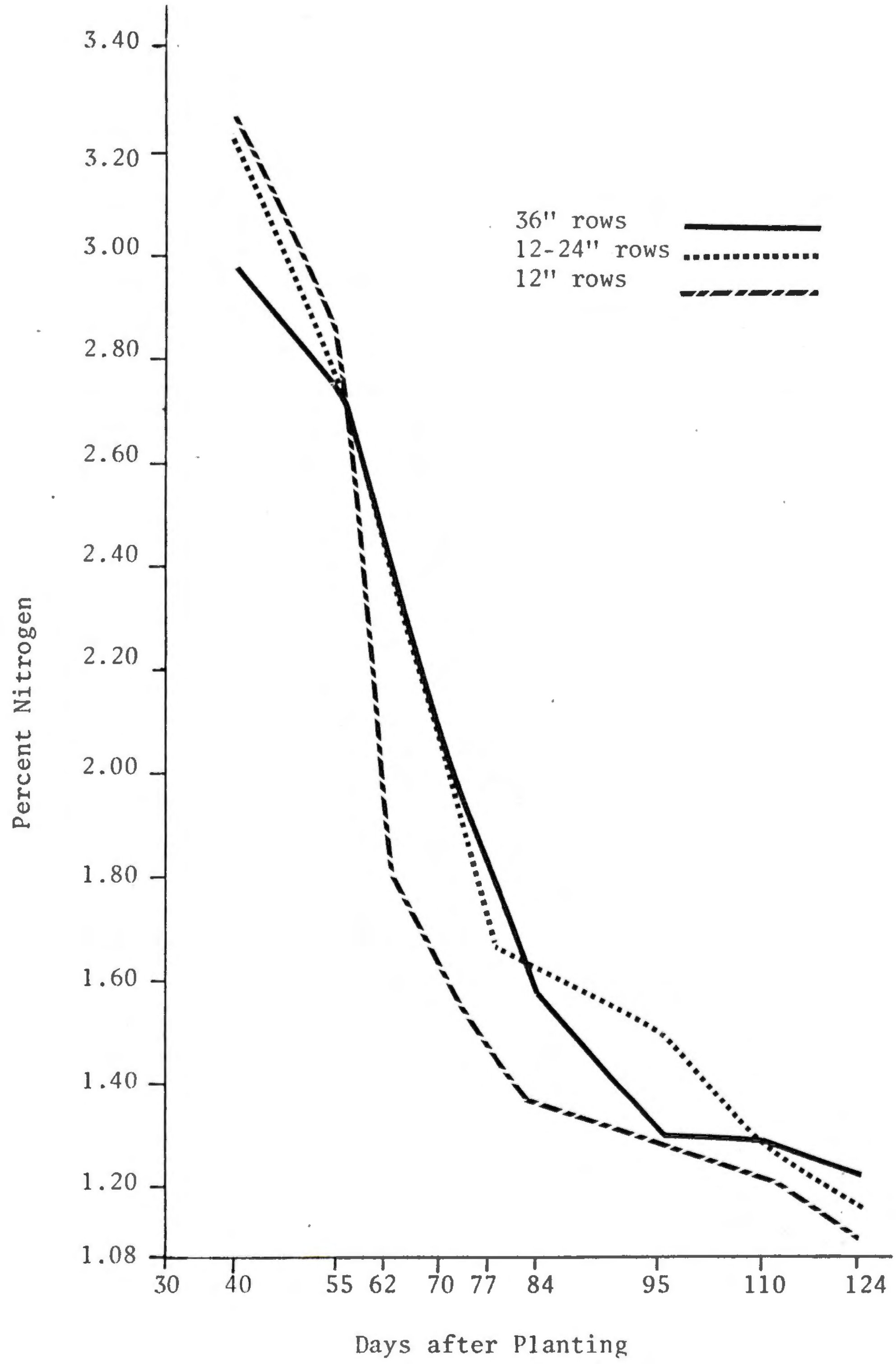

Figure 1. Percent nitrogen in the above ground corn plant for samples taken at different days after planting within three row arrangement.

Phosphorus

The data for the percent phosphorus at the different stages of growth are presented in Figure 2. The percent phosphorus dropped from day 40 until day 77 at which time it rose slowly till day 91 and then decreased to harvest. This agrees with results obtained by Sayre (47, 48), Bromfield (7), and Nelson (39) for the percent phosphorus in the whole corn plant. They reported that percent phosphorus tended to reach a maximum about the first of September and then decrease slightly as the plant matured.

At day 40 the corn in the 12-24 inch row spacing contained the lowest percent phosphorus of any row spacing but by day 84 it contained a higher percent phosphorus than the 36 inch rows although it was not significantly different from the 12 inch rows until day 110 and 124.

Potassium

The data for percent potassium for the various stages of growth are shown in Figure 3. The percentage of potassium in corn generally decreased from the first sampling date to the last. A steady decrease throughout the season has been reported by other researchers (4, 14, 33, 52). Throughout the season percent potassium in the different row spacing was similar, however, from day 77 to day 95 corn in the 12-24 inch spaced rows had a higher percent potassium than the other two spacings. This is similar to the results found with nitrogen and phosphorus.

Calcium

The data for percent calcium are shown in Figure 4. The average percent calcium decreased from the first to the last sampling date;

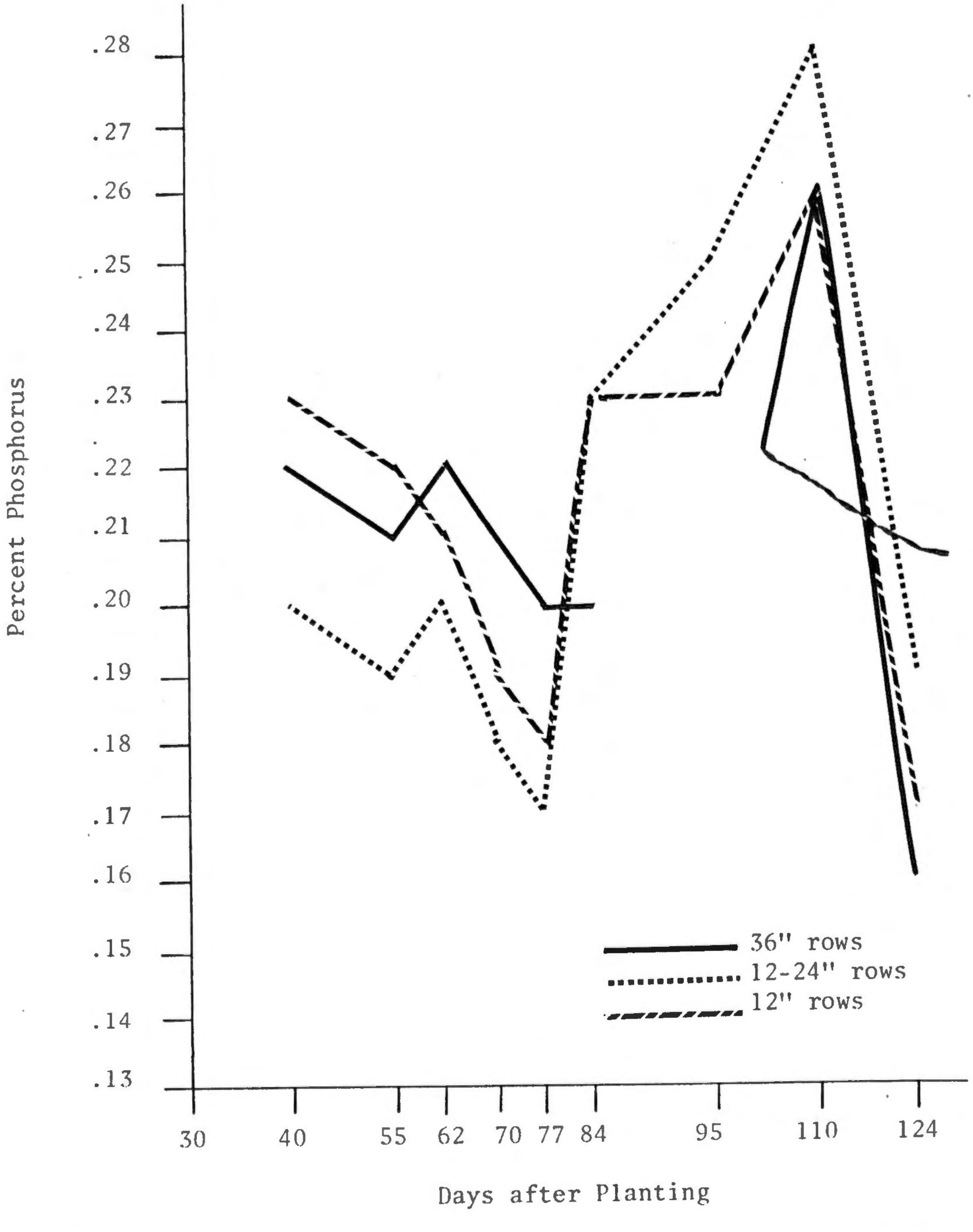

Figure 2. Percent phosphorus in the above ground corn plant for samples taken at different days after planting within three row arrangements.

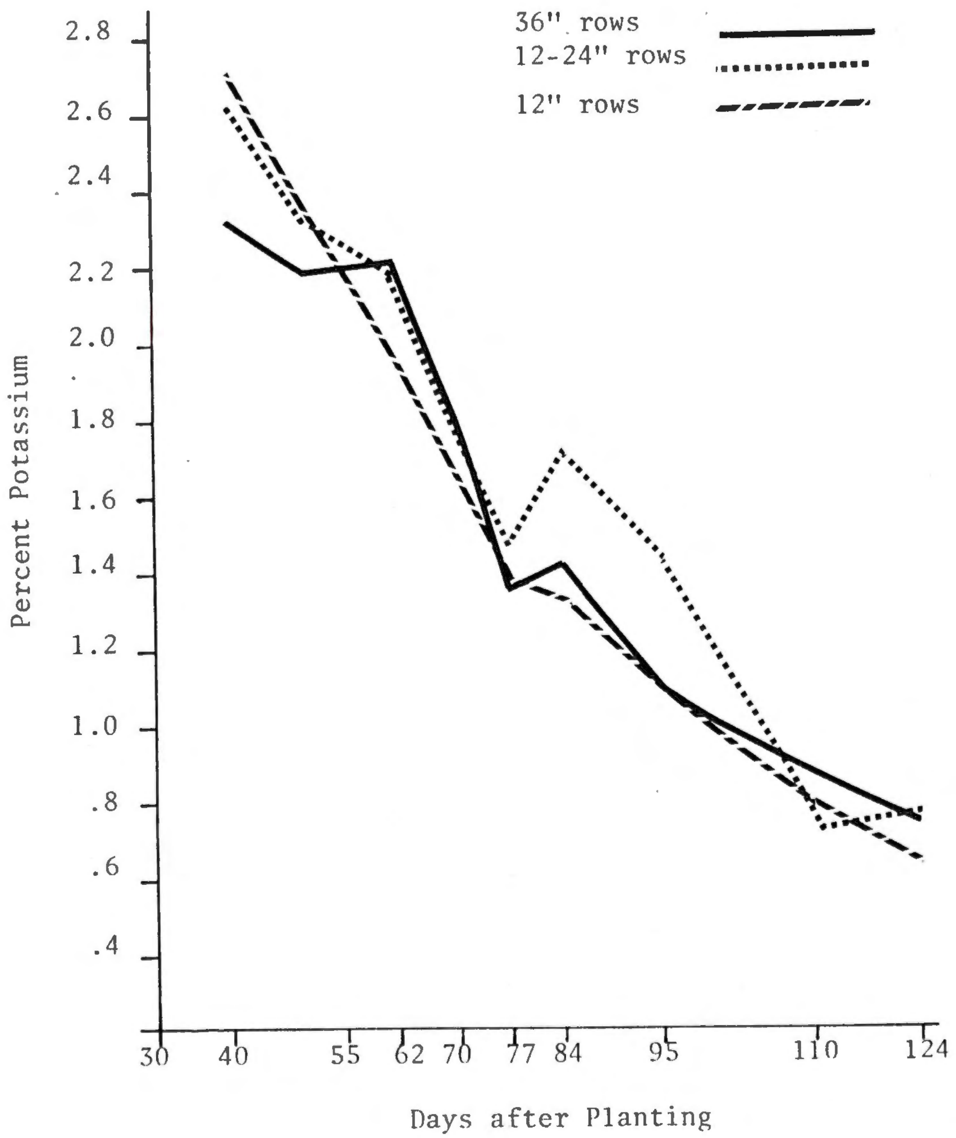

Figure 3. Percent potassium in the above ground corn plant for samples taken at different days after planting within three row arrangements.

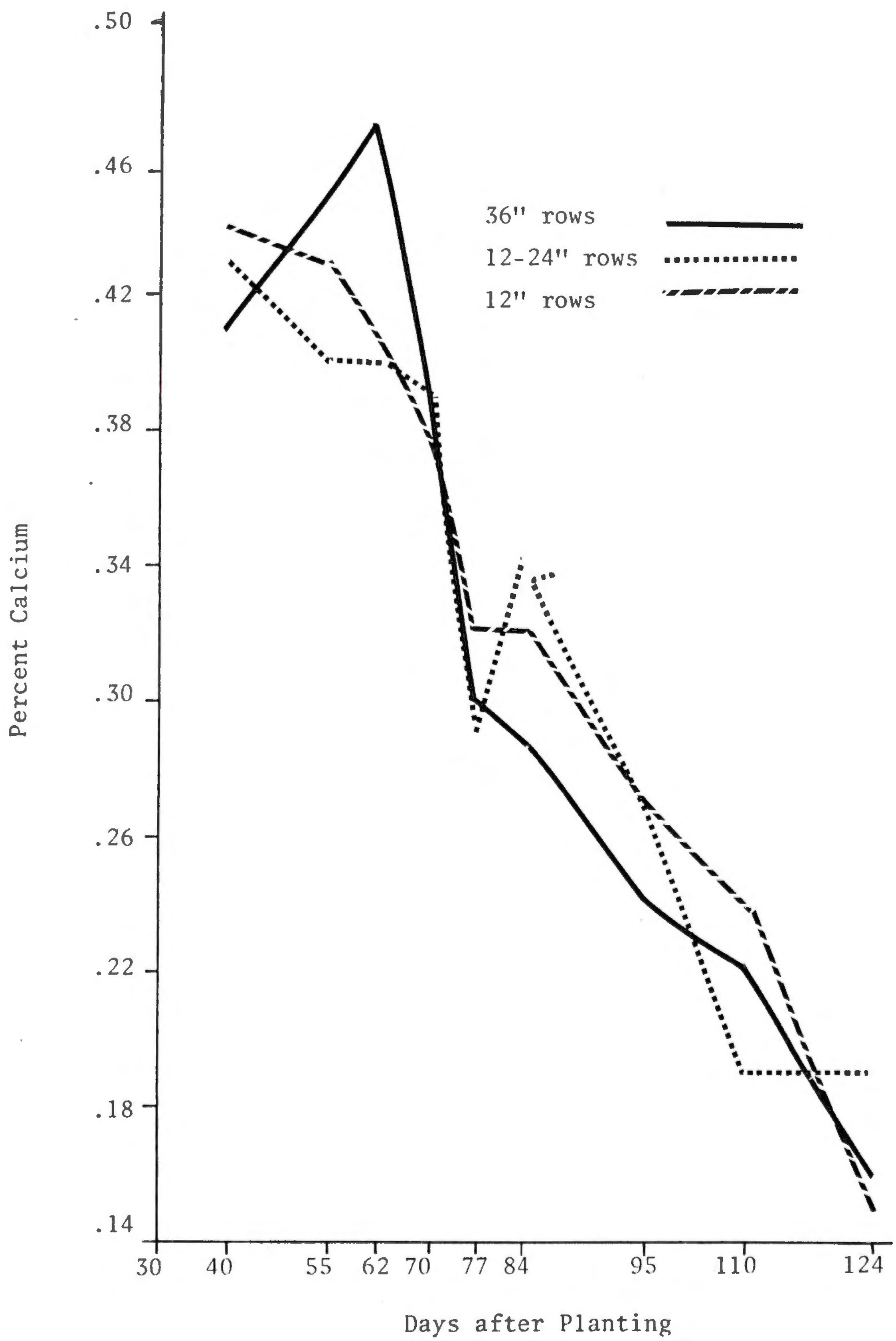

Figure 4. Percent calcium in the above ground corn plant for samples taken at different days after planting within three row arrangements.

this agrees with the results reported by Sayer (47) and Nelson (39). However, corn in the 36 inch row spacing increased in percent calcium between day 55 and day 62; and corn in the 12-24 inch spacing made a large increase in percent calcium between day 77 and 84. The 12-24 inch row spacing contained the highest percent calcium on day 84. Even though the percent calcium in the 12-24 inch row dropped below the other two treatments on day 110, it had the highest percent calcium on day 124.

