A STUDY OF THE INFLUENCE OF NITROGEN, PHOSPHORUS, AND POTASSIUM CONCENTRATIONS ON GRAIN SORGHUM YIELDS

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A STUDY OF THE INFLUENCE OF NITROGEN,

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CONCENTRATIONS ON GRAIN

SORGHUM YIELDS

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CHAPTER I

INTRODUCTION

Grain sorghum yields have greatly increased in Oklahoma in recent years. These increased yields have been the result of a number of improved production practices including the use of adapted hybrids and fertilizers.

Sorghum is not a high valued cash crop, therefore, efficient fertilizer use is mandatory for profitable production. Soil tests are valuable in helping predict fertilizer needed for the most profitable production, but there are certain inherent limitations.

In many areas of the country, plant analyses are being used to supplement soil tests in assessing fertilizer requirements for some crops. However, before plant analyses can be utilized for a given crop, critical levels of the nutrients must be established. Sampling procedures must also be standardized. Procedures and nutrient levels have not been experimentally established for grain sorghum.

This study was initiated to determine the feasibility of using foliar analysis and tissue testing as a means of determining the availability of soil nutrients to grain sorghum, and to determine if correlations between yields and nutrient concentrations in the sap and foliar material exist.

CHAPTER II

LITERATURE REVIEW

Attempts have been made for over 150 years to determine the nutrient needs of plants by determining their composition chemically. In 1804 De Saussure (22)[1] analyzed the ash of plants and observed that the composition varied with the soil, plant part, and the age of the plant. Liebig (14) considered the percent nutrient content of plants to be constant. He concluded that it was possible to maintain soil fertility by analyzing the harvested crops and returning the nutrients removed to the soil. In field plots, Lawes and Gilbert (13) found that more phosphorus was needed than that found in the plant ash.

Hall (7) established in 1905 that the proportion of phosphoric acid and potash in the ash of a plant varied with the amount available in the soil, but that this variation was limited and was often no greater than the changes that could be induced by changes in seasonal or other environmental factors. He, therefore, concluded that plant analysis was not a practicable method of determining the ability of a soil to supply nutrients for plant growth.

Macy (16) considered the data obtained from plant analysis as showing the "sufficiency of nutrients" relative to all growth factors influencing yields. In his opinion, plant analysis could be a very useful

[1]Figures in parentheses refer to Literature Cited.

method for determining the fertilizer needs of a crop. Macy defined the "critical percentage" as the percent of a nutrient below which there is "poverty adjustment." Yields in the poverty adjustment region of a plant-fertilizer response curve were proportional to the deficiency until the minimum percentage was reached.

The question of whether or not variations in composition of the whole plant are sensitive enough to reflect responses to environmental changes was considered. Thomas (29) reported that the leaves reflected larger differences in potatoes than did the whole plant. The leaf petioles of grapes were found by Ulrich (34, 35) to reflect the status of nitrates and potassium better than the leaf blade. He found that the most recently matured petioles were the best samples from a physiological point of view and ease of sampling.

Lundergardh (15) stated that plants would indicate the availability of nutrients more precisely than would a soil test, however, variability due to environmental factors presented a problem. Ulrich (36) concluded that this sensitivity to environmental change made the plant analysis of greater value than soil analysis in determining the fertilizer requirements of crops. He considered the plant analysis as giving an intergraded value of all factors that influence its nutrient composition. Shear et al., (24) considered the leaf composition as the only valid criterion of the nutritional status of the plant. Maximum growth and yield could occur only upon the coincidence of optimum intensity and balance of nutrients, according to Shear et al. It is only through plant analysis that this balance can be determined.

In 1926, Hoffer (11) started another approach to plant analysis. This approach was to determine the concentration of nitrates and potassium in the conductive tissue of living plants. The tests show the presence or absence of these nutrients in the soluble or unassimilated form and indicate the status of the plant at that moment. The tests are semiquantitative and show relative nutrient supplies in the soil. The tests have the advantage of being fast and easy and can be made in the field.

A test for phosphorus in live plant tissue was described by Emmert (4) in 1930 and Thornton (30) in 1932. Tissue testing procedures were improved by Thornton et al., (31), Melstead (17) and others.

Nitrogen and phosphorus content of the conducting tissue of tomatoes and lettuce were found by Emmert (5, 6) to correspond well with yields on several different soils. The effects of fertilization were readily detected. Carolus (1) found low concentrations of nutrients in several vegetable crops grown on deficient soils.

Scarseth (23) reported that the nutrients varied with the position of the plant part sampled. Phosphorus and potassium were found to decrease in the lower part of the plant before the upper part. Nitrogen decreases were evidenced in the upper portion of the plant before the lower plant parts.

Harrington (10) found that nutrient concentrations from tissue tests varied at different times of sampling. Also he found that differences were greater and appeared more quickly in the petioles of spinach than in the blade.

In corn, work has been done primarily with foliar analysis. Tyner (33) used leaf analysis to determine the nutrient balance of corn. Highly significant correlations were found between yields and the percent nitrogen, phosphorus, and potassium. The critical concentrations were tentatively set at 2.90 percent total nitrogen, 0.295 percent phosphorus, and 1.30 percent potassium for the bloom stage in corn, based on air dry samples. Tyner used the sixth leaf from the base of the plant, which more or less set the trend for future sampling.

Viets et al., (37) reported a high correlation between nitrogen content and yield. However, the critical levels could not be determined by sampling the growers' fields. They did not consider it possible to predict yields because of the many unknown and uncontrolled factors.

Hanway (8, 9) found that nitrogen, phosphorus, and potassium supplied by the soil were related to the leaf area of corn, and that grain yields were proportional to the weight of the corn leaves. Though not measured, Hanway thought leaf area and leaf weight should be highly correlated. The greatest difference in percent nitrogen, phosphorus, and potassium were found to be in the leaves and sheaths of the corn plant. Maximum differences occurred during silking. Hanway used total nitrogen to get a better measure of nitrogen status. Below 3.0 percent total nitrogen, very little soluble nitrate was found in the leaves. The absence of soluble nitrate would indicate low nitrogen, but would give no indication as to how low. Either water soluble or total phosphorus and potassium were found to be satisfactory indications of sufficiency or deficiency.

Hanway defined the critical level as the concentration above which no further yield increases were obtained. The optimum level is the most profitable level. Environmental conditions affect these levels. Hanway set the critical levels for corn at 3.2 percent for nitrogen, 0.34 percent for phosphorus, and 1.7 percent for potassium. He set the optimum levels at 2.9 to 3.1 percent for nitrogen, 0.31 to 0.29 percent for phosphorus, and 1.5 percent for potassium.

Dumenil (3) found that different combinations of nitrogen and phosphorus can produce the same yields. The nitrogen-phosphorus balance appeared to become more critical as yields approached a maximum value. Only at the maximum yield were the levels of nitrogen and phosphorus constant.

Grain sorghum production has increased rather dramatically in recent years. Yields have increased due to the use of hybrids, increased irrigation, increased fertilization, and other improved production practices. The higher yield has increased interest in more accurately defining the nutritional needs of the sorghum crop. Only limited studies have been reported on diagnosing fertilizer requirements of sorghum by plant analyses.

The first approach reported was a study of the effect of fertility treatments on grain quality. Nelson (18) reported that nitrogen fertilizer treatments increased grain protein on irrigated grain sorghum. Tucker et al., (32) reported that the nitrogen content of grain was increased by fertilizing dryland sorghum with nitrogen. Smith (26), however, found no significant change in the nitrogen content of Redlan grain due to nitrogen fertilizer applications, but potassium did decrease the grain nitrogen. He also found a significant difference between fertilizer treatments on the nitrogen content of Sumac 1712 sorghum forage.

Using Hegari sorghum, Samuels and Capō (21) found the nitrogen and phosphorus content of the plant were changed by fertilizer applications. They analyzed the entire above ground portion of the plant at flowering. Nitrogen applications increased the nitrogen concentration of sorghum.

Phosphorus applications increased phosphorus, but depressed the nitrogen concentrations.

Netherton (20), using Kafir 44-14 grain sorghum, found no significant differences between fertilizer treatments on the nitrogen content of the leaves. The leaves were collected at three stages of growth; when the plants were 14 inches tall, 24 inches tall, and when the sorghum was in boot stage. He did find differences in nitrogen content of the grain, and phosphorus content of the leaves at the 14 inch and boot stages due to the fertilizer treatments.

CHAPTER III

MATERIALS AND METHODS

OK 612 grain sorghum was planted in a randomized complete block design on a Taloka silt loam (28) near Muskogee, Oklahoma, in 1965 and 1966. The soil test data are given in Table XVII, appendix. The plots were 60 feet long and six rows wide with a 40 inch row spacing. The experiment was replicated four times. Only three replications were sampled and harvested in 1966 due to chinch bug damage to the fourth replication. The planting dates were June 4, 1965, and June 10, 1966.

Fertilizer applications were made at planting as a band, two inches to the side and two inches below the sorghum seed. The fertilizer rates ranged from 0 to 120 pounds of nitrogen, 0 to 90 pounds of phosphate (P_2O_5) and 0 to 80 pounds of potash (K_2O) per acre in various combinations as shown in Table I. The sources of nitrogen, phosphate, and potash were ammonium nitrate (33.5-0-0), triple superphosphate (0-46-0), and murate of potash (0-0-60), respectively.

Leaf and sap samples were collected at three stages of growth; preboot stage, anthesis, and milk stage. In 1965, the sample were collected on August 10, August 21, and September 10, and on July 27, August 10, and August 31 in 1966. The youngest fully mature leaf, or the leaf just below the flag leaf was collected from the second and fifth rows of each plot. To compare the effect of sample position on the nutrient concentrations, the fourth and the seventh leaf from the top

TABLE I

COMBINATIONS OF NITROGEN, PHOSPHATE (P_2O_5), AND POTASH (K_2O) FERTILIZERS APPLIED TO OK 612 GRAIN SORGHUM, MUSKOGEE, OKLAHOMA, 1965-1966

Treatment Number	N	P_2O_5	K_2O
	Pounds per Acre		
1	0	60	40
2	40	60	40
3	80	60	40
4	120	60	40
5	80	0	40
6	80	30	40
7	80	90	40
8	80	60	0
9	80	60	80
10	0	0	0
11	120	90	80
12	120	90	0

were also collected from four treatments in 1966. These samples were taken only at one stage of growth, during anthesis (August 10, 1966). Four to six hours after collecting, the leaves for foliar analysis were oven dried at 90 degrees centigrade. The leaves used for tissue testing were separated into the blade and midrib. The midribs were pressed in a Carver laboratory hydraulic press with a pressure of 4000 pounds per square inch to extract the sap. This sap was frozen in the field with dry ice, then stored in a freezer for analyses.

The dried leaves for foliar analysis were ground in a Wiley mill to pass through a 20 mesh sieve and analyzed for nitrate nitrogen, total nitrogen, total phosphorus, and total potassium. The nitrate nitrogen was determined by the phenoldisulfonic acid procedure as described by Johnson and Ulrich (12). Total nitrogen was determined by a modified micro-Kjeldhal procedure. Plant material was wet ashed with 3:1 nitric acid-perchloric acid mixture for phosphorus and potassium determinations. Phosphorus was determined by the procedure described by Shelton and Harper (25). Potassium was determined on the Beckman DU spectrophotometer with flame attachment.

The sap for tissue testing was analyzed for nitrate nitrogen, phosphorus, and potassium. The procedure as described by Nelson et al., (19) was used to determine the nitrate nitrogen. Phosphorus was determined by the procedure described by Dickman and Bray (2). The Beckman DU spectrophotometer with flame attachment was used to determine potassium.

Grain yields were determined from the third and fourth plot rows. The plants from twenty-five feet of each row were headed and thrashed with an Almaco nursery plot thrasher.

The coefficient of variance, correlation coefficients, and analysis of variance were made on all data. Where warranted, LSD values were calculated using procedures suggested by Steele and Torrie (27).

CHAPTER IV

RESULTS AND DISCUSSION

Rainfall at Muskogee was below normal in 1965 and 1966. The low rainfall was reflected in grain yields, foliar analysis, and tissue testing data. A summary by months for precipitation is given in Table XVIII, appendix. In 1965, all months except June received below normal precipitation. In the 1966 growing season, all months except August received below normal precipitation.

Results in 1965

Grain Yields

Grain yields in 1965 were very low, due to the limited precipitation, but treatments significantly influenced yields at the 5% confidence level*.[1] Yields varied from 850 to 1928 pounds of grain sorghum per acre. The largest yield response was obtained from phosphate applications (Figure 1b). Yields were increased from 850 pounds of grain for the 80-0-40 treatment to 1908 pounds for the 80-90-40 treatment. The 1050 pound difference was significant at the 5% level#.[2] The smaller yield increases of 470 pounds obtained from the 120 pound

[1]* indicates that the confidence level was determined by F test.

[2]# indicates that the confidence level was determined by LSD.

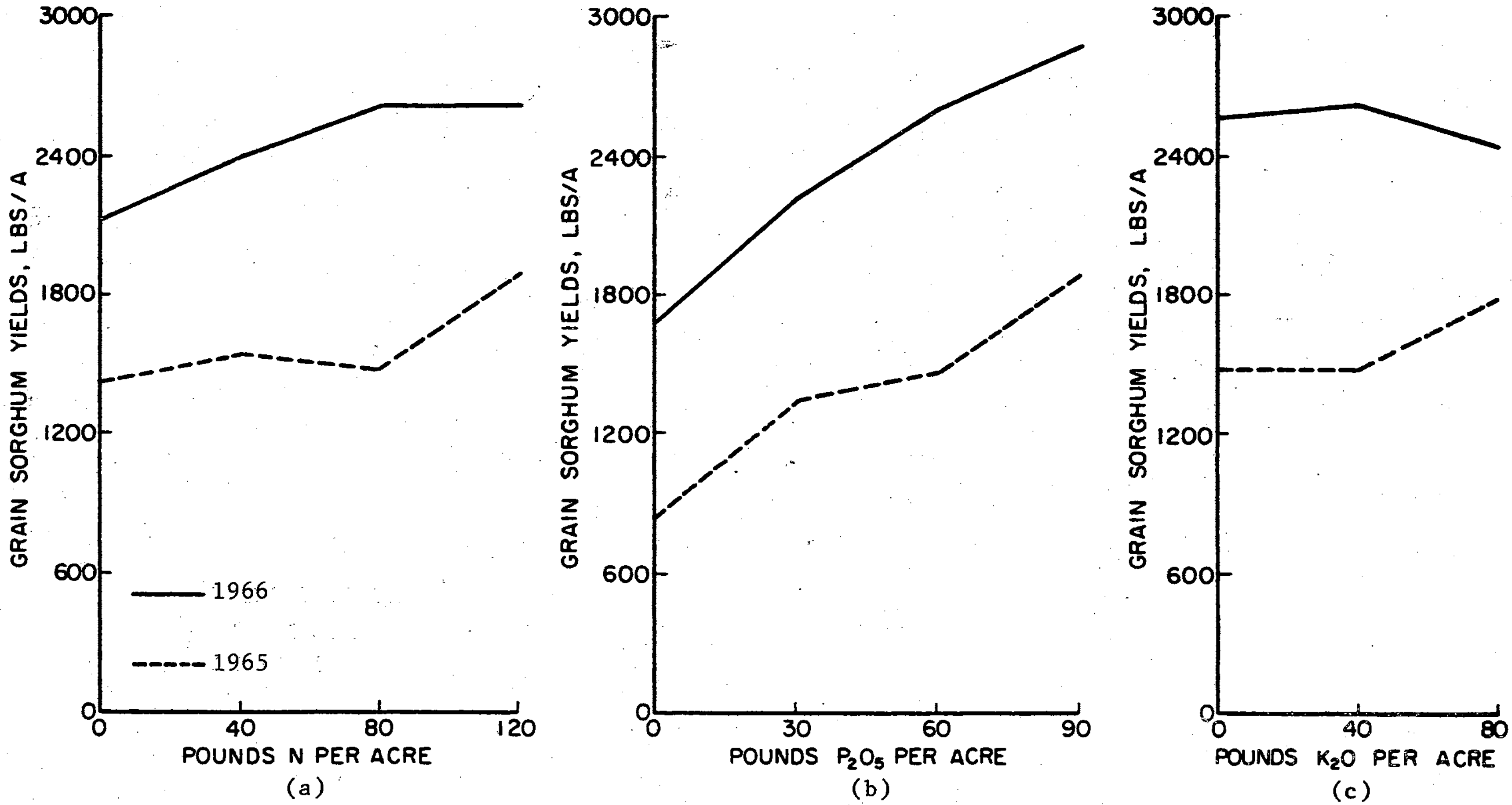

Figure 1. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on Grain Sorghum Yields in 1965 and 1966

application of nitrogen fertilizer (Figure 1a) and 300 pounds from the 80 pound potash application (Figure 1c) were significant at the 10% and 20% confidence level#, respectively. The yield data shown in Table XIX, appendix, are arranged to show responses to the varying rates of nitrogen, phosphate and potash applications.

Leaf Analysis

Nitrate nitrogen level. As indicated in Table XX, appendix, nitrate nitrogen concentrations in the leaf samples were found to be significantly different at preboot stage at the 5% level*. At anthesis and milk stages the nitrate nitrogen concentrations were significantly different at the 11% and 7% level*, respectively.

Nitrate nitrogen concentrations in leaves increased with added amounts of nitrogen fertilizer (Figure 2a) for all three leaf sample dates. The greatest concentration difference occurred at the preboot stage at which time the nitrate nitrogen concentration increased from 385 ppm for the 0-60-40 treatment to 2266 ppm for the 120-60-40 treatment. This 1880 ppm difference was significant at the 5% level#. Smaller nitrate nitrogen concentration responses were obtained at anthesis and milk stage; the responses at anthesis were significant at the 10% level# while the concentration differences at milk stage were not statistically significant at any reasonable confidence level#.

There were some interactions between nitrate nitrogen content of leaves with phosphate and potash applications. Nitrate nitrogen concentrations were significantly decreased (Figure 2b) at the 5% level# at all three stages of growth with phosphate fertilizer applications.

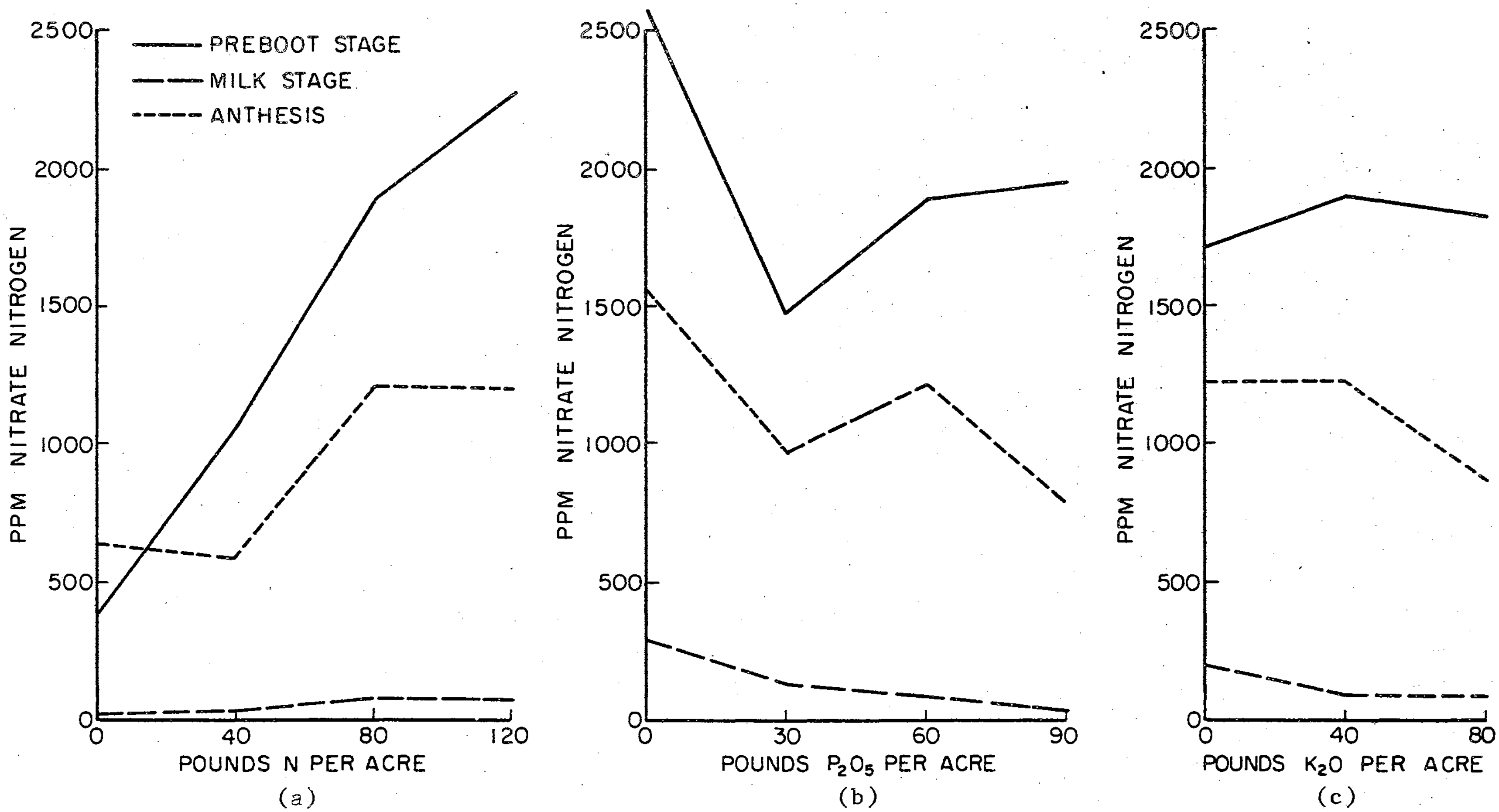

Figure 2. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrate Nitrogen Content of Grain Sorghum Leaves, 1965

Potash applications resulted in small decreases of nitrate nitrogen (Figure 2c) in leaf samples at anthesis and milk stages. These values were different at the 35% and the 20% confidence levels#, respectively. Results were inconsistent at the preboot stage for potash applications.