Magnesium

Data for the percent magnesium at the various stages of growth are shown in Figure 5. The percent magnesium tended to decrease from the first to the last of the season. One significant increase did occur in the 12-24 inch row spacing between day 77 and day 110. This increase resulted in the 12-24 inch row spacing having the highest percent magnesium at day 110. This corresponds to the same type of results obtained with nitrogen, phosphorus, potassium and calcium. On day 94 the 12-24 inch spacing had significantly higher percent of nitrogen and potassium, phosphorus. This spacing also had a higher percent of phosphorus calcium and magnesium although it was not significant at the 0.05 probability level.

II. NUTRIENT ACCUMULATION OF CORN

All data for the accumulation of nitrogen, phosphorus, potassium, calcium and magnesium are given in the Appendix, Table 4. Statistical analysis was not run on the accumulation data or dry matter accumulation. These data are presented to show trends.

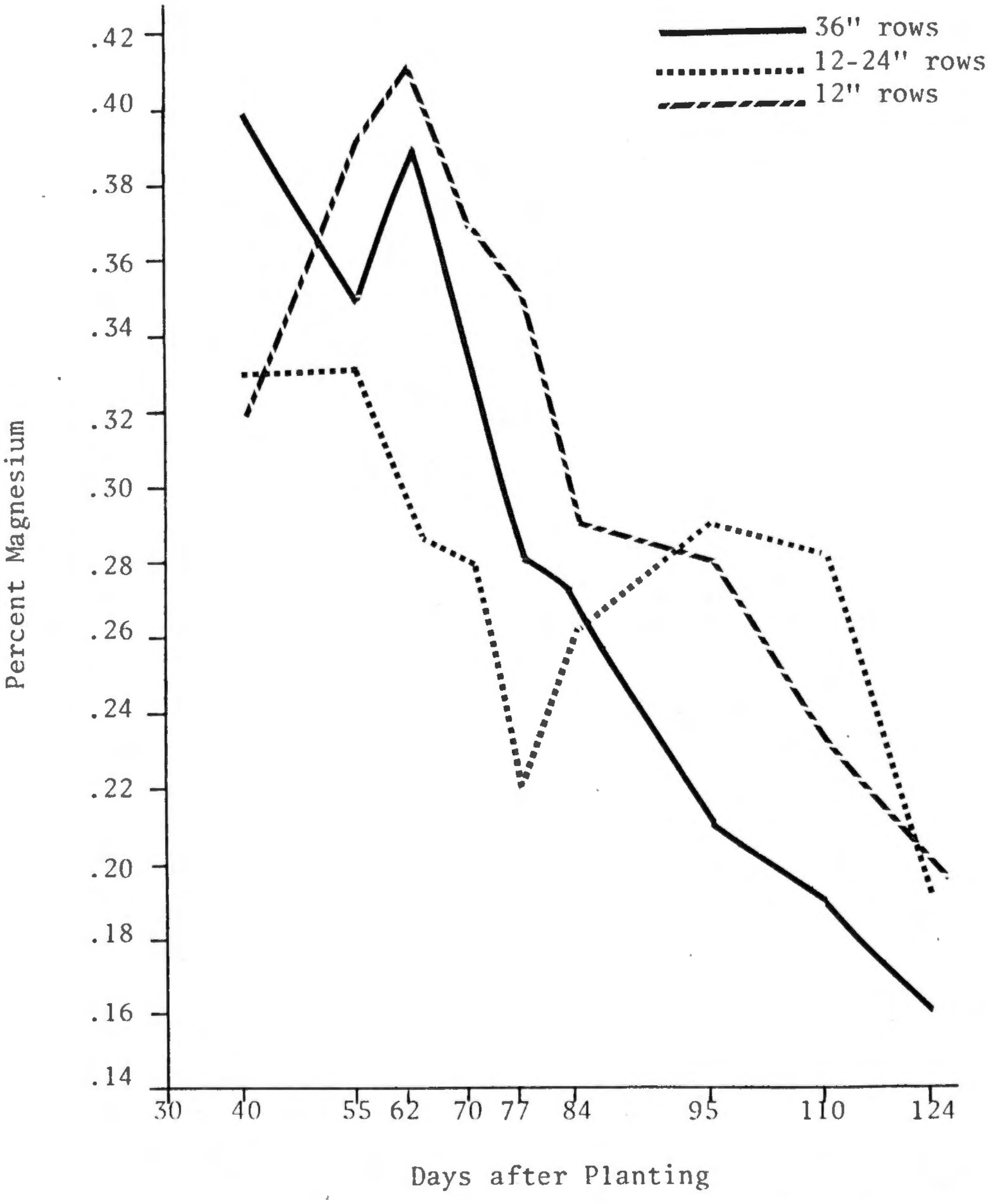

Figure 5. Percent magnesium in the above ground corn plant for samples taken at different days after planting within three row arrangements.

Accumulation of Nitrogen

The data for the accumulation of nitrogen are shown in Figure 6. Nitrogen accumulation increased from the first to the last of the season; at day 110 there was a leveling off of accumulation in the 12 inch row, but accumulation was still occurring in the 12-24 inch row spacing and the 36 inch row spacing at the last sampling date. Figure 6 shows that the accumulation of nitrogen for all three row spacings were similar at the first of the season and only began to differ at the last of the season.

Accumulation of Phosphorus

The data for phosphorus accumulation are shown in Figure 7. The amount of phosphorus accumulated at increasing rates until day 110 after which time there was a decrease in pounds per acre of phosphorus in all row spacings. There is no known reason for this decrease. The accumulation of phosphorus in all row spacings was similar until the last of the season. This was similar to the results found with nitrogen.

Accumulation of Potassium

The accumulation of potassium is shown in Figure 8. Potassium accumulation increased over the season with a loss occurring at the end of the season in all three row spacings. The maximum rate of accumulation occurred during the first of the season. The accumulation of potassium was similar in all row spacings until the end of the season at which time the uptake in the 12-24 row spacing became erratic and in the 12 inch and 36 inch rows uptake decreased. No explanation is known for this decrease.

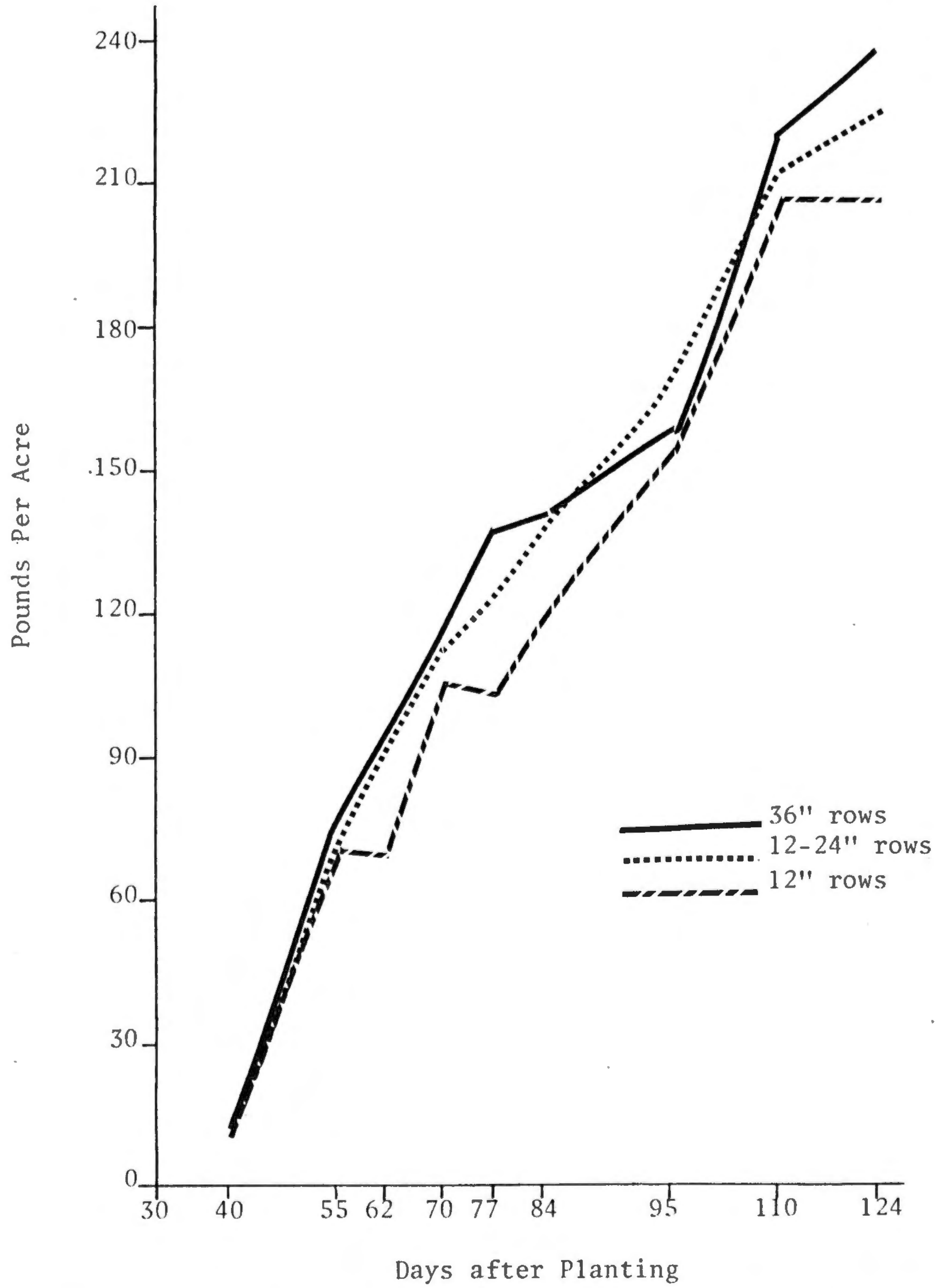

Figure 6. Nitrogen accumulation in the above ground corn plant for samples taken at different days after planting within three rows arrangements.

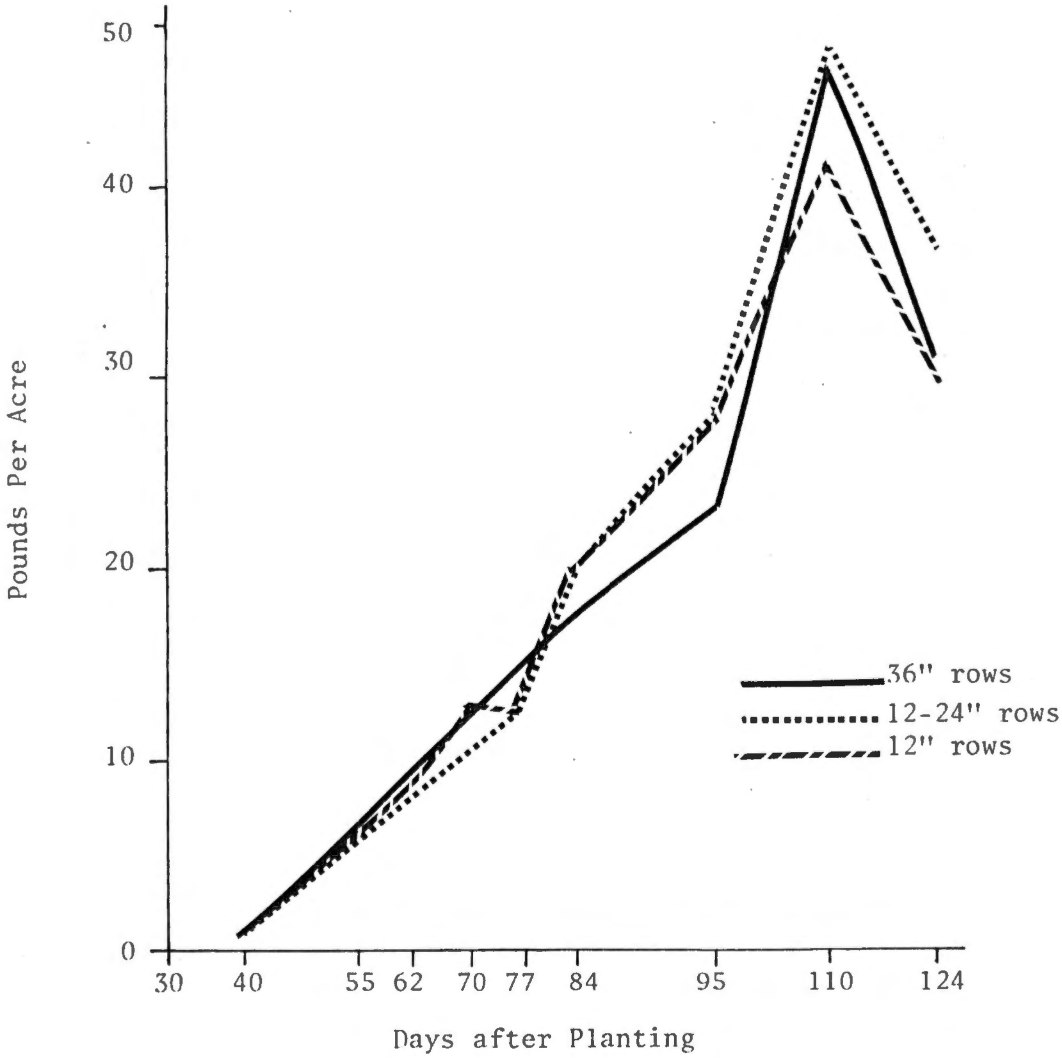

Figure 7. Phosphorus accumulation in the above ground corn plant for samples taken at different days after planting within three row arrangements.

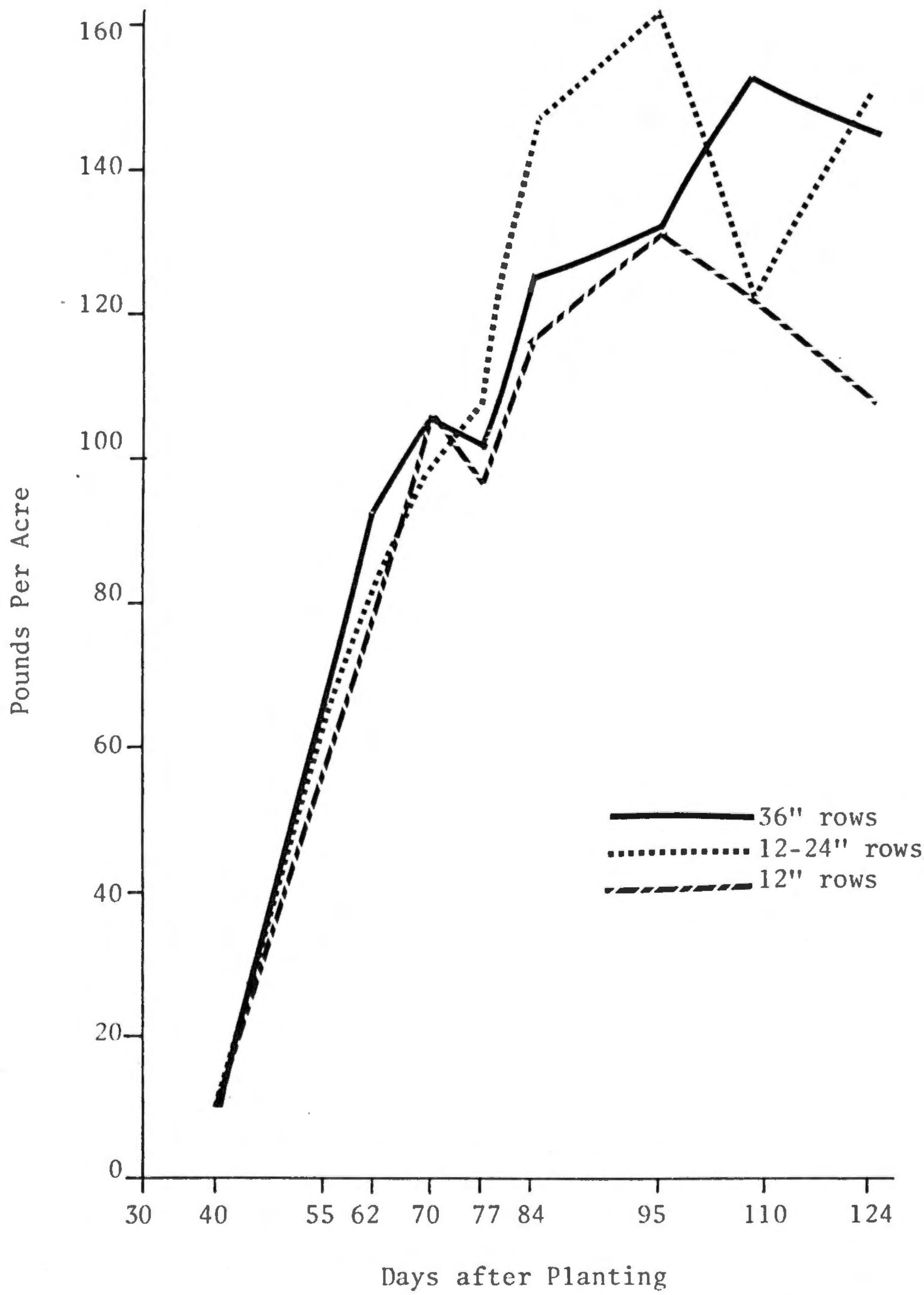

Figure 8. Potassium accumulation in the above ground corn plant for samples taken at different days after planting within three row arrangements.

Accumulation of Calcium

The accumulation of calcium is given in Figure 9. The accumulation of calcium continued to the end of the season in the 12-24 inch spacing, and to day 110 in the other two row spacings and then decreased. The maximum rate of accumulation of calcium in all spacings occurred at the first of the season. No reason is known for the decrease in accumulation of calcium. The accumulation for all row spacings were similar until the last of the season.

Accumulation of Magnesium

The data for the accumulation of magnesium are shown in Figure 10. Magnesium accumulated from the first sampling date to day 110. From day 110 until the last sampling date accumulation of magnesium decreased in all row spacings.

The accumulation of magnesium are similar in all row spacings at the first of the season and only began to differ from each other as the season progressed. The 12-24 inch row spacing showed a large increase in accumulation between day 95 and day 110, which resulted in the 12-24 inch row having the largest accumulation of magnesium.

IV. DRY MATTER ACCUMULATION IN CORN

The dry matter accumulation for the above ground portion of corn is presented in the Appendix, Table 5. Dry matter increased from the first to the last of the season as shown by Figure 11.

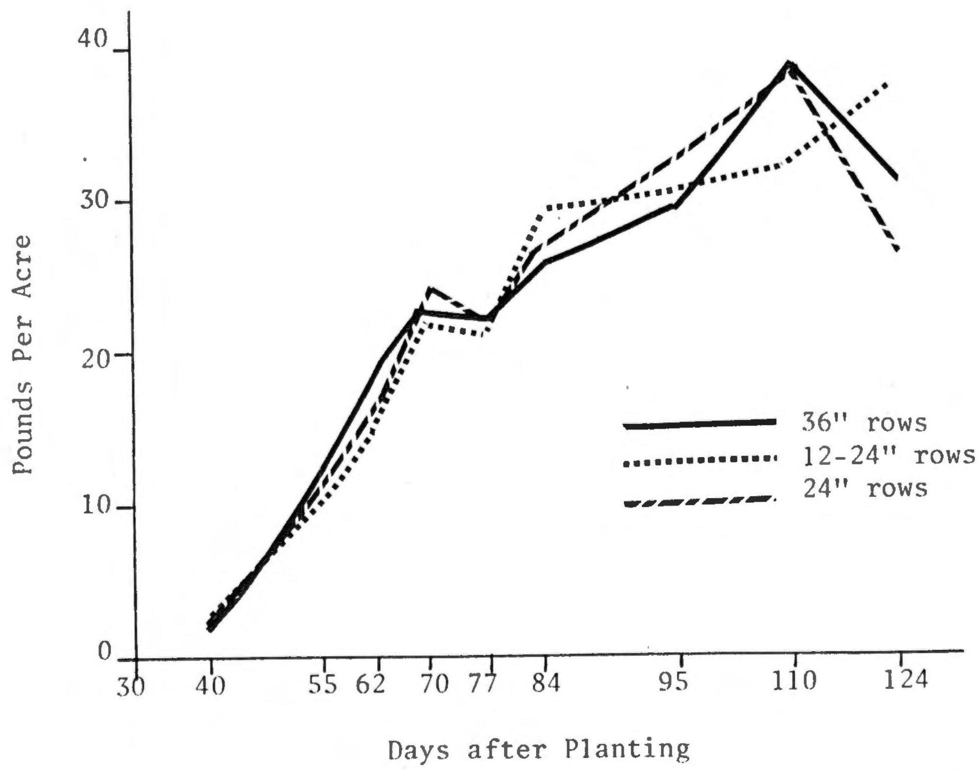

Figure 9. Calcium accumulation in the above ground corn plant for samples taken at different days after planting within three row arrangements.

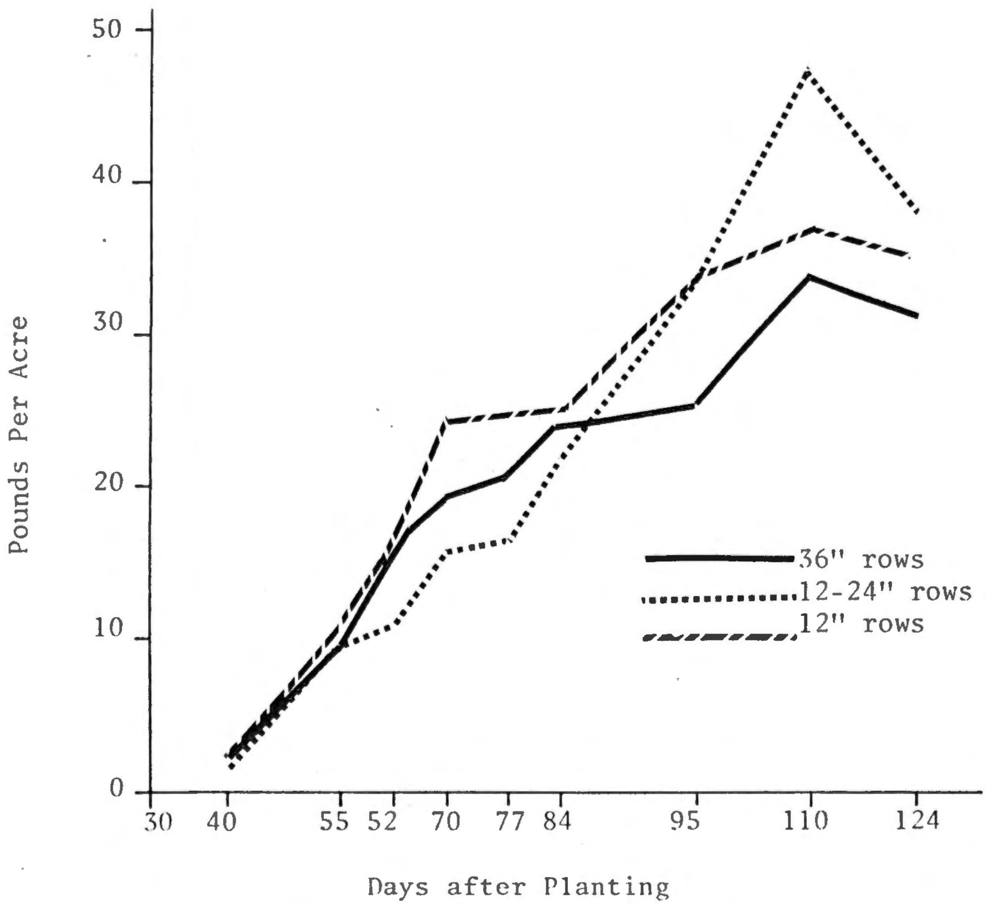

Figure 10. Magnesium accumulation in the above ground corn plant for samples taken at different days after planting within three row arrangements.

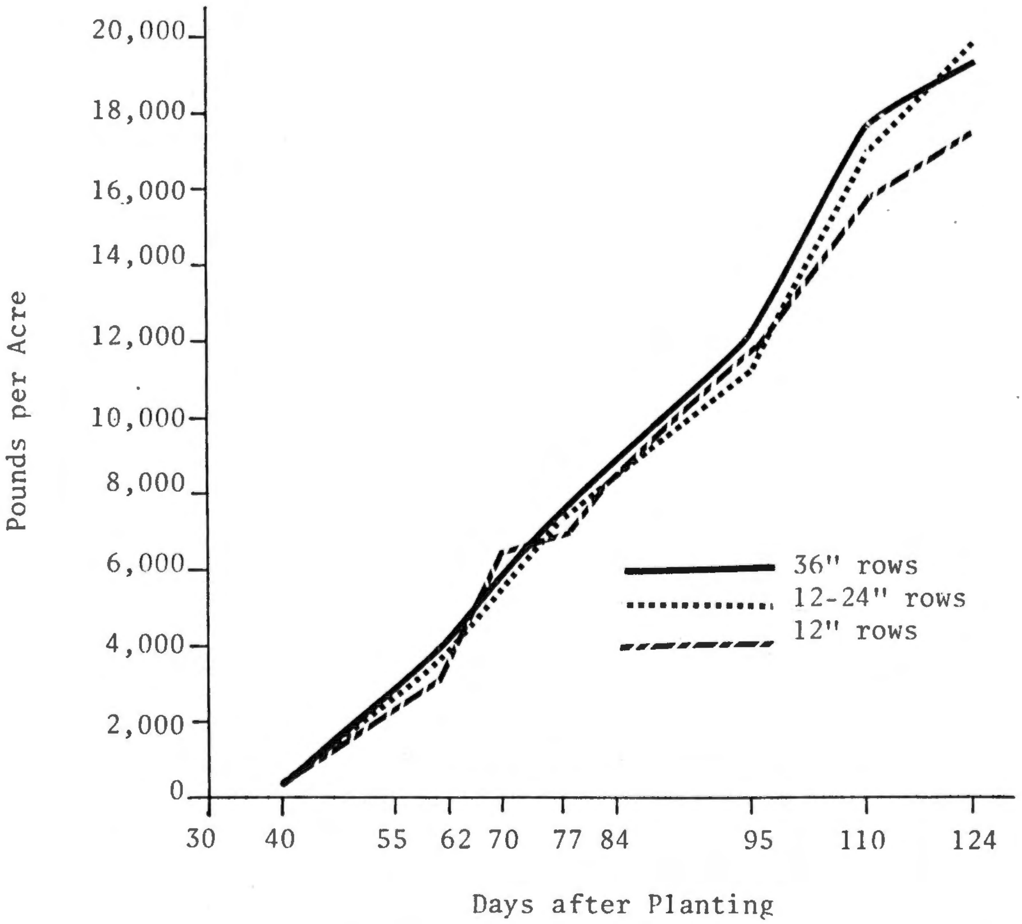

Figure 11. Dry matter accumulation in the above ground corn plant for samples taken at different days after planting within three row arrangements.

Other researchers (2, 22, 46) reporting dry matter accumulation obtained similar results. The dry matter production of corn in the 12-24 inch rows was lower than the 36 inch row spacing until the last harvest date, at which time the corn in the 12-24 inch row widths had the greatest pounds of dry matter per acre. Corn in the 12 inch rows had the lowest dry matter production per acre.

The higher dry matter yields in the 12-24 inch rows of corn might be attributable to less plant competition within the rows than in the case of 12 and 36 inch rows. The 36 inch row widths would have the greatest intrarow competition, the 12 inch row widths would have the greatest interrow competition whereas the total intra-interrow competition would be lowest in the 12-24 inch row spacing. The 24 inch space between every two rows, in the 12-24 inch row spacing, provided a break in the canopy which may have resulted in the lower leaves intercepting more sunlight than would be possible with a 12 inch row spacing and the narrower row widths resulted in a more even canopy with more light interception than corn in rows 36 inches wide. The higher yield of the 12-24 inch spacing is probably due not only to decreased plant competition above ground but also to decreased competition between roots of adjacent plants. From the nutrient data taken it is evident that corn in the 12-24 inch spacing contained a higher percentage of nitrogen, phosphorus, potassium, calcium, and magnesium than the other row spacings between day 84 and day 110 sampling dates. Data in the Appendix, Table 5, show that the 12-24 inch row spacing provided conditions for more rapid growth later in the season than did the other two spacings.

Samples were taken from these same plots to provide bulk density, large pore space, and root volume data. This work was conducted by Matosinho Figueiredo (15) in 1972 and 1973. He found no correlation between nutrient mobility, root volume and nutrient percent or accumulation.