Nitrate nitrogen levels decreased with maturity of grain sorghum. The concentrations ranged from 2564 to 385 ppm at preboot stage, 1549 to 481 ppm at anthesis, and 280 to 18 ppm at milk stage.

Nitrogen level. Nitrogen concentrations were significantly different at the 5% level* due to fertilizer treatments at anthesis and milk stages, and at the 25% level* at preboot stage. The data are shown in Table XXI, appendix.

Nitrogen content of sorghum leaves were significantly increased at the 5% level# at all three stages of growth (Figure 3a) with increased applications of nitrogen fertilizer. The concentrations varied from 39,050 to 46,150 ppm at preboot stage, from 29,425 to 37,575 ppm at anthesis and from 24,875 to 30,525 ppm at milk stage.

Phosphate applications resulted in a significant decrease (Figure 3b), at the 5% level#, of nitrogen concentrations in sorghum leaves at anthesis. At preboot and milk stages, nitrogen concentrations were increased by phosphate applications. This increase was significant at the 20% confidence level#.

No changes of nitrogen concentrations were observed due to potash applications (Figure 3c).

Nitrogen concentrations of the sorghum leaves decreased as the season progressed. They ranged from 46,150 to 38,375 ppm at preboot stage, 37,575 to 29,425 ppm at anthesis, and 30,850 to 24,875 ppm at milk stage.

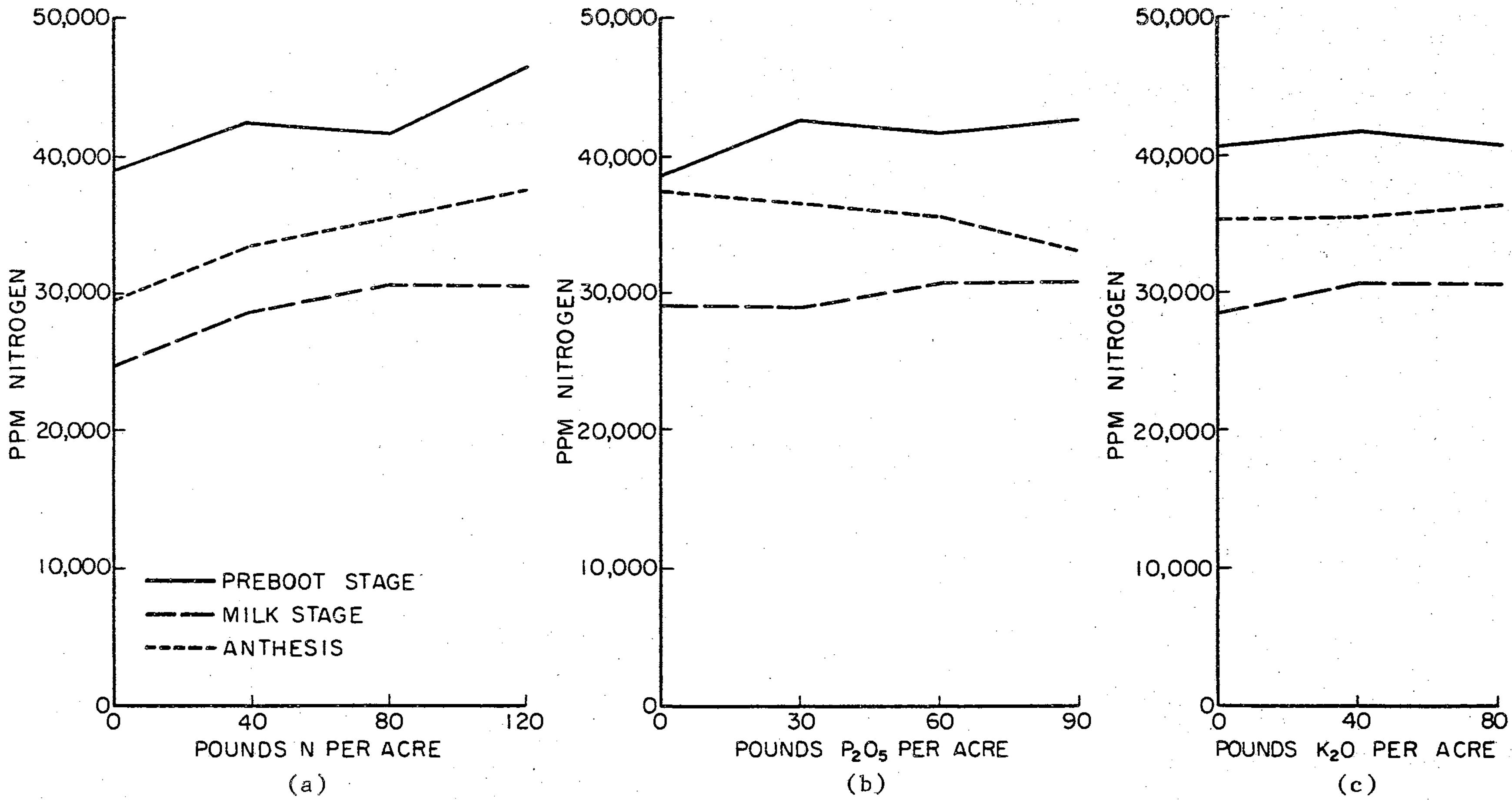

Figure 3. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrogen Content of Grain Sorghum Leaves, 1965

Phosphorus level. The phosphorus content of grain sorghum leaves were statistically different at the 5% level* due to fertilizer treatments at all three leaf sampling dates. The phosphorus concentration values are given in Table XXII, appendix.

In all three sampling dates, phosphorus concentrations were significantly increased at the 5% level# by applications of phosphate fertilizer (Figure 4b), with the greatest increase occurring at the preboot stage. The phosphorus concentrations were increased from 1875 ppm for the 80-0-40 treatment to 4025 ppm for the 80-90-40 treatment at the preboot stage. At anthesis and milk stage, highest phosphorus concentrations were found to occur with the 80-60-40 treatment. Concentrations ranged from 1850 ppm to 2500 ppm at anthesis and from 2000 ppm to 2650 ppm at milk stage.

Phosphorus was significantly increased in the sorghum leaves by nitrogen fertilizer applications (Figure 4a), at the 5% confidence level# at preboot stage, but results were inconsistent with nitrogen application rates at anthesis and milk stage.

Only at the milk stage were phosphorus concentrations statistically different due to potash applications (Figure 4c), and this difference was at the 10% confidence level#. The highest concentration at this stage occurred at the 40 pound rate of potash. Differences at preboot stage and anthesis were not significant.

Phosphorus concentrations were highest at the preboot stage and lowest at anthesis. The ranges were from 4200 to 1875 ppm at preboot stage, 2800 to 1625 ppm at anthesis, and 2775 to 2000 ppm at milk stage.

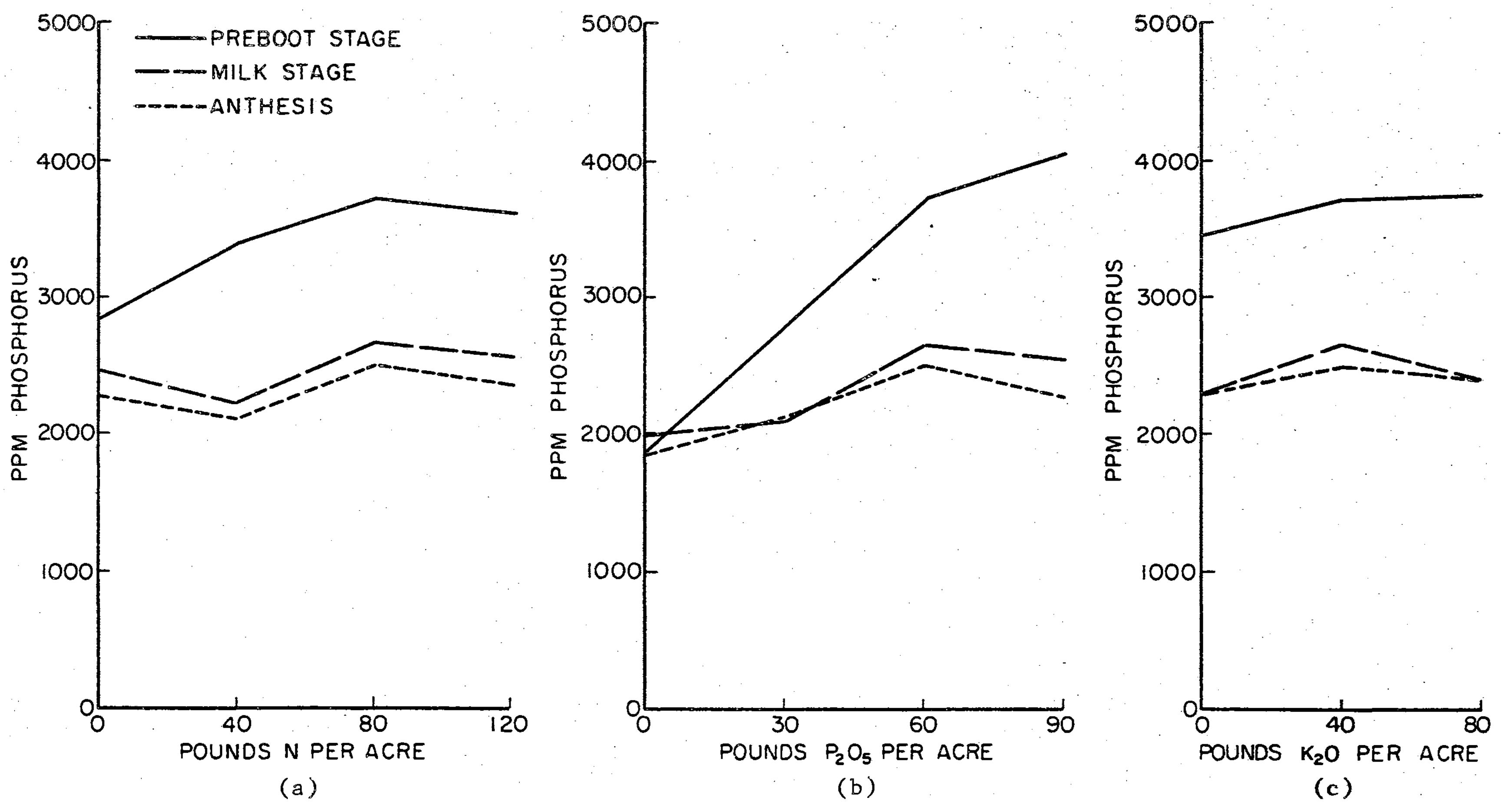

Figure 4. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Phosphorus Content of Grain Sorghum Leaves, 1965