IV. YIELD OF CORN

The yield data are summarized in Table 1. A yield of 148.5 bushels per acre was obtained for corn in the 12-24 inch row widths which was significantly higher than the grain yields obtained for the corn in the other two row spacings. The grain yield of corn in the 12 inch row spacing was significantly higher than the grain yield of corn in the 36 inch row spacing. As with dry matter production yield was related to the higher nutrient content in the 12-24 inch rows, during the critical period. The different spacings also may have had an influence on light interception.

TABLE 1

YIELD OF CORN PLANTED IN THREE ROW ARRANGEMENTS

Treatment	1972 Bushels per Acre
36"	132.0a*
12-24"	148.5c
12"	141.2b

*All figures represent an average of four replications.

V. NUTRIENT CONTENT OF SOYBEANS

The data for the percent nitrogen, phosphorus, potassium, calcium and magnesium in soybeans are given in the Appendix, Table 6.

Nitrogen

The data for percent nitrogen at the different sampling dates are given in Figure 12. The percent nitrogen in the soybean plants decreased from the seedling stage to day 73 and day 81 after which time it increased until the end of the season. This agrees with work done by others (21, 25). On sampling day 81 the 12 inch rows had the highest percent nitrogen, the 36 inch rows the next highest, and the 12-24 rows the lowest percent nitrogen. It should be noted that on day 112, the percent nitrogen was highest in the 12-24 inch rows and lowest in the 36 inch spaced rows. It is interesting to note that this follows the same pattern as yields. This pattern also was the same in corn; with the 12-24 inch rows having the highest yield and 36 inch rows the least.

Phosphorus

The percent phosphorus data are presented in Figure 13. The percent phosphorus has been reported to increase initially, then decrease slowly until early bloom and then increase until maturity (6, 21, 25, 27). The data presented in Figure 13 show this same trend. The percent of phosphorus in the soybeans increased from day 42 to day 48, decreased to day 73, and then increased until the last of the season. Between day 81 and day 112 the 12 inch row spacing had a higher percent phosphorus

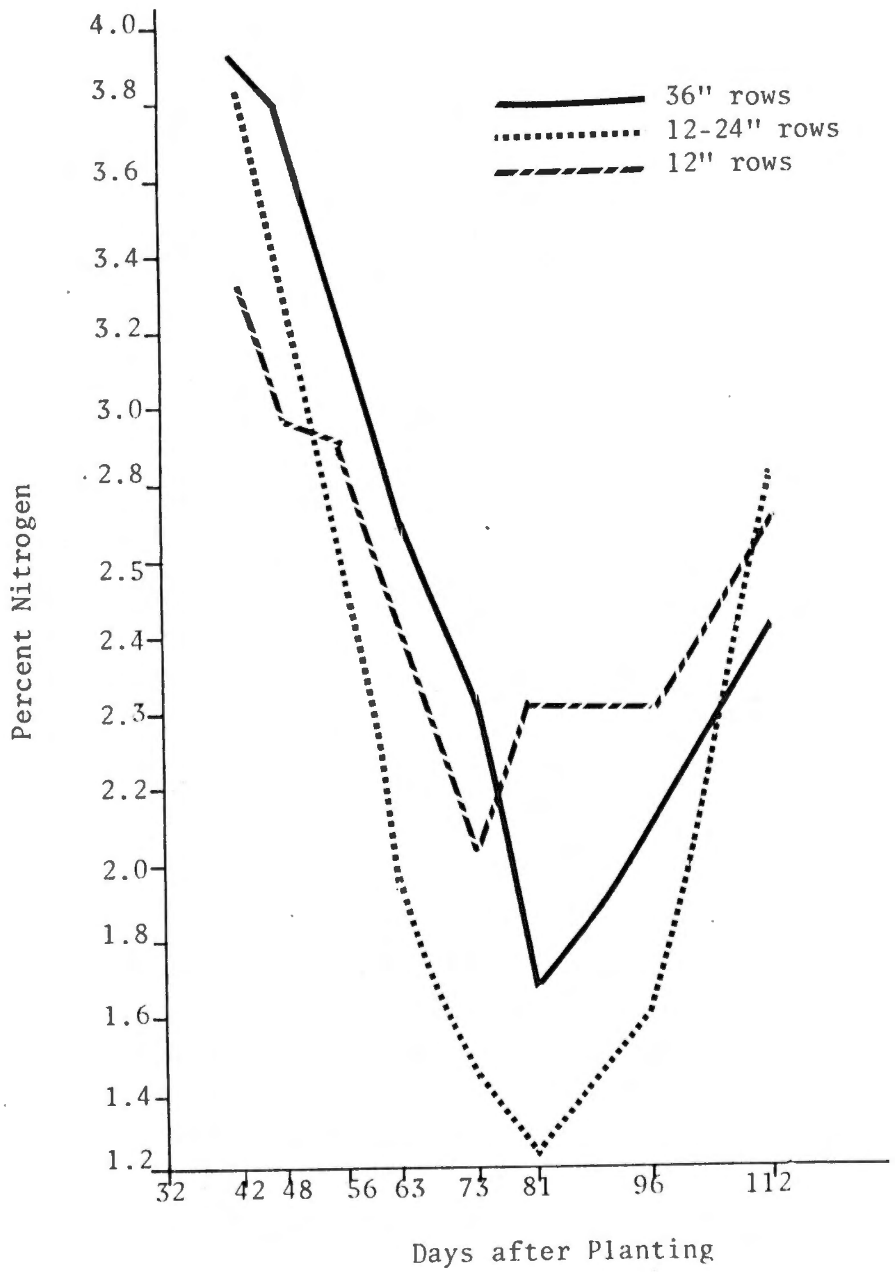

Figure 12. Percent nitrogen in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

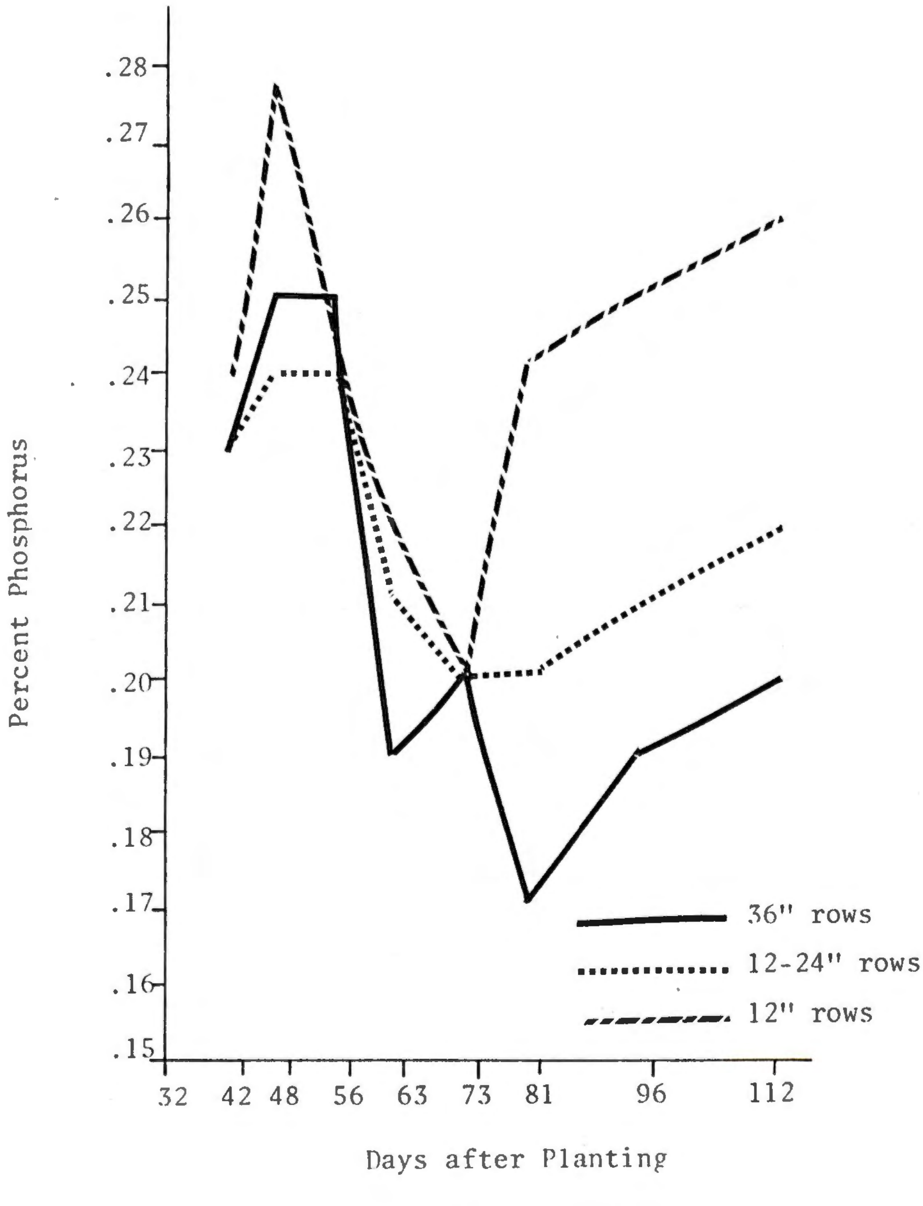

Figure 13. Percent phosphorus in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

than did the 36 inch row widths. The 12 inch row spacing had a significantly higher percent phosphorus than did the 12-24 inch rows on day 81 but not day 96 and 112.

Potassium

Data in Figure 14 show that the percent potassium in soybeans decreased from the first to the last of the season. On day 96 the 12-24 inch row spacing had the highest percent potassium, the 12 inch row width the next highest and 36 inch row width had the lowest percent potassium. The 12-24 inch row spacing was also the spacing that had the greatest bushel per acre yield and the 36 inch row spacing had the lowest bushel per acre yield, although it was not significant at the 5 percent probability level.

Calcium

Figure 15 shows that the percent calcium decreased from the first to the last of the season; however, it tended to level off as the season progressed. On day 96 the 12-24 inch spaced rows had the highest percent calcium. Also during this period the 36 inch spaced rows had the lowest percent calcium although it was not significantly different from the 12 inch rows.

Magnesium

Data in Figure 16 show that the percent magnesium decreased from the first of the season to day 96. From day 96 to day 112 there was a slight increase in all but the 12 inch row spacing which remained the same.

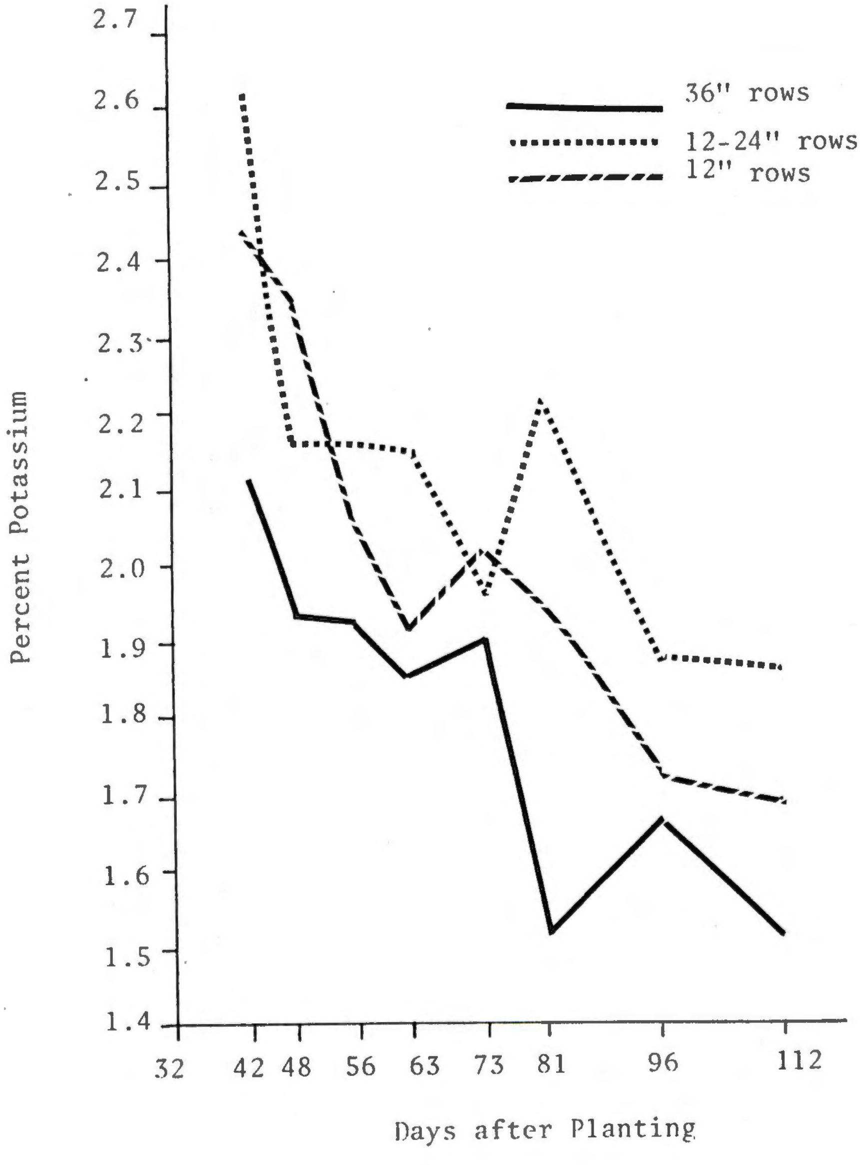

Figure 14. Percent potassium in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

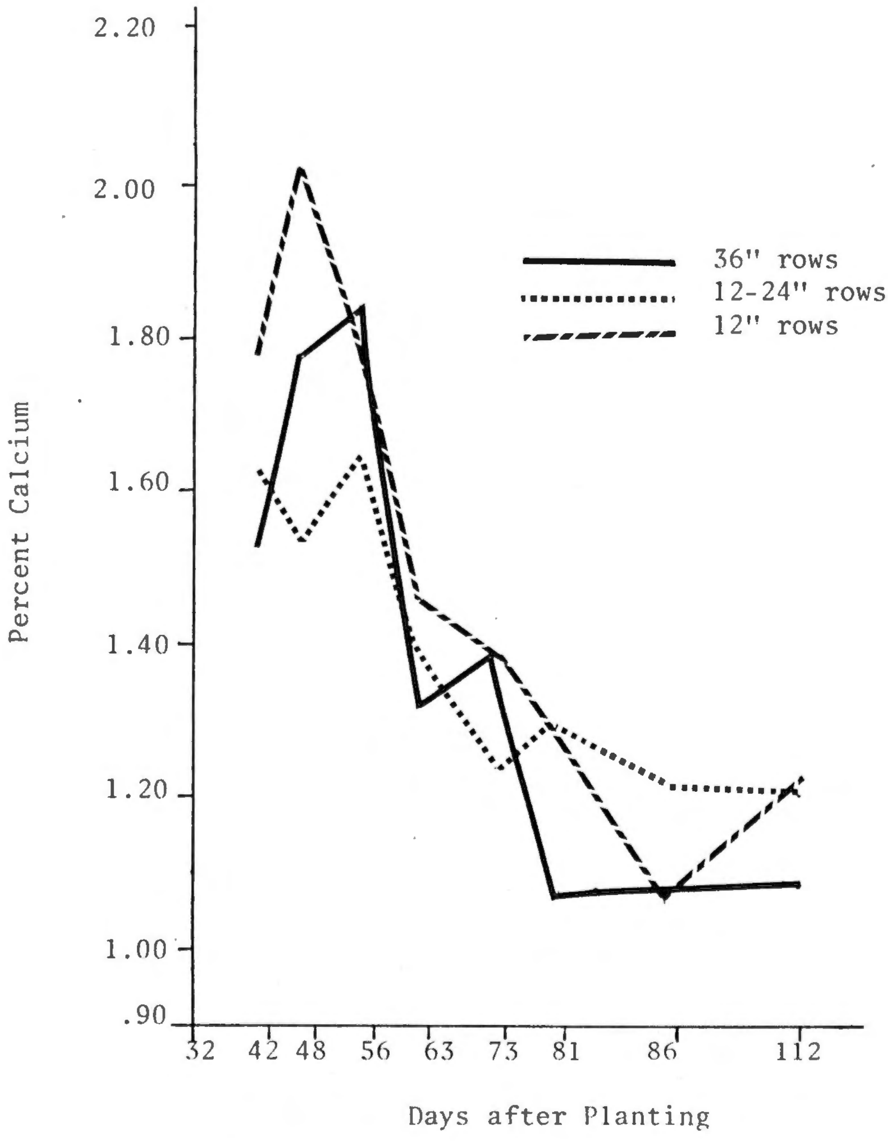

Figure 15. Percent calcium in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

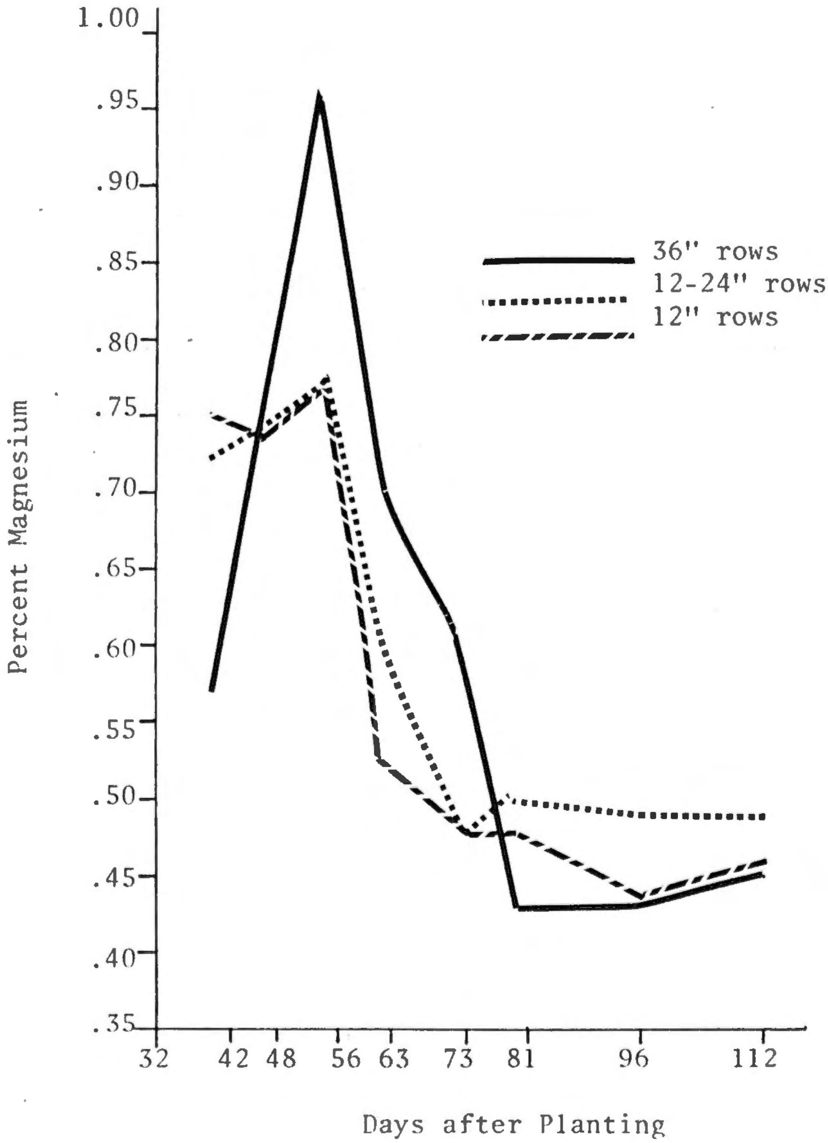

Figure 16. Percent magnesium in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

During the first of the season the 36 inch row spacing had the highest percent magnesium but from day 81 to the last sampling date it had the lowest percent magnesium. However, the difference was significantly lower on only one date. On day 81, 96 and 112 the 12-24 inch row had the highest percent magnesium, and was significantly higher on day 96 and day 112. The 12 inch row spacing had the next highest percent magnesium and the 36 inch row spacing had the lowest percent magnesium.

VI. NUTRIENT ACCUMULATION OF SOYBEANS

All data for the accumulation of nitrogen, phosphorus, potassium, calcium, and magnesium are given in the Appendix, Table 7. Statistical analyses was not run on nutrient accumulation or dry matter. This data are presented only to show trends.

Accumulation of Nitrogen

The data for accumulation of nitrogen are given in Figure 17. Accumulation of nitrogen increased until harvest with the greatest accumulation occurring during the period of pod set and initial filling. It should be noted that the 12-24 inch row spacing accumulated more nitrogen over the season than did the 12 inch or the 36 inch row spacing. The soybeans in the 12-24 inch rows had the greatest accumulation of nitrogen from day 42 to day 96.

Accumulation of Phosphorus

The data for the accumulation of phosphorus are shown in Figure 18. The accumulation of phosphorus increased from the first to the last of

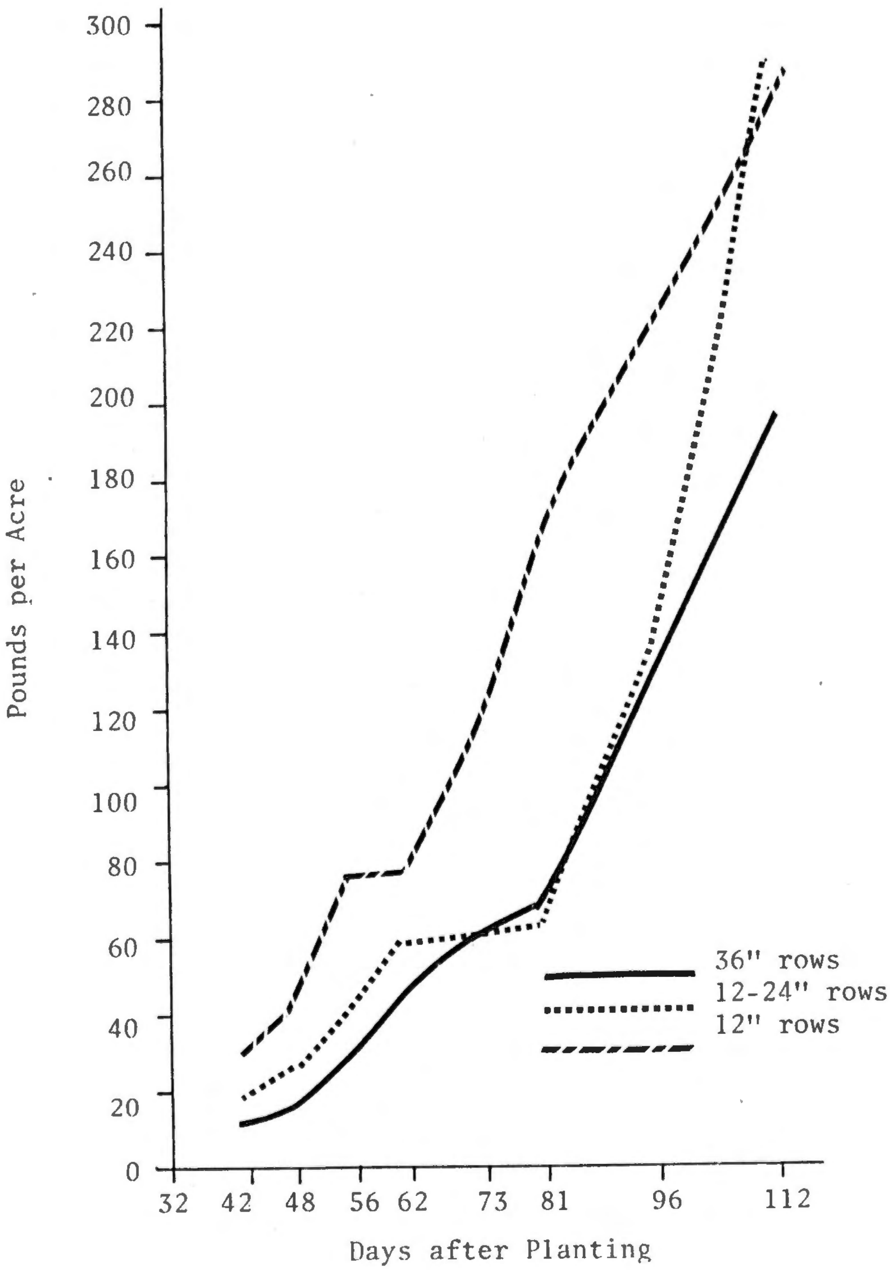

Figure 17. Nitrogen accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

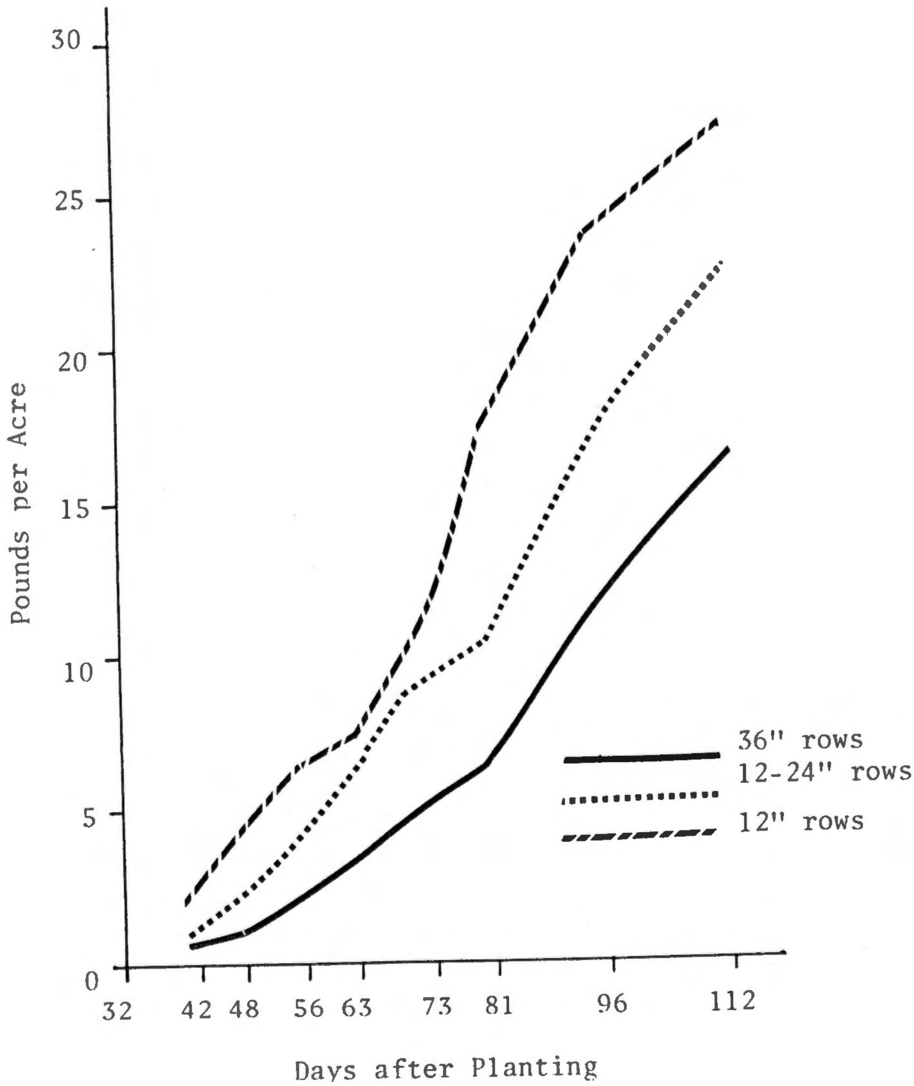

Figure 18. Phosphorus accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

the season with the greatest uptake occurring between day 81 and day 96. The 12 inch row spacing had the greatest uptake of phosphorus throughout the whole season. The 12-24 inch rows had the second highest accumulation of phosphorus while the 36 inch rows had the lowest accumulation of phosphorus.

The magnitude of phosphorus uptake was much less than that for nitrogen. The greatest uptake in pounds per acre of nitrogen was 288.4 while the highest accumulation for phosphorus was 27.1 pounds per acre. The nitrogen accumulation is over 10 times greater than that of phosphorus.

Accumulation of Potassium

Data in Figure 19 show that potassium accumulation increased from the first to the last of the season, with the greatest uptake occurring at the time of pod filling. The 12 inch row spacing had the greatest accumulation in pounds per acre of potassium for all but the last sampling date. The 12-24 inch row spacing had the second highest accumulation in pounds per acre for all but the last sampling date at which time it was highest. The 36 inch rows had the lowest accumulation of potassium throughout the season.

Accumulation of Calcium

Accumulation of calcium is shown in Figure 20. Accumulation increased from the first to the last of the season. The 12 inch rows had the highest accumulation throughout the season, the 12-24 inch rows had the second highest accumulation throughout the season, and the 36 inch rows had the lowest accumulation throughout the season.