Potassium level. Potassium concentrations were significantly different at the 5% level* on all three sampling dates. The data are presented in Table XXIII, appendix.

Concentrations of potassium in the sorghum leaves were significantly increased (Figure 5c) at the 5% level# on all sampling dates with potash applications. The potassium concentrations were increased from 9,000 ppm to 18,947 ppm at anthesis and from 9,650 ppm to 13,650 ppm at milk stage for the 80-60-0 and 80-60-80 treatments, respectively. At preboot stage the highest concentration was found to be with the 80-60-40 treatment, where concentrations increased from 10,850 to 17,550 ppm. Potassium concentrations were also higher in the 120-90-80 treatment than in the 120-90-0 treatment at all leaf sampling dates (Table XXIII, appendix).

Nitrogen fertilizer applications did not change the potassium concentrations in the sorghum leaves (Figure 5a).

At milk stage, potassium concentrations were significantly decreased at the 5% level# by phosphate applications (Figure 5b). No significant differences were obtained at preboot stage or anthesis.

Potassium concentrations decreased slightly with advanced maturity of the grain sorghum. Concentrations ranged from 17,550 to 9,950 ppm at preboot stage, 18,950 to 9,000 ppm at anthesis and 14,300 to 9,600 ppm at milk stage.

Correlation coefficients. Table II gives the correlation coefficient (r) values between the leaf analyses and grain sorghum yields over all data from this experiment in 1965, while Table III gives the correlation coefficient (r) values between leaf analyses and grain yields from selected data. By selecting data, an attempt was made to remove any

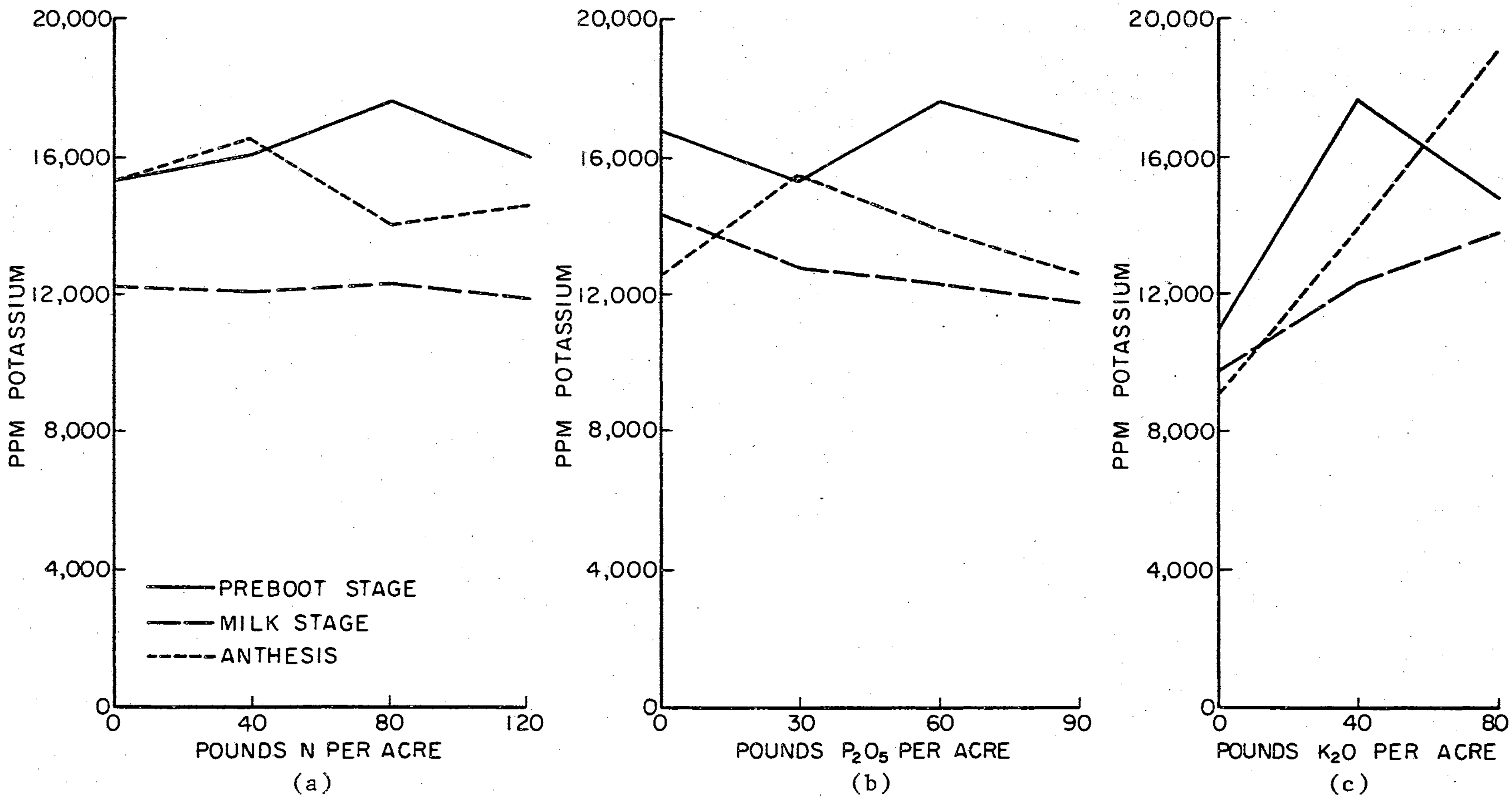

Figure 5. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Potassium Content of Grain Sorghum Leaves, 1965

TABLE II

CORRELATION COEFFICIENT (r) VALUES COMPARING LEAF ANALYSES AND YIELDS, MUSKOGEE, OKLAHOMA, 1965

Variables	Correlation Coefficients*		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Nitrogen	-.105	-.328	.171
Nitrate-Phosphorus	-.597	-.028	.311
Nitrate-Potassium	.054	-.492	-.187
Nitrate-Yield	.056	-.082	.050
Nitrogen-Phosphorus	-.067	-.178	-.500
Nitrogen-Potassium	-.274	-.223	-.210
Nitrogen-Yield	.254	-.140	-.159
Phosphorus-Potassium	.043	.321	-.114
Phosphorus-Yield	.012	.009	-.345
Potassium-Yield	.063	.020	.031

*Significant value of r at 5% confidence level = .408

TABLE III

CORRELATION COEFFICIENT (r) VALUES COMPARING LEAF ANALYSES AND YIELDS, CALCULATED FROM SELECTED DATA, MUSKOGEE, OKLAHOMA, 1965

Variables	Correlation Coefficients		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Yield*	.290	-.208	.146
Nitrogen-Yield*	.694	.673	.521
Phosphorus-Yield*	.701	.327	.625
Potassium-Yield**	.583	.200	.103

*Significant value of r at 5% confidence level = .697

**Significant value of r at 5% confidence level = .795

effect due to fertilizer interactions. The data were selected such that only data from plots receiving varied rates of nitrogen fertilizer were used to calculate nitrate-yield and nitrogen-yield correlation coefficient (r) values; data from plots receiving varied rates of phosphate fertilizer were used to calculate phosphorus-yield correlation coefficient (r) values; and data from plots receiving varied rates of potassium fertilizer were used to calculate potassium-yield correlation coefficient (r) values.

Poor correlations existed between nitrate nitrogen content of sorghum leaves and grain yields over all treatments in 1965. Nitrate nitrogen concentrations of the leaf samples and yields were both increased by nitrogen fertilizer applications. Yields were inconsistent with nitrate nitrogen concentrations in treatments in which nitrogen applications were held constant and phosphate and potash applications were varied. Correlation coefficient (r) values between nitrate nitrogen and yield were .056 at preboot stage, -.082 at anthesis, and .050 at milk stage. An inverse correlation, at the 5% confidence level, was found between nitrate nitrogen and phosphorus at preboot stage and between nitrate nitrogen and potassium at anthesis. The correlation coefficient (r) values calculated from data in which only nitrogen applications were varied, were .290 at preboot stage, -.208 at anthesis, and .146 at milk stage.

Nitrogen concentrations of the leaf samples and yields were both increased by nitrogen applications. Yields were inconsistent with nitrogen concentrations in treatments in which the nitrogen fertilizer applications were held constant, and phosphate and potash applications were varied, indicating an interaction with phosphorus and potassium.

Correlation coefficient (r) values between nitrogen concentrations and yields were .254, -.140, and -.159 for preboot, anthesis, and milk stages, respectively. An inverse correlation was found between nitrogen and phosphorus concentrations in leaf material by the correlation coefficient at the 5% confidence level. The correlation coefficient (r) values between nitrogen and yields, calculated from the data in which only the nitrogen fertilizer applications were varied, were .694 at preboot stage, .673 at anthesis, and .521 at milk stage.

Phosphorus concentrations of the leaf samples and yields were both increased by increased phosphorus fertilizer applications. Yields were inconsistent with phosphorus concentrations in treatments in which phosphate applications were held constant, and nitrogen and potash applications were varied. Correlation coefficient (r) values between phosphorus concentrations and yields were .012 at preboot stage, .009 at anthesis, and -.345 at milk stage. The correlation coefficient (r) values between phosphorus concentrations and grain yields calculated from the data in which only the phosphorus applications were varied were .701 at preboot stage, .327 at anthesis, and .625 at milk stage. The .701 value was significant at the 5% confidence level.