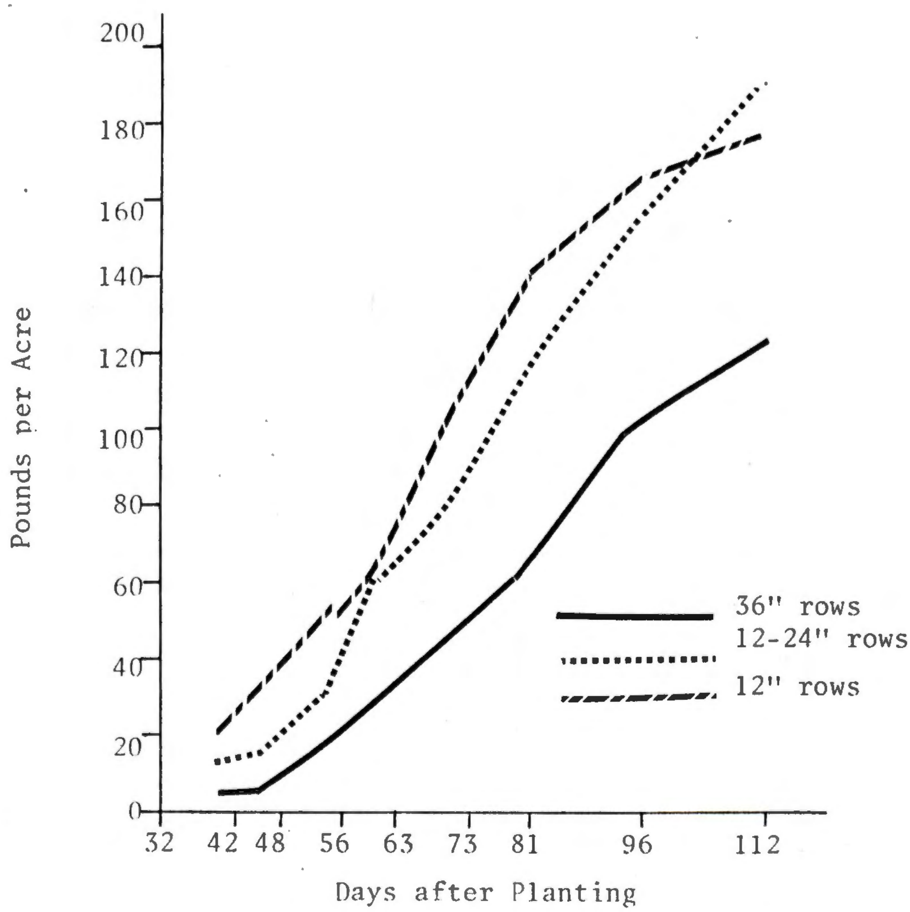

Figure 19. Potassium accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

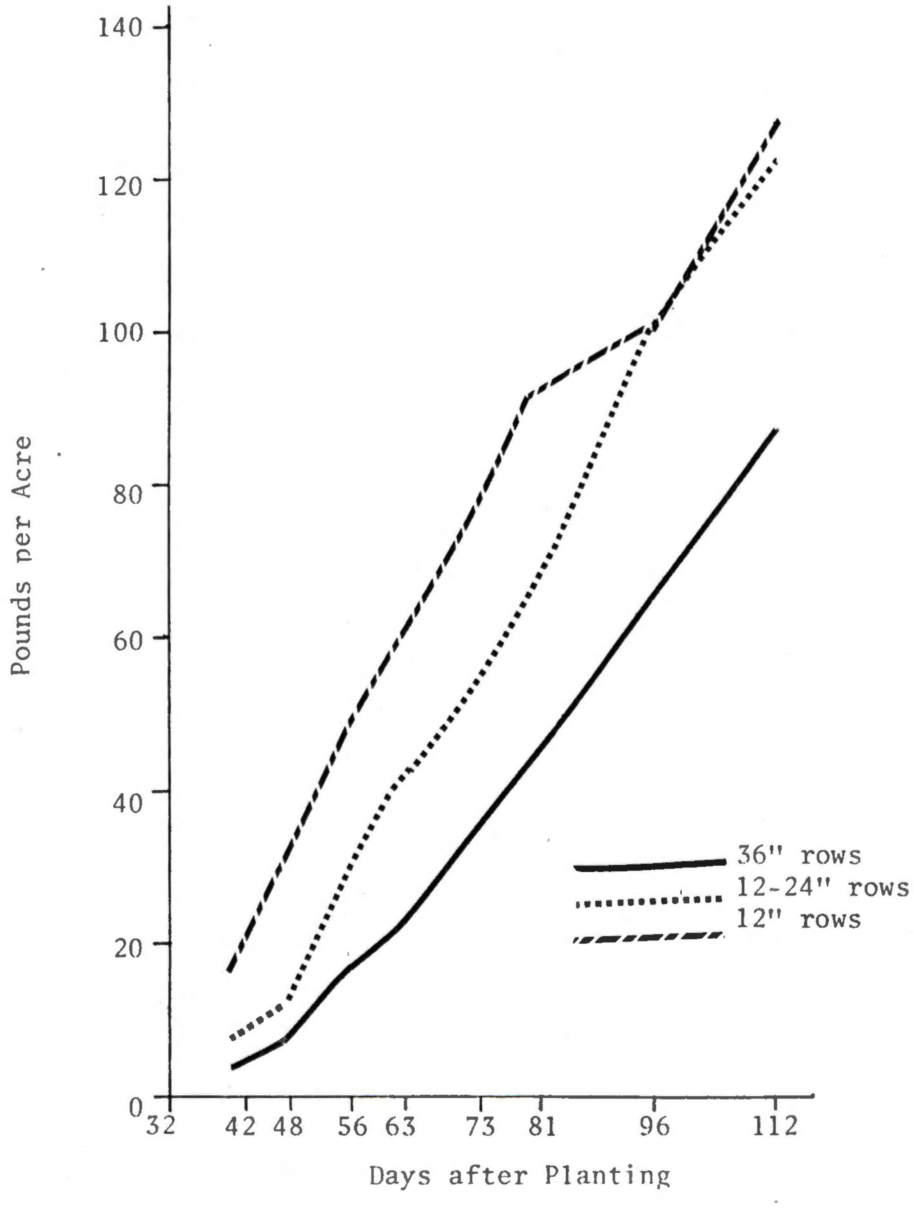

Figure 20. Calcium accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

Accumulation of Magnesium

The data for the accumulation of magnesium are shown in Figure 21. Magnesium accumulated from the first to the last of the season. Soybeans in the 12 inch rows had the highest accumulation in pounds per acre of magnesium for all but the last harvest date at which time the 12-24 inch rows had the highest accumulation. The 36 inch rows had the lowest accumulation throughout all the season.

VII. DRY MATTER ACCUMULATION IN SOYBEANS

The dry weight data are presented for soybeans in the Appendix, Table 8 and Figure 22. The data show that the more narrow the rows, the higher the dry matter production. This agrees with work done by Weber et al. (57) and Shibles and Weber (49, 50). They reported that those plant population arrangement combinations favoring a rapid attainment of high LAI (Leaf Area Index) were those also having the greatest dry matter production. They also reported that the greatest seed yield would occur at less than maximum dry matter production. The data show that the 12 inch rows produced the highest dry matter per acre and the 12-24 inch row widths produced the greatest seed yield per acre. The highest rate of dry matter accumulation occurred at approximately the same time the plants reached their maximum height.

Samples were taken from these same plots to provide bulk density, large pore space, and root volume data. This work was conducted by Matosinho Figueiredo (15) in 1972 and 1973. He found no correlation between nutrient mobility, root volume and nutrient percent or accumulation.

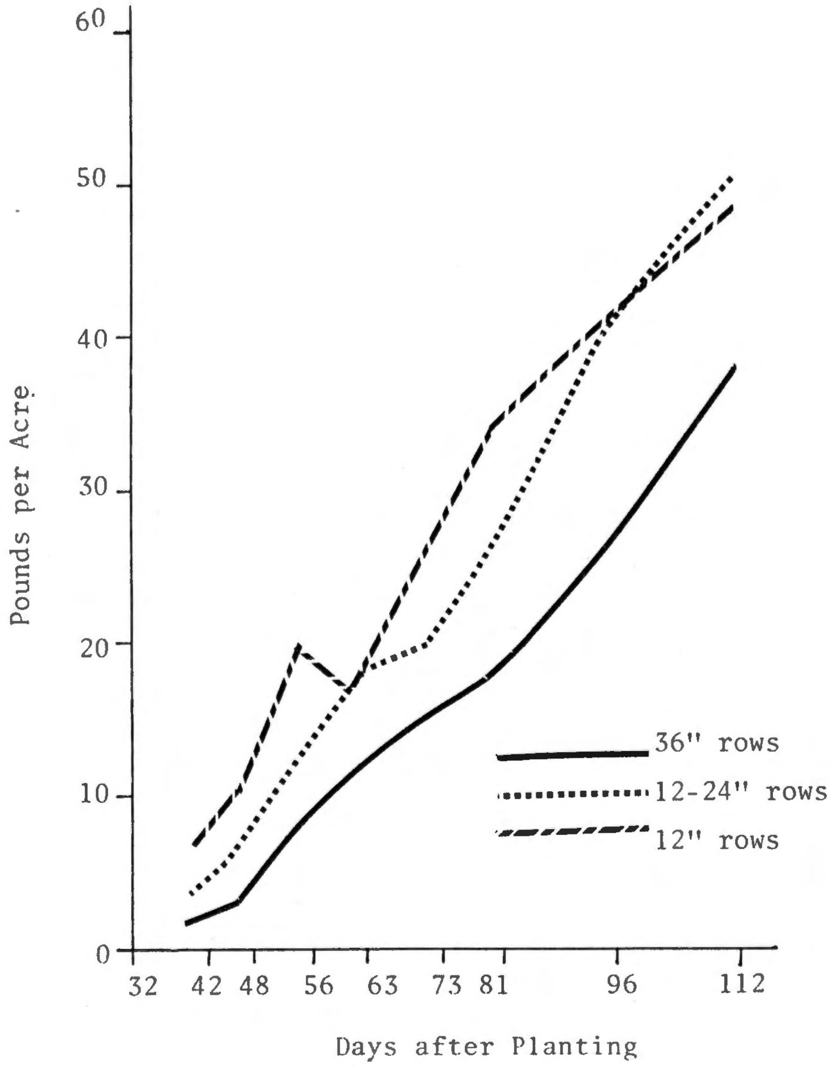

Figure 21. Magnesium accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

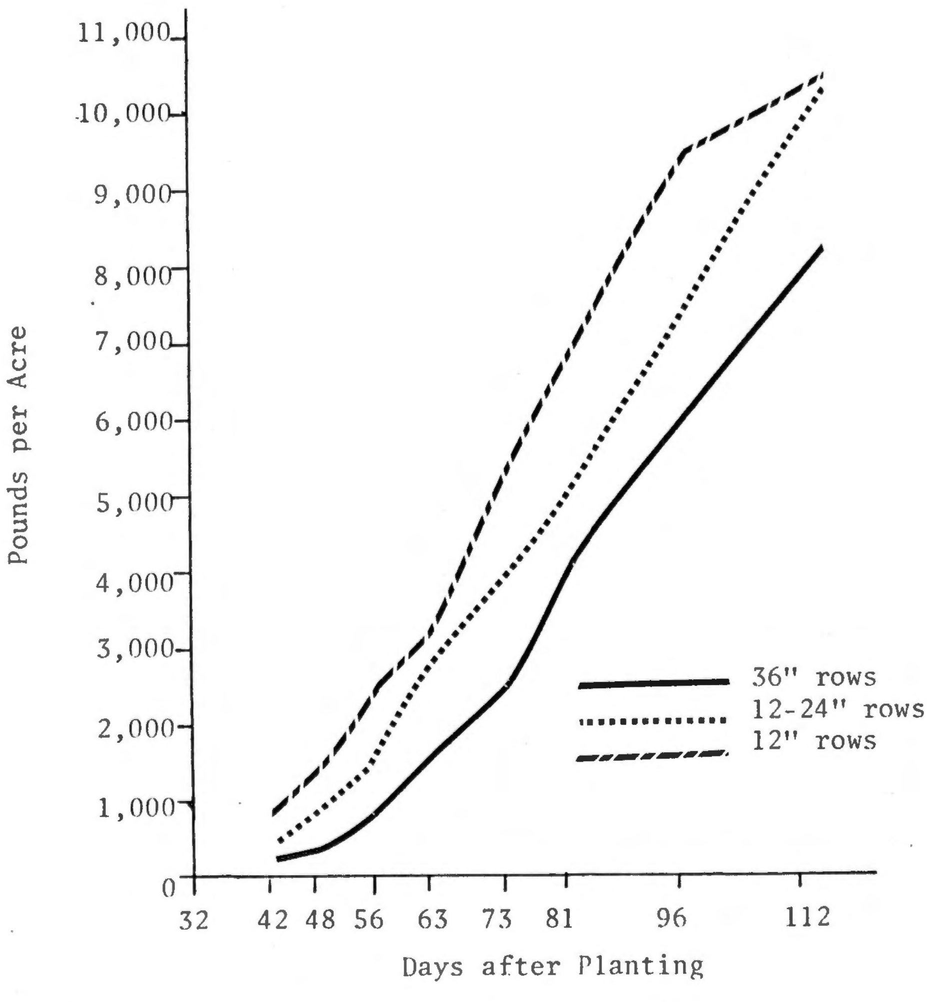

Figure 22. Dry matter accumulation in the above ground soybean plant for samples taken at different days after planting within three row arrangements.

VIII. YIELD OF SOYBEANS

The yields are summarized in Table 2. A yield of 42.4 bushels per acre was obtained for soybeans in the 12-24 inch row width, a 40.1 bushel per acre yield for the 12 inch row width, and a 39.4 bushel per acre yield in the 36 inch row width. Although there was no significant difference in yield at the 5 percent probability level it is interesting to note that the yields followed the same pattern as those of corn. Lodging in the soybeans may have affected yield. The soybeans began lodging about the middle of the season. The more narrow row spacings resulted in a taller growth which resulted in more lodging. The lodging was estimated to be 70 percent for the 12 inch row spacing, 50 percent for the 12-24 inch row spacing, and 10 percent for the 36 inch row spacing. Lodging in the corn was not considered as a factor of importance because of its small extent.

TABLE 2

YIELD OF SOYBEANS PLANTED IN THREE ROW ARRANGEMENTS

Treatment	1972 Bushels per Acre
36"	39.4a*
12-24"	42.4a
12"	40.1a

*All figures represent an average of four replications.

Plots with the narrowest rows had the highest dry matter production but did not produce the highest seed yield.

The 12-24 inch rows and the 12 inch rows had a higher accumulation of nutrients and percent of nutrients throughout the season.

CHAPTER V

SUMMARY

I. CORN

The data on percent of nitrogen, phosphorus, potassium, calcium, and magnesium present in the above ground corn plants show the dilution effect.

On day 76 the 12-24 inch rows had a higher percent of nitrogen and potassium. They also had a higher percent of phosphorus, calcium, and magnesium although they were not significantly different at the 0.05 probability level.

There is a trend that indicates the possibility that the yield of corn was related to the percent of nitrogen, phosphorus, potassium, calcium and magnesium present in the corn plant at about 95 days after planting.

The accumulation of nitrogen, phosphorus, potassium, calcium and magnesium was progressive from day 40 to day 95. There was a decrease in accumulation at the end of the season for which no reason is known. The accumulation for the different nutrients varied little between the different row spacing at the first of the season but began to show more change on about day 77. On the last sampling date, corn in the 12-24 inch rows had the greatest accumulation of phosphorus, potassium, calcium, and magnesium and the 36 inch rows had the greatest accumulation of nitrogen.

The magnitude of accumulation of nitrogen, phosphorus, and potassium was much higher than that of calcium and magnesium.

Dry matter production in corn was highest in the 36 inch row spacing until day 124 at which time the 12-24 inch spacing was highest.

Corn in the 12-24 inch rows yielded significantly more than corn in the 12 inch rows which yielded significantly more than corn in the 36 inch rows.

II. SOYBEANS

The percent data for soybeans showed the dilution effect. The percent nitrogen and phosphorus decreased for the first 81 days after planting and then increased until the end of the season, while percent potassium decreased as the season progressed and the percent calcium and magnesium leveled off. The 12-24 inch row spacing had the highest percent potassium, calcium, and magnesium from day 77 until the end of the season and the second greatest percent nitrogen and phosphorus, although the differences were not significant. The percent of the various nutrients was similar for the different row spacings at the first of the season and only began to differ at about 73 days after planting.

Accumulation of all nutrients in soybeans increased throughout the season. Nitrogen and potassium accumulation in soybeans was of much greater magnitude than that of phosphorus, calcium, and magnesium. Accumulation at the last sampling day showed nitrogen, potassium, and magnesium to be highest in the 12-24 inch rows. Accumulation of phosphorus was highest in the 12 inch rows. The 36 inch rows were lowest in all nutrients.

Dry matter production was greatest in the narrowest rows and least in the widest rows. Greatest dry matter production did not result in the greatest seed yield.

Lodging occurred in the soybeans with the greatest lodging occurring in the narrower rows and the least lodging occurring in the widest rows.

The yield of soybeans in bushels per acre were not significantly different at the 0.05 probability level but followed the same pattern as corn with the 12-24 inch rows having the greatest yield, the 12 inch rows the second greatest yield and the 36 inch rows the lowest yield.

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APPENDIX

Procedure for the digestion of plant tissue for the determination of nitrogen.

1. Dry plant tissue at 70°C, grind into fine particles (40 mesh screen), and store in air tight bottles.
2. Weigh a 0.2000 gram sample and place in a 125 ml Erlemeyer flask.
3. Add 10 ml of concentrated H_2SO_4 to each flask and allow to predigest for four hours or more at room temperature.
4. After predigesting, set the flasks on a hot plate and heat to 200-225°C for 1.5 to 2 hours, or until the volume is reduced by about 50 percent.
5. Remove flasks from the hot plate and allow to cool.
6. After sufficient cooling, add 15 ml of 35 percent H_2O_2 to each flask and place back on the hot plate and heat at 200-225°C for 45 minutes after clearing.
7. Remove clear samples from hot plate, cool, and transfer to 250 ml volummetric flasks.
8. Take to volume in distilled water, shake thoroughly, and allow samples to equilibrate.

Automated colorimetric determination of N in wet digested corn tissue samples.

1. The instrumentation for the Technicon Autoanalyzer used consisted of 7 separate modules as follows: small automatic sample equipped with a liquid wash system; one positive displacement proportioning pump; one water bath; one colorimeter equipped with a continuous tubular flow cell; one recorder; one voltage stabilizer; and one range expander.

2. The sample stream goes through two dilutions

a. One part sample diluted with two parts water

b. One part diluted sample diluted with 6.5 parts of 0.4 N NaOH.

3. The diluted sample stream is then joined by a stream of alkaline phenol (250 grams phenol and 108 grams NaOH made to 1 liter).

4. After mixing, the stream is then joined by a stream of sodium hypochlorite (commercial grade "Clorox") and is mixed further.

5. The stream then passes into a 85°C (±5°C) heating bath for 5 minutes and, after cooling, enters the colorimeter containing a 10 mm flow cell where the percent transmittance is measured at 610 mμ.

6. The N concentration of samples is determined by comparing with the semi-log plot of percent transmittance vs. ppm N of a group of standards containing 0, 5, 10, 20, 30, 40, and 45 ppm N as NH_4^+.

7. The proportioning pump manifold designed to supply the correct volumes of sample, water, NaOH, alkaline phenol, and sodium hypochlorite to the colorimeter is shown in Figure 23.

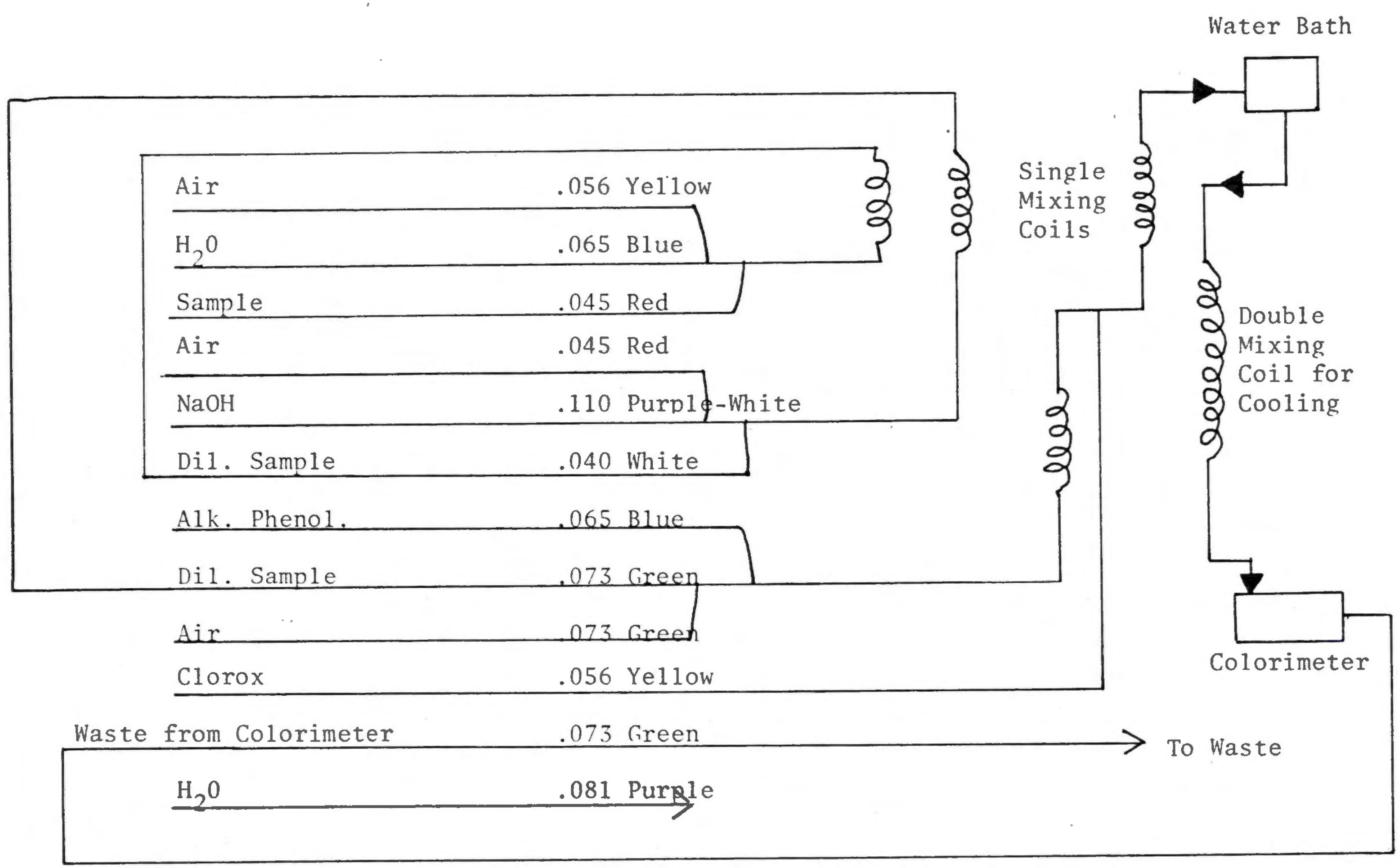

Figure 23. Nitrogen manifold.

Procedure for the wet ashing of K, Ca, Hg, and P by the aluminum heating block method.

1. Dry plant tissue at 70°C, grind into fine particles (40 mesh scrren) and store in air tight bottles.
2. Weigh a 0.5000 gram portion of each sample and place into a 50 ml tube.
3. Add 2 small glass beads, and 3 ml of concentrated nitric acid to each sample. Place a small funnel in the mouth of each tube to act as a condenser.
4. Place tubes into the aluminum heating block, and let the sample digest at room temperature overnight.
5. Place block on hotplate and raise the temperature to 150°C. Digest at this temperature for 1 hour.
6. Add 2 ml of 60 to 70 percent perchloric acid to each tube and digest at 235°C for 2 hours. The liquid in each sample should be clear at this point. If not, continue digestion until clear.
7. Cool the block to room temperature and add 1 ml of concentrated hydrochloric acid. Digest at 150°C for 15 to 20 minutes.
8. Transfer cooled samples into 100 ml volumetric flasks and make to volume with distilled water.
9. Shake the flask thoroughly and let stand overnight.
10. At this point the samples are ready for analysis on the Technicon Autoanalyzer.

Simultaneous determination of Ca, K, P, and Mg concentrations of wet-digested corn tissue samples by Autoanalysis.

1. The instrumentation for the Technicron Autoanalyzer employed here consisted of 14 separate modules as follows: small automatic sampler equipped with a liquid wash system; three positive displacement proportioning pumps; two colorimeters equipped with continuous tubular flow cells; one dual-channel flame photometer; two 2-pen recorders; two voltage stabilizers; one time-delay coil; and two range expanders.

2. Potassium and calcium determinations were made by using the Technicon III dual-channel flame photometer. Lithium nitrate (.525 g in 1 liter of water) was used as an internal standard and lanthanum chloride (5 g in 1 liter of water) was used to increase the calcium flame response. The proportioning-pump manifold designed to supply the correct volume of sample, $LiNO_3$, and $LaCl_3$ to the dual-channel flame photometer is shown in Figure 24.

3. Phosphorus determinations were made using a colorimeter. The sample is first diluted with .05 N HCl. The diluted sample stream is then joined by a stream of ammonium vanadate (25 g ammonium molybdate in 400 ml of water mixed with an equal volume of a solution of 1.25 g ammonium metavanadate in 300 ml of water with a few drops of concentrated $NH_4)H$ and 250 ml of concentrated HNO_3). The stream then passes through the colorimeter, equipped with a 420 mμ filter, where phosphorus is determined as PO_4^{-3}. The proportioning-pump manifold designed to supply the correct volume of sample, HCl, and ammonium vanadate to the colorimeter is shown in Figure 25.

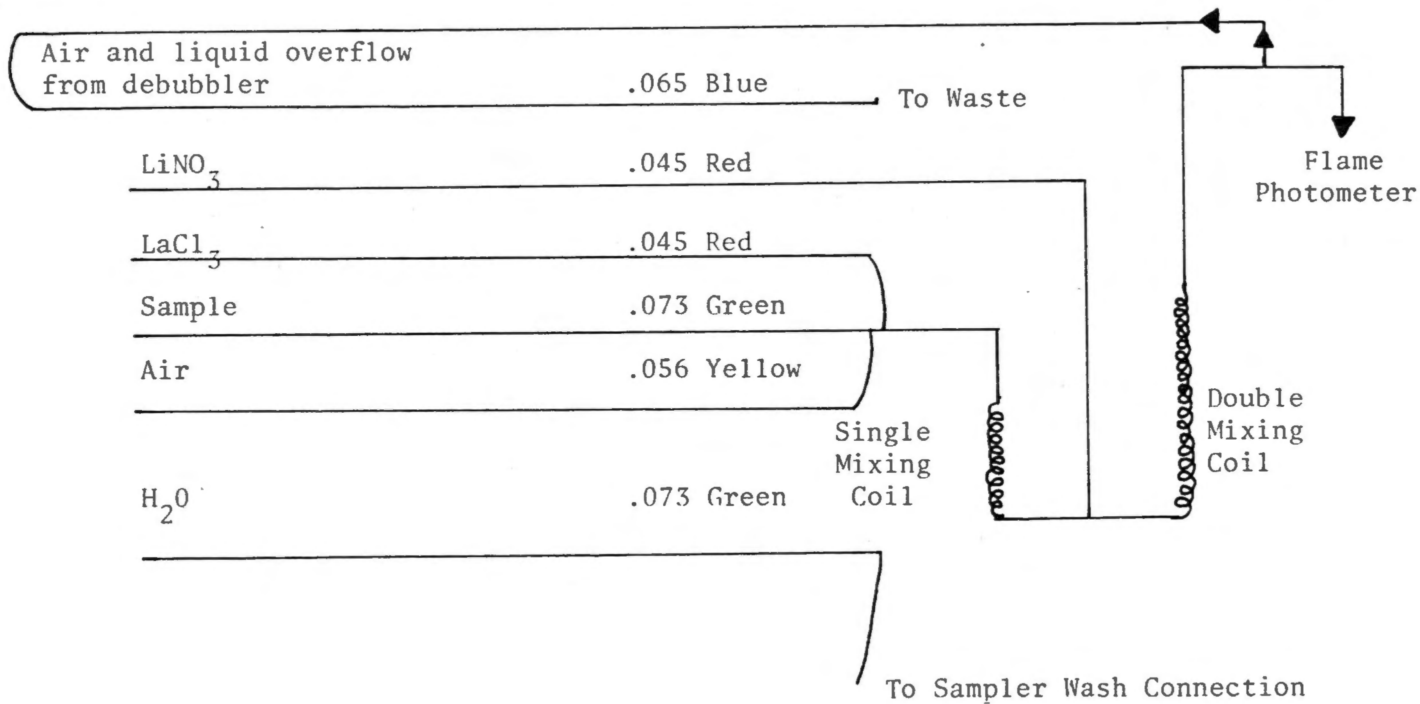

Figure 24. Potassium-calcium manifold.

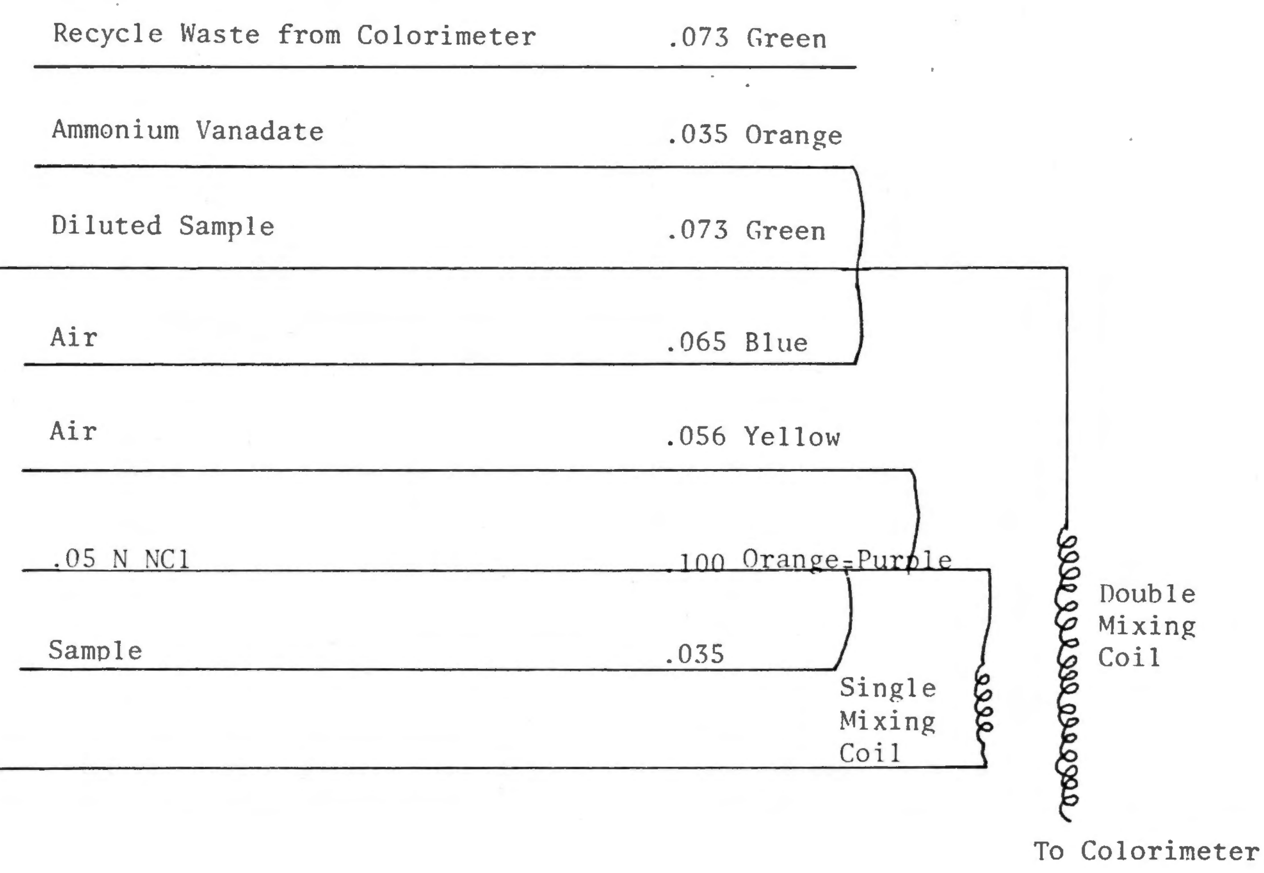

Figure 25. Phosphorus manifold.