Potassium concentrations of the leaf samples and yields were both increased by increased potash applications. Yields were inconsistent with potassium concentrations in treatments in which potash applications were held constant, and nitrogen and phosphate applications were varied. Correlation coefficient (r) values between potassium concentrations and yields were .063 at preboot stage, .020 at anthesis, and .031 at milk stage. The correlation coefficient (r) values between potassium concentrations and grain yields calculated from data in which only the potash applications were varied were .583 at preboot stage, .200 at anthesis, and .103 at milk stage.

Sap Analysis

Nitrate nitrogen level. Nitrate nitrogen data for tissue testing in 1965 are presented in Table XXIV, appendix. The nitrate nitrogen data for sap at preboot stage and anthesis are presented; the analysis for the sap at milk stage was not recorded because the nitrate concentrations were so low that chlorophyll interfered with the colorimetric reading.

Differences in nitrate nitrogen content of the plant sap due to fertilizer treatments were significant at the 20% and 24% confidence level*, at preboot stage, and anthesis, respectively.

The 85 ppm difference in nitrate nitrogen at anthesis between the 0-60-40 and 120-60-40 treatments was significant at the 20% level#. However, the nitrate nitrogen concentrations were not consistent with the increasing trend for the 40 and 80 pound rates of nitrogen fertilizer (Figure 6a). There were no statistical differences in nitrate nitrogen due to nitrogen fertilizer applications at the preboot stage.

Nitrate nitrogen concentrations in the sap were inconsistent with the varying rates of phosphate (Figure 6b) and potash (Figure 6c) fertilizer applications.

The nitrate nitrogen content of grain sorghum sap was lower at preboot stage than at anthesis, which was contrary to expected values. Concentration values ranged from 252 to 119 ppm at preboot stage and 575 to 410 ppm at anthesis.

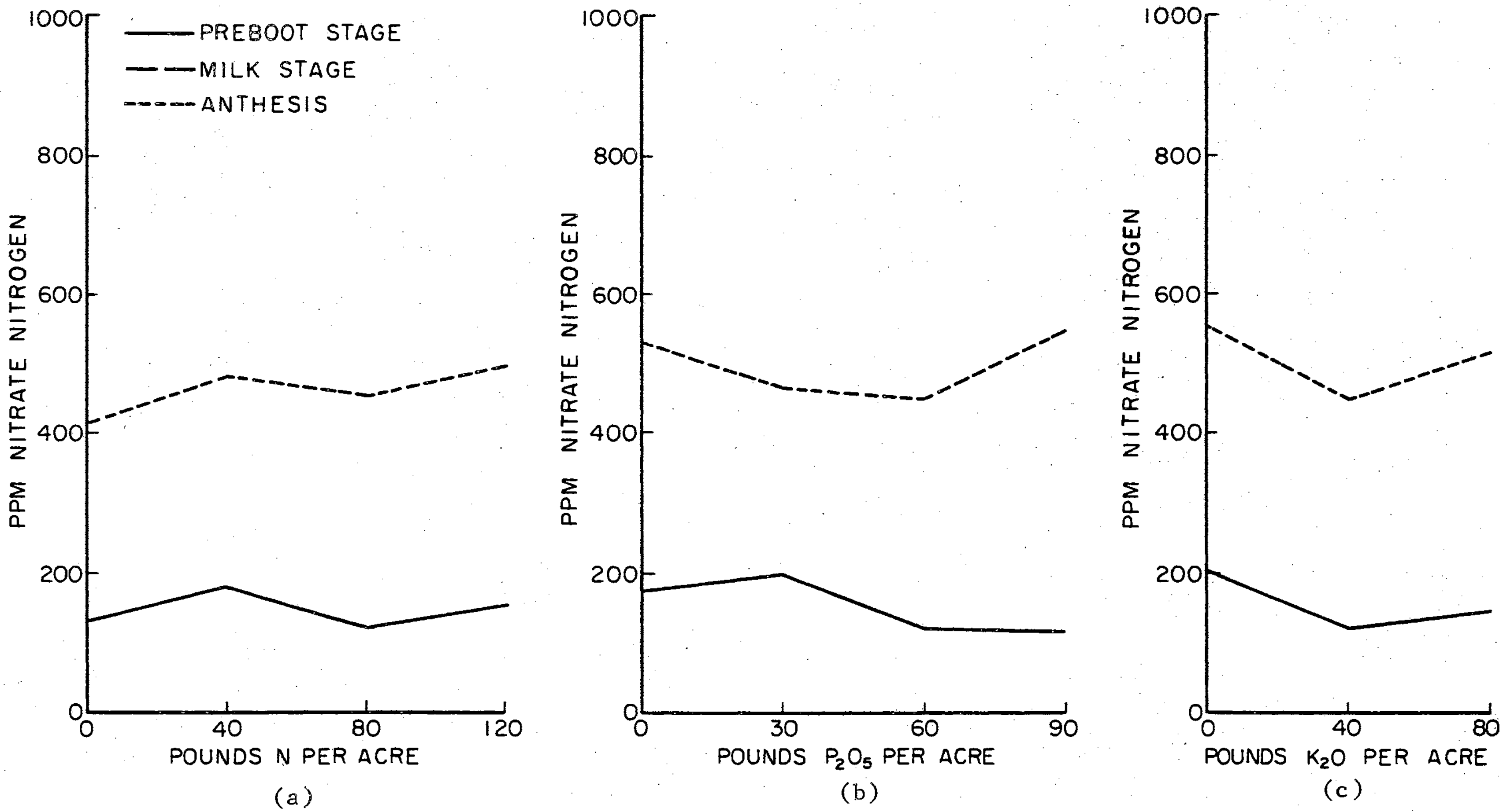

Figure 6. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrate Nitrogen Content of Grain Sorghum Sap, 1965

<u>Phosphorus level</u>. In Table XXV, appendix, differences in phosphorus concentrations of sorghum sap are shown to be significant at the 5% level* at preboot stage and anthesis and at the 12% confidence level* at milk stage.

Phosphorus concentrations in the plant sap increased significantly at the 5% level# with increased rates of phosphate fertilizer (Figure 7b). The differences ranged from 112 ppm to 327 ppm at preboot stage, 204 ppm to 307 ppm at anthesis, and 626 ppm to 844 ppm at milk stage for the 80-0-40 and 80-90-40 treatments, respectively.

Phosphorus concentrations of the sap were not statistically different due to nitrogen fertilizer applications (Figure 7a) in this experiment.

Phosphorus concentrations were decreased by applications of potash fertilizer (Figure 7c). At preboot stage and anthesis a 40 pound application of potash resulted in a significant decrease of phosphorus in the sorghum sap. The decrease was significant at the 10% level# at preboot stage and the 5% level# at anthesis. Additional potash applications resulted in an increase of phosphorus in the sap. The decrease of phosphorus at milk stage was not statistically significant.

<u>Potassium level</u>. The potassium concentrations of grain sorghum sap in 1965 are shown in Table XXVI, appendix. Differences in potassium concentrations of sap were significant at the 5% level* at preboot stage and anthesis, and at the 29% level* at milk stage.

Potash applications increased the potassium concentrations of sorghum sap at all three stages of growth (Figure 8c), significant at the 5% level#. The concentrations ranged from 3094 to 4500 ppm at preboot stage, 1156 to 3219 ppm at anthesis, and 3188 to 4250 ppm at milk

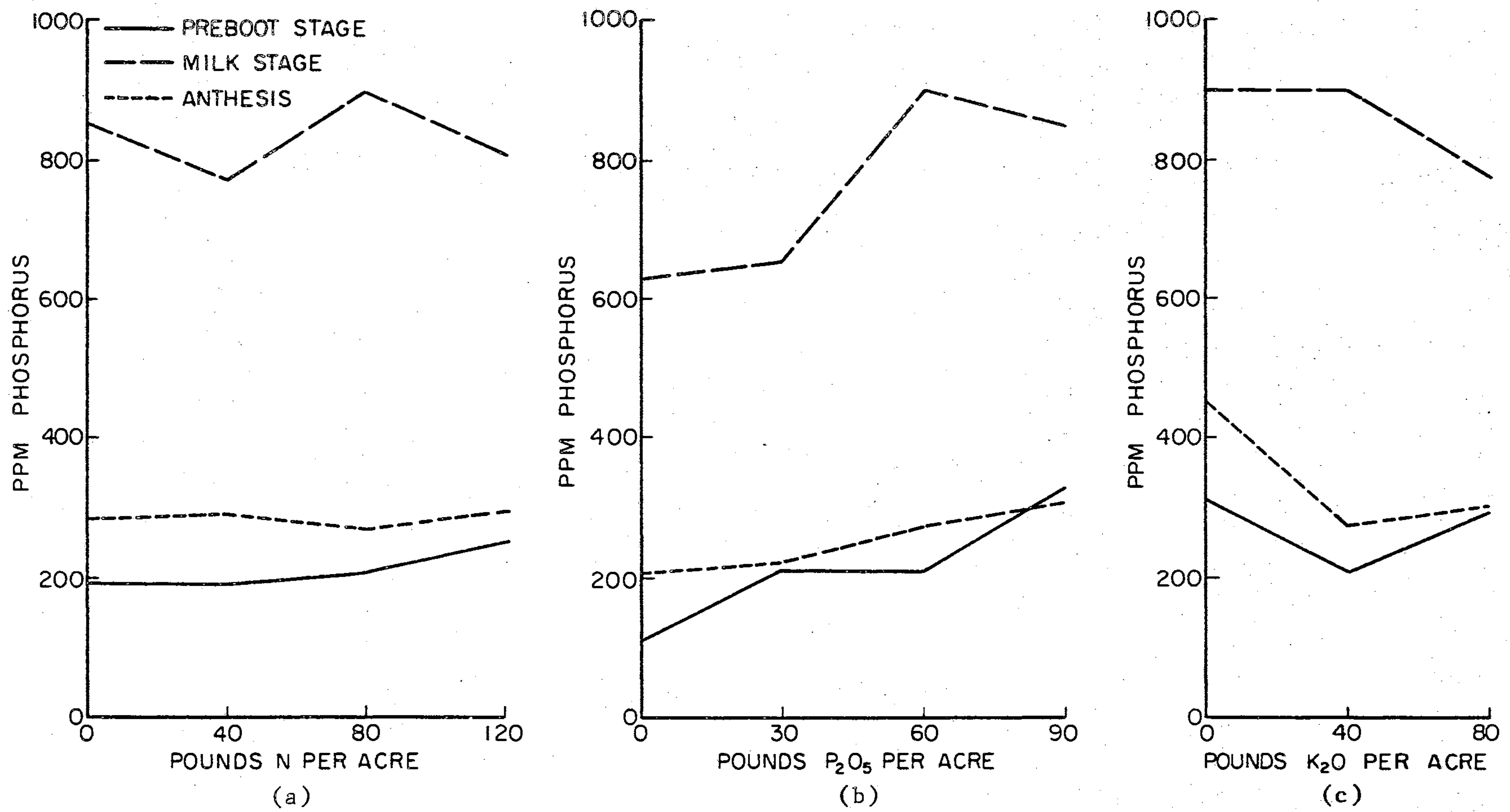

Figure 7. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Phosphorus Content of Grain Sorghum Sap, 1965

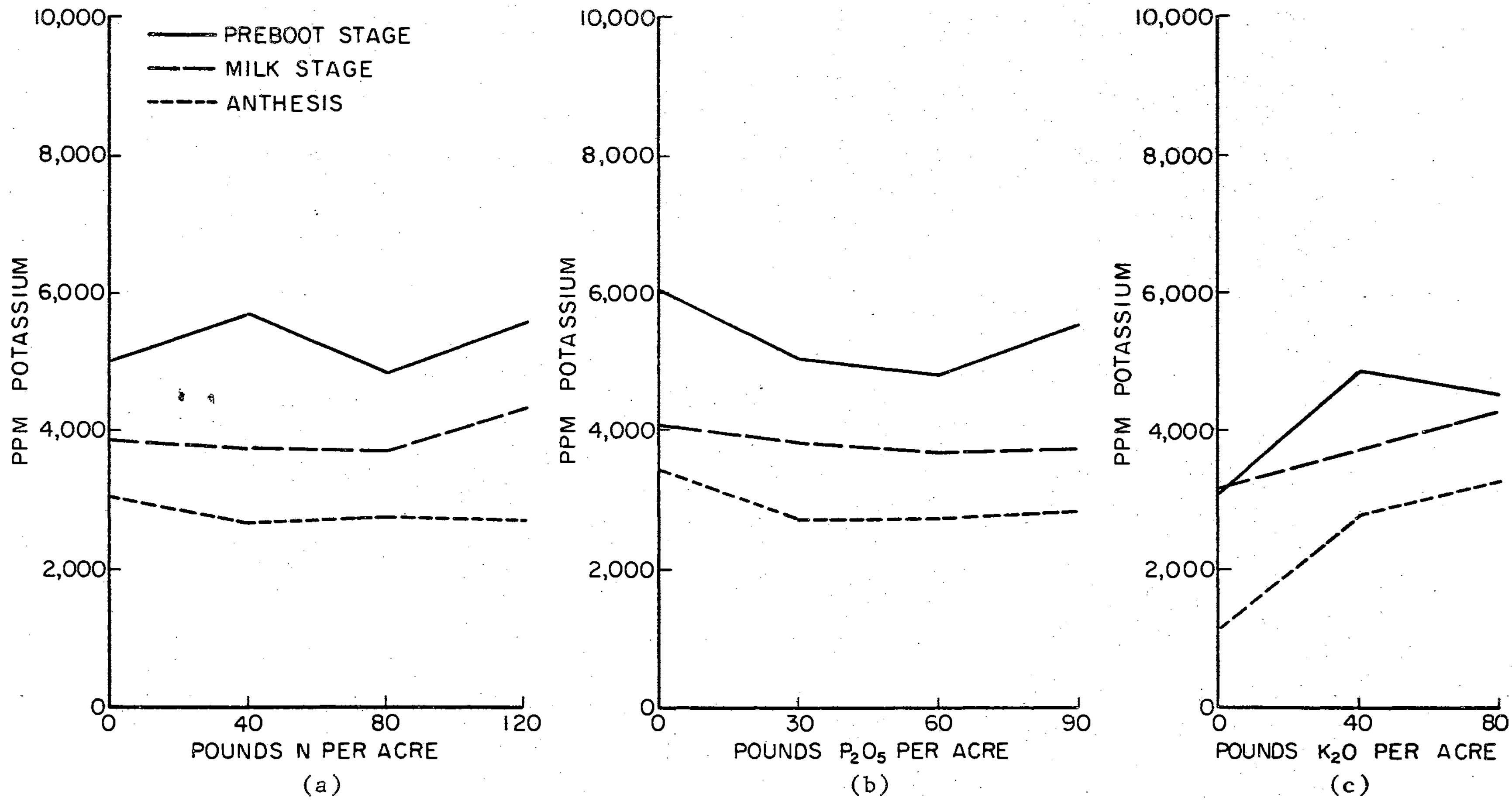

Figure 8. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Potassium Content of Grain Sorghum Sap, 1965

stage for the 80-60-0 and 80-60-80 treatments, respectively.

Nitrogen (Figure 8a) and phosphate (Figure 8b) applications had no evident effect on potassium concentrations of the sorghum sap.

Concentrations of potassium in the sap were the highest at preboot stage and decreased to a low at anthesis. The concentrations ranged from 6063 to 3094 ppm at preboot stage, 3500 to 1156 ppm at anthesis, and 4344 to 2931 ppm at milk stage.

Correlation coefficient. The correlation coefficient (r) values between sap analyses and yields for all treatments are shown in Table IV and correlation coefficient (r) values calculated from selected data are shown in Table V.

No significant correlations were found between nitrate nitrogen content of sorghum sap and yield. Correlation coefficient (r) values were .196 at preboot stage and .088 at anthesis. The correlation coefficient (r) values between nitrate nitrogen and yield calculated from data in which only nitrogen fertilizer applications were varied were -.119 at preboot stage and -.590 at anthesis.

Phosphorus concentrations of the sap samples and yields were both increased by phosphate fertilizer applications. However, no significant correlations were found between phosphorus content of sorghum sap and grain yields. Correlation coefficient (r) values were -.132 at preboot stage, .168 at anthesis, and .210 at milk stage. A positive correlation between phosphorus and potassium concentrations in plant sap was found at the preboot stage. Correlation coefficient (r) values calculated from data in which only the phosphorus applications were varied, were .628 at preboot stage, .288 at anthesis, and .519 at milk stage.

TABLE IV

CORRELATION COEFFICIENT (r) VALUES COMPARING SAP ANALYSES WITH YIELDS, MUSKOGEE, OKLAHOMA, 1965

Variables	Correlation Coefficients*		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Phosphorus	-.163	.261	
Nitrate-Potassium	.141	.379	
Nitrate-Yield	.196	.088	
Phosphorus-Potassium	.683	-.022	-.305
Phosphorus-Yield	-.132	.168	.210
Potassium-Yield	.230	.134	.255

*Significant at 5% confidence level = .408

TABLE V

CORRELATION COEFFICIENT (r) VALUES COMPARING SAP ANALYSES WITH YIELDS, CALCULATED FROM SELECTED DATA, MUSKOGEE, OKLAHOMA, 1965

Variables	Correlation Coefficients		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Yield*	-.119	-.590	
Phosphorus-Yield*	.628	.288	.519
Potassium-Yield**	.186	.207	-.030

*Significant at 5% confidence level = .697

**Significant at 5% confidence level = .795

Potassium concentrations of the sap samples and grain yields were both increased by increased fertilizer applications, however, poor correlations were found between potassium concentrations in sorghum sap and sorghum grain yields in 1965. Correlation coefficient (r) values were .230 at preboot stage, .134 at anthesis, and .255 at milk stage. The correlation coefficient (r) values calculated from data in which only the potash fertilizer applications were varied were .186 at preboot stage, .207 at anthesis, and -.030 at milk stage.

Results in 1966

Grain Yields

Grain yields were higher in 1966 than in 1965, but were still below expected averages. They ranged from a low of 1680 pounds of grain per acre for the 80-0-40 treatment to a high of 2883 pounds for the 80-90-40 treatment. This 1200 pound difference was also the yield response to 90 pounds of phosphate fertilizer, which was significant at the 5% level#. The five hundred pound yield increase obtained from an 80 pound nitrogen fertilizer application (Figure 1a) was significant at the 10% level#. No response to potash applications was recorded (Figure 1c). Yield data are presented in Table XIX, appendix.

Leaf Analysis

Nitrate nitrogen level. Data for nitrate nitrogen concentrations in grain sorghum leaves in 1966 are presented in Table XXVII, appendix. The plant material collected at milk stage was accidently discarded before nitrate nitrogen determinations were made; therefore, only results from the first and second sampling dates are shown. Differences in nitrate nitrogen due to fertilizer applications were significant at the 30% level* at preboot stage and at the 5% confidence level* at anthesis. Nitrate nitrogen concentrations were considerably lower in 1966 than in 1965 at each sample date.

There were no apparent nitrate nitrogen concentration responses to nitrogen (Figure 9a), phosphate (Figure 9b), and potash (Figure 9c) fertilizer applications. Concentration differences of nitrate nitrogen in the leaf samples were great enough to be significant, however, there were no apparent trends with the varied rates of fertilizer applications.

Nitrate nitrogen content of the sorghum leaves were greater at preboot stage than at anthesis. They ranged from 817 to 292 ppm at preboot stage and from 295 to 93 ppm at anthesis.

Nitrogen level. In Table XXVIII, appendix, are shown the nitrogen concentrations in sorghum leaves. There were no differences in leaf nitrogen due to fertility treatments. Responses to nitrogen, phosphate, and potash fertilizer applications are shown in Figures 10a, 10b, and 10c, respectively. The range of concentrations was very narrow over all treatments. They ranged from 29,433 to 36,733 ppm over all three leaf sampling dates. The nitrogen levels were lower in 1966 than in 1965 on the first sample date. At anthesis and milk stage the values were comparable.

The nitrogen content of the leaves decreased with advanced stages of growth. They ranged from 36,733 to 31,800 ppm at preboot stage, 35,300 to 31,033 ppm at anthesis, and 34,667 to 29,433 ppm at milk stage.