4. Magnesium concentrations were determined in a colorimeter by a modified lake procedure in which $Mg(OH)_2$ is precipitated in an alkaline solution and Magnesium Blue dye (.02 percent) is absorbed on the $Mg(OH)_2$ in the presence of a detergent (.05 percent Brij 35 in water) and a suspending material (2 g EGTA and 2 g polyvinyl alcohol in 1 liter H_2O). The proportioning-pump manifold designed to supply the correct volume of sample, PVA-EGTA, Magnesium Blue (2N) to the flow cell of the colorimeter is shown in Figure 26. The colorimeter used in this procedure was equipped with a 630 mμ filter.

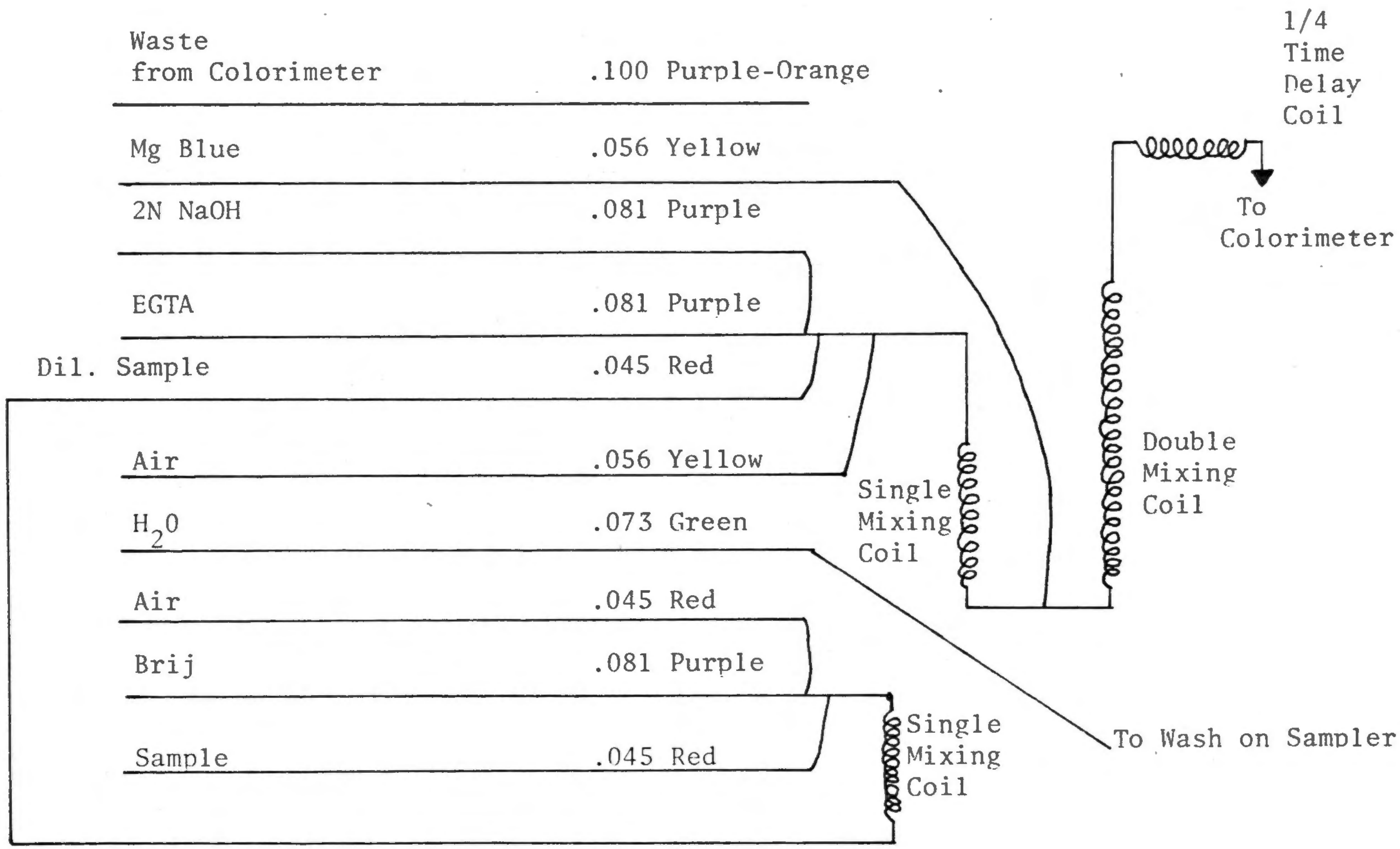

Figure 26. Magnesium manifold.

TABLE 3

PERCENT N, P, K, Ca, AND Mg IN THE ABOVE GROUND CORN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Nutrient	Row Spacing	Days after Planting 40	55	62	70	77	84	95	110	124
N	36"	2.98*b	2.75b	2.40a	2.04a	1.84a	1.59a	1.31b	1.29a	1.23a
	12-24"	3.25ab	2.77b	2.38a	2.03a	1.69b	1.62a	1.51a	1.27b	1.15b
	12"	3.28a	2.85a	1.84b	1.63b	1.48c	1.37b	1.28b	1.23c	1.11c
P	36"	.22b	.21ab	.22a	.21a	.20a	.20b	.19b	.26b	.16c
	12-24"	.20c	.19b	.20b	.18c	.17b	.23a	.25a	.28a	.19a
	12"	.23a	.22a	.21ab	.19b	.18ab	.23a	.23a	.26b	.17b
K	36"	2.32c	2.19c	2.31a	1.80a	1.36c	1.41b	1.09b	.86a	.75b
	12-24"	2.63b	2.31b	2.18b	1.75ab	1.48a	1.71a	1.43a	.73b	.76a
	12"	2.71a	2.37a	1.96c	1.64b	1.39b	1.33c	1.09b	.77b	.62c
Ca	36"	.41c	.45a	.47a	.39a	.30b	.29c	.24a	.22a	.16b
	12-24"	.43b	.40c	.40b	.39a	.29c	.34a	.27a	.19c	.19a
	12"	.44a	.43b	.41b	.38b	.32a	.32a	.27a	.24a	.15c
Mg	36"	.39a	.35b	.39a	.33a	.28ab	.27b	.21b	.19c	.16c
	12-24"	.33b	.33c	.29b	.28b	.22b	.26c	.29a	.28a	.19b
	12"	.32c	.39a	.41a	.37a	.35a	.29a	.28a	.23b	.20a

*All figures represent an average of 2 subsamples from each of 4 replications.

TABLE 4

N, P, K, Ca, AND Mg ACCUMULATION IN THE ABOVE GROUND CORN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Nutrient	Row Spacing	Days after Planting								
		40	55	62	70	77	84	95	110	124
N	36"	15.1*	78.0	95.9	118.8	137.0	141.4	158.7	228.0	238.4
	12-24"	11.2	75.2	88.8	114.7	122.5	138.4	170.0	214.5	227.1
	12"	16.1	75.0	71.9	105.4	103.3	118.7	154.4	195.3	194.5
P	36"	1.1	6.0	8.8	12.2	14.9	17.8	23.0	46.0	31.0
	12-24"	.7	5.2	7.5	10.2	12.3	19.6	28.1	47.3	37.5
	12"	1.1	5.8	8.2	12.3	12.6	19.9	27.7	41.3	29.8
K	36"	11.8	62.1	92.3	104.9	101.2	125.4	132.1	152.0	145.4
	12-24"	9.1	62.7	81.3	98.9	107.3	146.1	160.9	123.3	150.0
	12"	13.3	62.4	76.6	106.1	97.0	115.2	131.5	122.2	108.6
Ca	36"	2.1	12.8	18.8	22.7	22.3	25.8	29.1	38.9	31.0
	12-24"	3.1	10.7	14.9	22.0	21.0	29.1	30.4	32.1	37.5
	12"	2.2	11.3	16.0	24.6	22.3	27.7	32.6	38.1	26.3
Mg	36"	2.0	9.9	15.6	19.2	20.8	24.0	25.4	33.6	31.0
	12-24"	1.1	9.0	10.8	15.8	16.0	22.2	32.6	47.3	37.5
	12"	1.6	10.3	16.0	23.9	24.4	25.1	33.8	36.5	35.0

*All figures represent an average of 2 subsamples from each of 4 replications.

TABLE 5

DRY MATTER ACCUMULATION IN THE ABOVE GROUND CORN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Row Spacing	Days after Planting								
	40	55	62	70	77	84	95	110	124
	Pounds per Acre								
36"	500*	2800	4000	5800	7400	8900	12100	17700	19400
12-24"	300	2700	3700	5700	7300	8500	11300	16900	19700
12"	500	2600	3900	6500	7000	8700	12000	15900	17500

*Figures represent an average of 3 subsamples from each of four replications.

TABLE 6

PERCENT N, P, K, Ca, AND Mg IN THE ABOVE GROUND SOYBEAN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Nutrient	Row Spacing	Days after Planting							
		42	48	56	63	73	81	96	112
		Pounds per Acre							
N	36"	3.92*a	3.80a	3.21a	2.76a	2.34a	1.68c	2.05a	2.41c
	12-24"	3.83ab	3.29ab	2.57c	2.00b	1.46b	1.23b	1.60b	2.82a
	12"	3.32b	2.98b	2.91b	2.42ab	2.06ab	2.31a	2.32a	2.70b
P	36"	.23b	.25b	.25a	.19c	.20a	.17b	.19b	.20b
	12-24"	.23b	.24c	.24b	.21b	.20a	.20b	.21ab	.22ab
	12"	.24a	.28a	.24b	.22a	.20a	.24a	.25a	.26a
K	36"	2.12b	1.94c	1.93b	1.86c	1.90c	1.52b	1.66c	1.51b
	12-24"	2.62a	2.16b	2.17a	2.15a	1.97b	2.21a	1.88a	1.86a
	12"	2.44a	2.35a	2.05ab	1.91b	2.02a	1.95a	1.73b	1.69ab
Ca	36"	1.52b	1.78b	1.84a	1.31c	1.38b	1.07b	1.08b	1.08c
	12-24"	1.62b	1.53b	1.64c	1.39b	1.24c	1.28a	1.21a	1.20b
	12"	1.78a	2.10a	1.78b	1.46a	1.39a	1.30a	1.06b	1.22a
Mg	36"	.57a	.75a	.96a	.71a	.61a	.43b	.43b	.45b
	12-24"	.73a	.74b	.78b	.61b	.48b	.50a	.49a	.49a
	12"	.75a	.74b	.77b	.53c	.48b	.48a	.44b	.46b

*All figures represent an average of 2 subsamples from each of 4 replications.

TABLE 7

N, P, K, Ca, AND Mg ACCUMULATION IN THE ABOVE GROUND SOYBEAN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Nutrient	Row Spacing	Days after Planting							
		42	48	56	63	73	81	96	112
		Pounds per Acre							
N	36"	10.1*	14.2	27.4	43.6	59.5	67.7	122.5	195.5
	12-24"	18.9	25.1	39.9	59.0	60.0	62.2	129.6	288.4
	12"	29.6	41.1	75.5	76.7	110.5	162.3	218.5	281.8
P	36"	.6	.9	2.9	3.0	4.9	6.8	11.3	16.2
	12-24"	1.1	1.8	3.7	6.1	8.2	10.1	17.0	22.5
	12"	2.1	3.9	6.2	7.0	10.7	16.9	23.5	27.1
K	36"	5.5	7.3	16.5	29.4	46.7	61.2	99.2	122.5
	12-24"	13.0	16.5	33.7	62.9	81.0	111.8	152.3	190.2
	12"	21.8	32.4	53.1	60.5	108.4	137.0	162.9	176.4
Ca	36"	3.9	6.7	15.7	20.7	33.9	43.1	64.5	87.6
	12-24"	8.0	11.7	25.5	40.7	51.0	64.7	98.0	122.7
	12"	15.9	29.0	46.1	46.2	74.6	91.3	99.8	127.3
Mg	36"	1.5	2.8	8.2	11.2	15.0	17.3	25.7	37.5
	12-24"	3.6	5.6	12.1	17.8	19.7	25.3	39.7	50.1
	12"	6.7	10.2	19.9	16.8	25.7	33.7	41.4	48.0

*All figures represent an average of 2 subsamples from each of 4 replications.

TABLE 8

DRY MATTER ACCUMULATION IN THE ABOVE GROUND SOYBEAN PLANT FOR SAMPLES TAKEN AT DIFFERENT DAYS AFTER PLANTING WITHIN THREE ROW ARRANGEMENTS

Row Spacing	Days after Planting							
	42	48	56	63	73	81	96	112
	Pounds per Acre							
36"	300*	400	900	1600	2500	4000	5000	8100
12-24"	500	800	1600	2900	4100	5100	8100	10200
12"	900	1400	2600	3200	5400	7000	9400	10400

*Figures represent an average of 3 subsamples from each of 4 replications.

VITA

Paul Logan Fulks was born on October 4, 1948, in Shelbyville, Tennessee. He attended public schools of that county and graduated from the Shelbyville Central High School in 1967. In June of 1967, he entered the University of Tennessee at Knoxville where he received his Bachelor of Science degree with a major in Agriculture Education. In 1971, he began study toward the Master of Science degree with a major in Plant and Soil Science at the University of Tennessee at Knoxville. In 1973, he accepted a position as assistant manager of Valleydale Farms in Morristown, Tennessee. In 1975, he accepted a position with the Soil Conservation Service as a Soil Scientist in Chattanooga, Tennessee. He finished his degree in June of 1976.

He is married to the former Anne Johnson of Middleton, Tennessee.