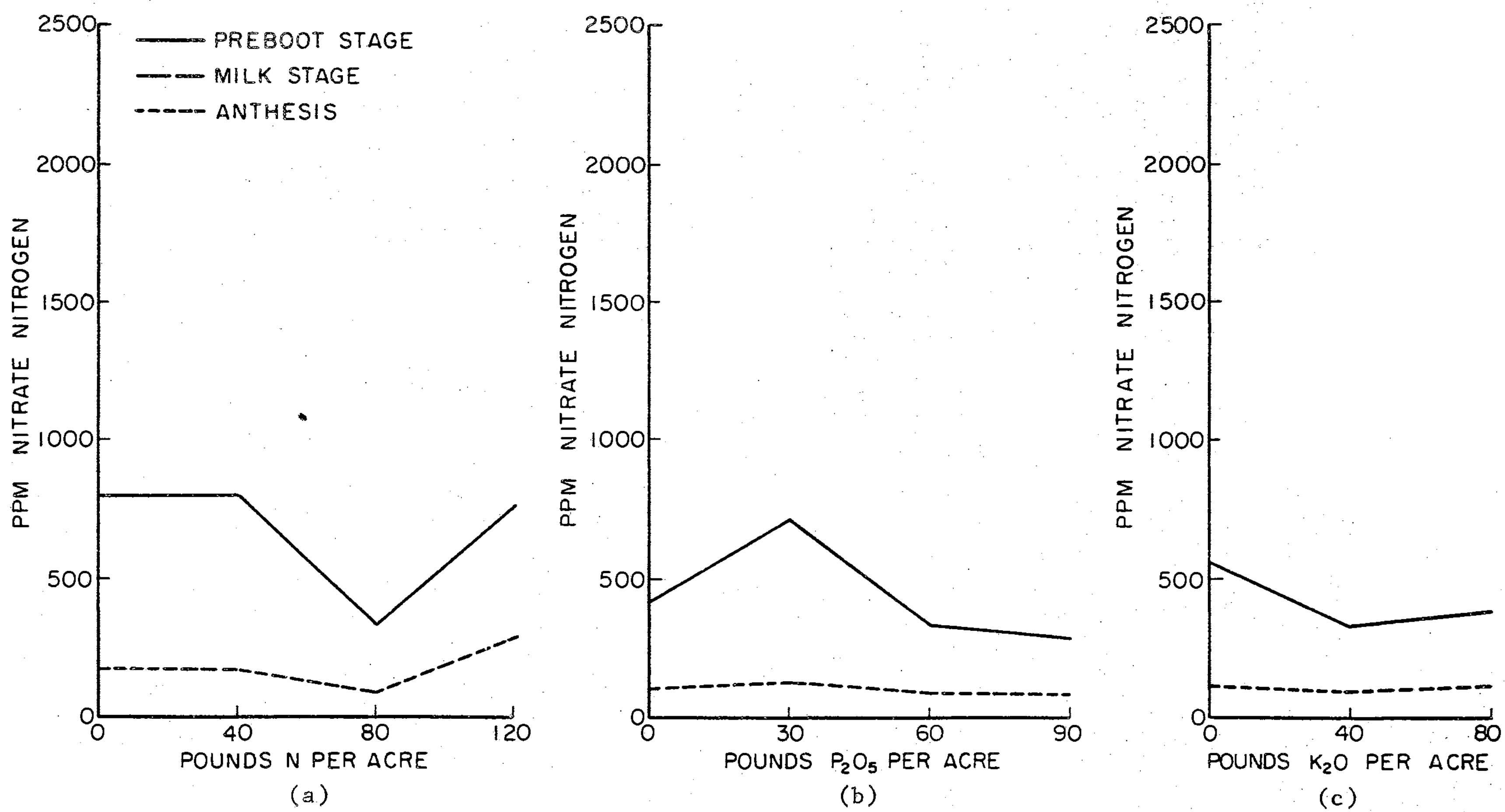

Figure 9. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrate Nitrogen Content of Grain Sorghum Leaves, 1966

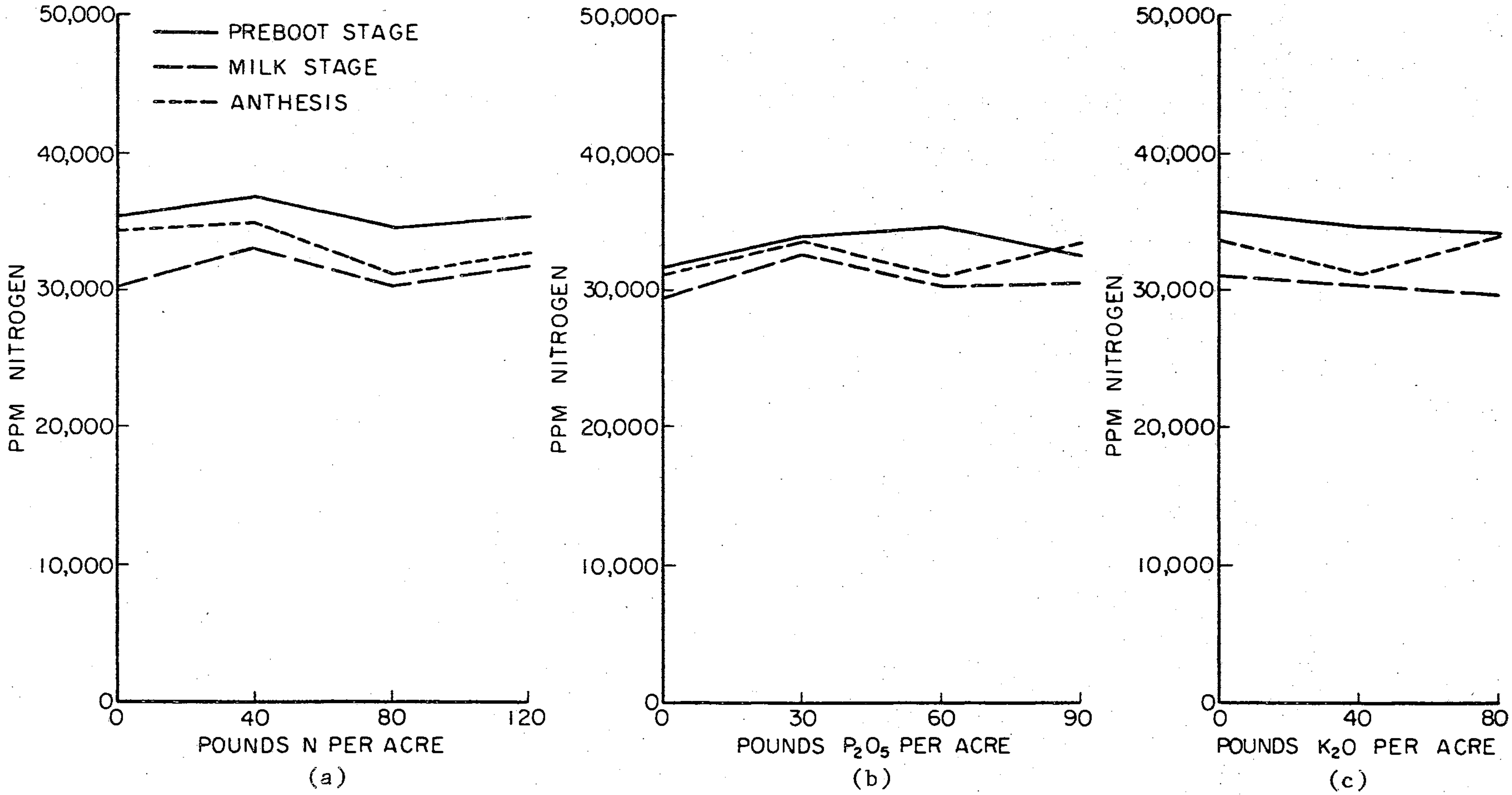

Figure 10. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrogen Content of Grain Sorghum Leaves, 1966

Phosphorus level. Phosphorus concentrations of the leaves of grain sorghum are presented in Table XXIX, appendix. Phosphorus concentrations were statistically different at preboot and milk stages, but not at anthesis. Differences were significant at the 18% confidence level* at preboot stage and 5% level* at milk stage.

Phosphorus concentration differences were large enough to be significiant by LSD, but were inconsistent with applied rates of nitrogen, phosphate and potash fertilizer applications. The responses are shown in Figures 11a, 11b, and 11c.

Phosphorus concentrations were highest at preboot stage and lowest at anthesis. They ranged from 4800 to 2600 ppm at preboot stage, 3333 to 2533 ppm at anthesis, and 3633 to 2267 ppm at milk stage.

Potassium level. Data from Table XXX, appendix, indicates that the potassium concentrations were not different due to any fertilizer treatments. Responses to fertilizer treatments are shown in Figures 12a, 12b, and 12c. Concentration values were comparable to those obtained in 1965.

Small decreases in concentrations were noted as more mature plant material was analyzed. Their concentrations ranged from 14,000 to 10,000 ppm at preboot stage, 13,067 to 10,500 ppm at anthesis, and 11,400 to 9,400 ppm at milk stage.

Correlation coefficient. In Table VI are shown the correlation coefficient (r) values for foliar analysis in 1966. In Table VII are shown the correlation coefficient (r) values calculated from data selected to minimize nutrient interactions.

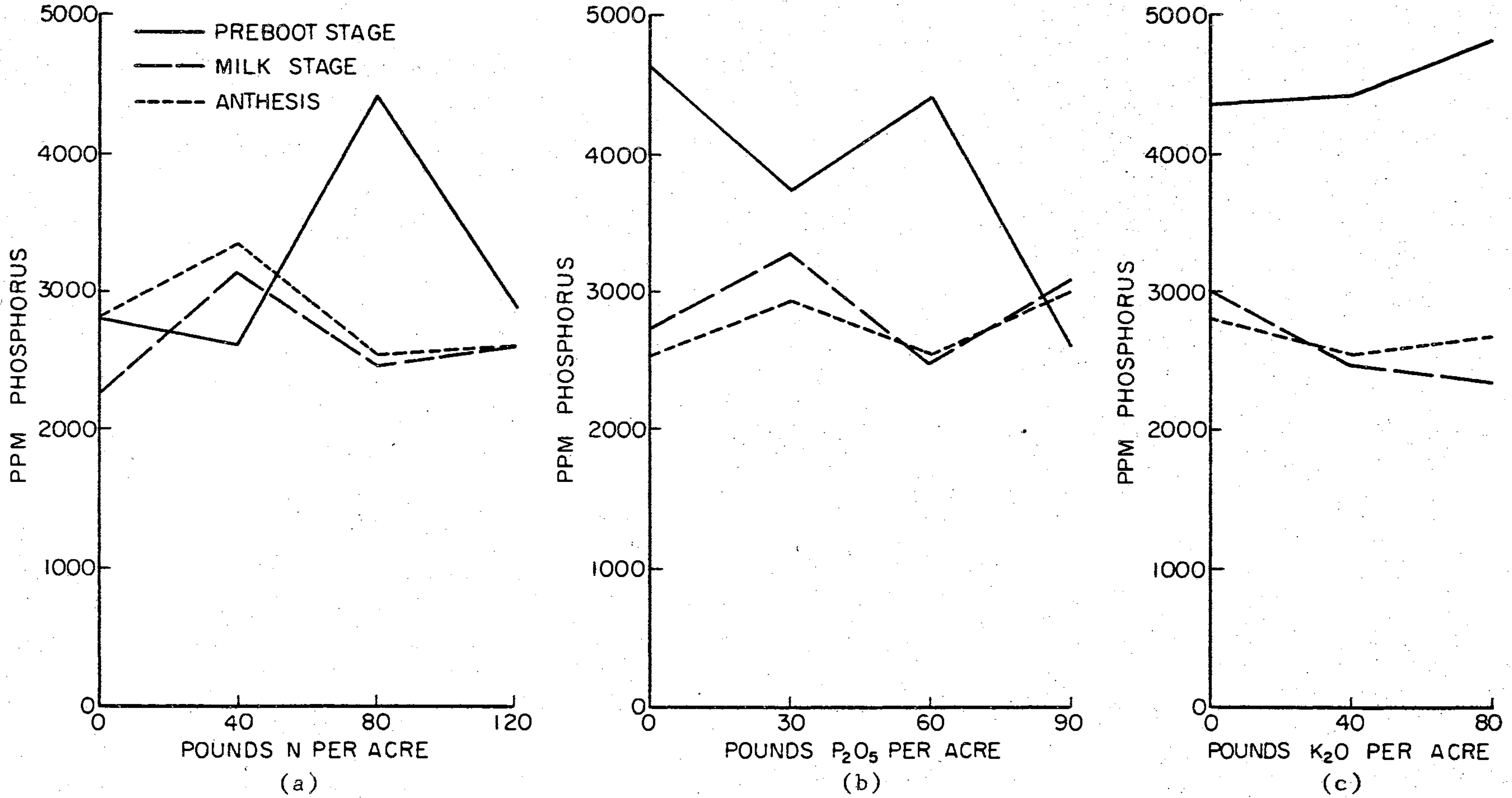

Figure 11. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Phosphorus Content of Grain Sorghum Leaves, 1966

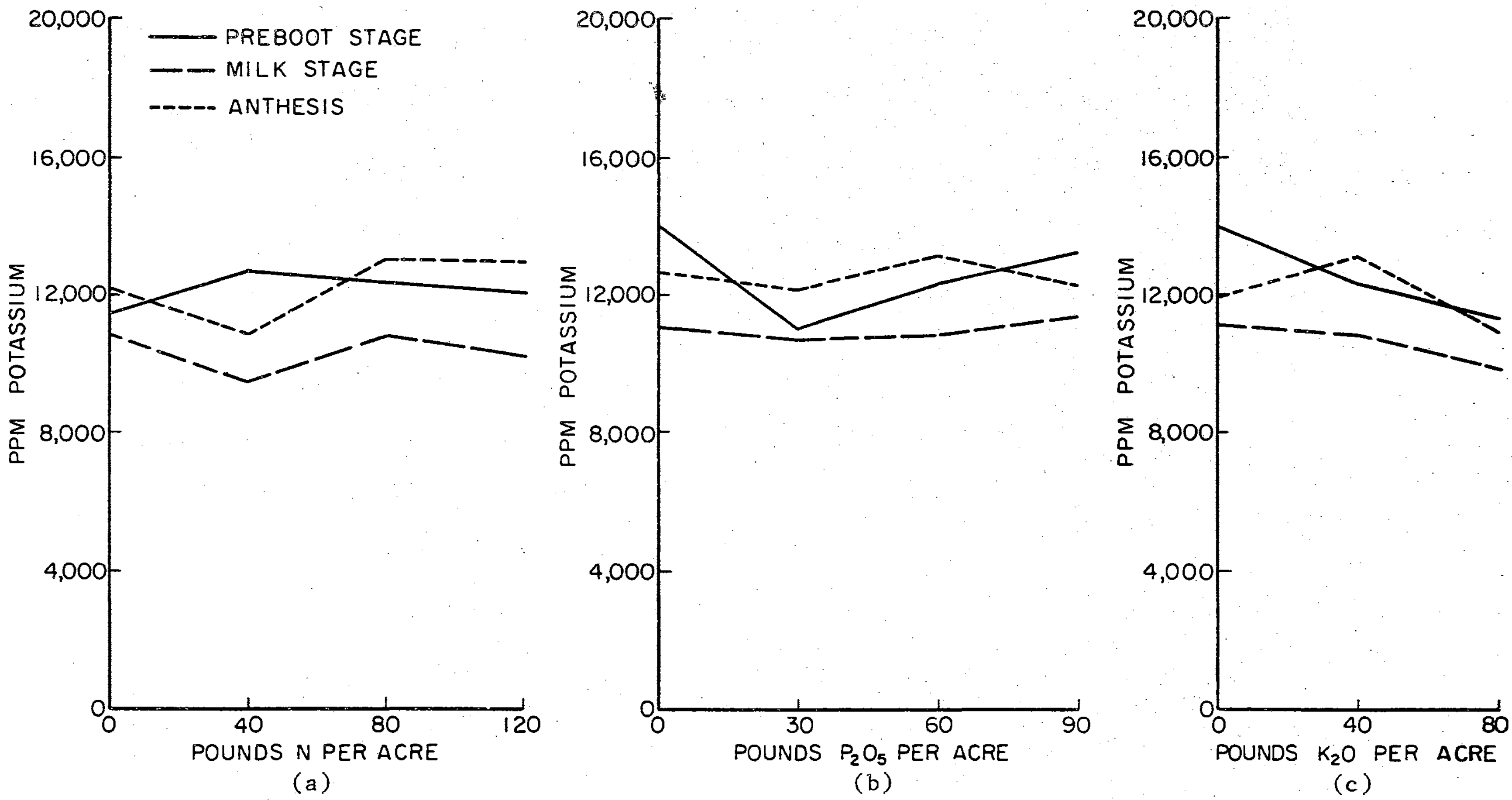

Figure 12. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Potassium Content of Grain Sorghum Leaves, 1966

TABLE VI

CORRELATION COEFFICIENT (r) VALUES COMPARING LEAF ANALYSES WITH YIELDS, MUSKOGEE, OKLAHOMA, 1966

Variables	Correlation Coefficients*		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Nitrogen	-.065	-.130	
Nitrate-Phosphorus	.443	.067	
Nitrate-Potassium	-.321	-.185	
Nitrate-Yield	.275	-.125	
Nitrogen-Phosphorus	.552	-.501	-.115
Nitrogen-Potassium	-.179	.073	.066
Nitrogen-Yield	-.455	-.112	-.266
Phosphorus-Potassium	.413	.283	.445
Phosphorus-Yield	.065	-.335	.051
Potassium-Yield	-.042	-.015	-.071

*Significant r at 5% confidence level = .488

TABLE VII

CORRELATION COEFFICIENT (r) VALUES COMPARING LEAF ANALYSES WITH YIELDS, CALCULATED FROM SELECTED DATA, MUSKOGEE, OKLAHOMA, 1966

Variables	Correlation Coefficients		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Yield*	-.616	.218	
Nitrogen-Yield*	.358	-.047	.390
Phosphorus-Yield*	-.371	.284	-.023
Potassium-Yield**	.539	-.190	.535

*Significant r at 5% confidence level = .795

**Significant r at 5% confidence level = .881

No significant correlations between grain yields and nitrate nitrogen concentrations were shown to exist. Correlation coefficient (r) values were .275 for preboot stage and -.125 for anthesis. Correlation coefficient (r) values between nitrate nitrogen and yields calculated from data in which only nitrogen fertilizer applications were varied were -.616 for preboot stage and .218 for anthesis.

No significant correlations were found between nitrogen content of sorghum leaves and grain yields. Correlation coefficient (r) values were -.455 at preboot stage, -.112 at anthesis and, -.266 at milk stage. A positive correlation at preboot stage and a negative correlation at anthesis between phosphorus concentrations and nitrogen concentrations were found to be significant at the 5% level. The correlation coefficient (r) values between nitrogen concentrations and yields calculated from data in which only nitrogen fertilizer rates were varied, were .358 at preboot stage, -.047 at anthesis, and .390 at milk stage.

No significant correlations were found between phosphorus concentrations of sorghum leaves and sorghum grain yields. Correlation coefficient (r) values were .065 at preboot stage, -.335 at anthesis, and .051 at milk stage. The correlation coefficient (r) values between phosphorus concentrations and yields calculated from data in which only phosphate fertilizer rates were varied, were -.371 at preboot stage, .284 at anthesis, and -.023 at milk stage.

No significant correlations were found between potassium concentrations and grain yields. Correlation coefficient (r) values were -.042 at preboot stage, -.015 at anthesis, and -.071 at milk stage. The correlation coefficient (r) values between potassium concentrations and yields calculated from data in which only potash fertilizer rates were varied, were .539 at preboot stage, -.190 at anthesis, and .535 at milk stage.

Sap Analysis

Nitrate nitrogen level. Nitrate nitrogen concentrations in sorghum sap were significantly different at the 21% confidence level* at anthesis due to fertilizer treatments. No significant differences were found at preboot or milk stages. Concentration values varied considerably from the values obtained in 1965. Data for nitrate nitrogen concentration values are shown in Table XXXI, appendix.

Nitrate nitrogen responses to nitrogen, phosphate, and potash fertilizer applications are shown in Figures 13a, 13b, and 13c. Nitrate nitrogen at anthesis was significantly higher with the 120-60-40 treatment than for the 0-60-40 treatment. This difference was significant at the 10% level#. No consistent responses were recorded for phosphate and potash fertilizer applications.

Nitrate nitrogen levels decreased with advanced stages of growth. The nitrate nitrogen in the sap ranged from 971 to 370 ppm at preboot stage, 207 to 39 ppm at anthesis, and 31 to 10 ppm at milk stage.

Phosphorus level. Phosphorus concentrations of sorghum sap were significantly different* due to fertilizer treatments at the 11% level at anthesis and 13% at milk stage, but were not significantly different at preboot stage. Concentration values in 1966 were lower than those in 1965. The phosphorus concentration data are presented in Table XXXII, appendix.

Phosphorus concentration responses to nitrogen, phosphate, and potash fertilizer applications are shown in Figures 14a, 14b, and 14c.

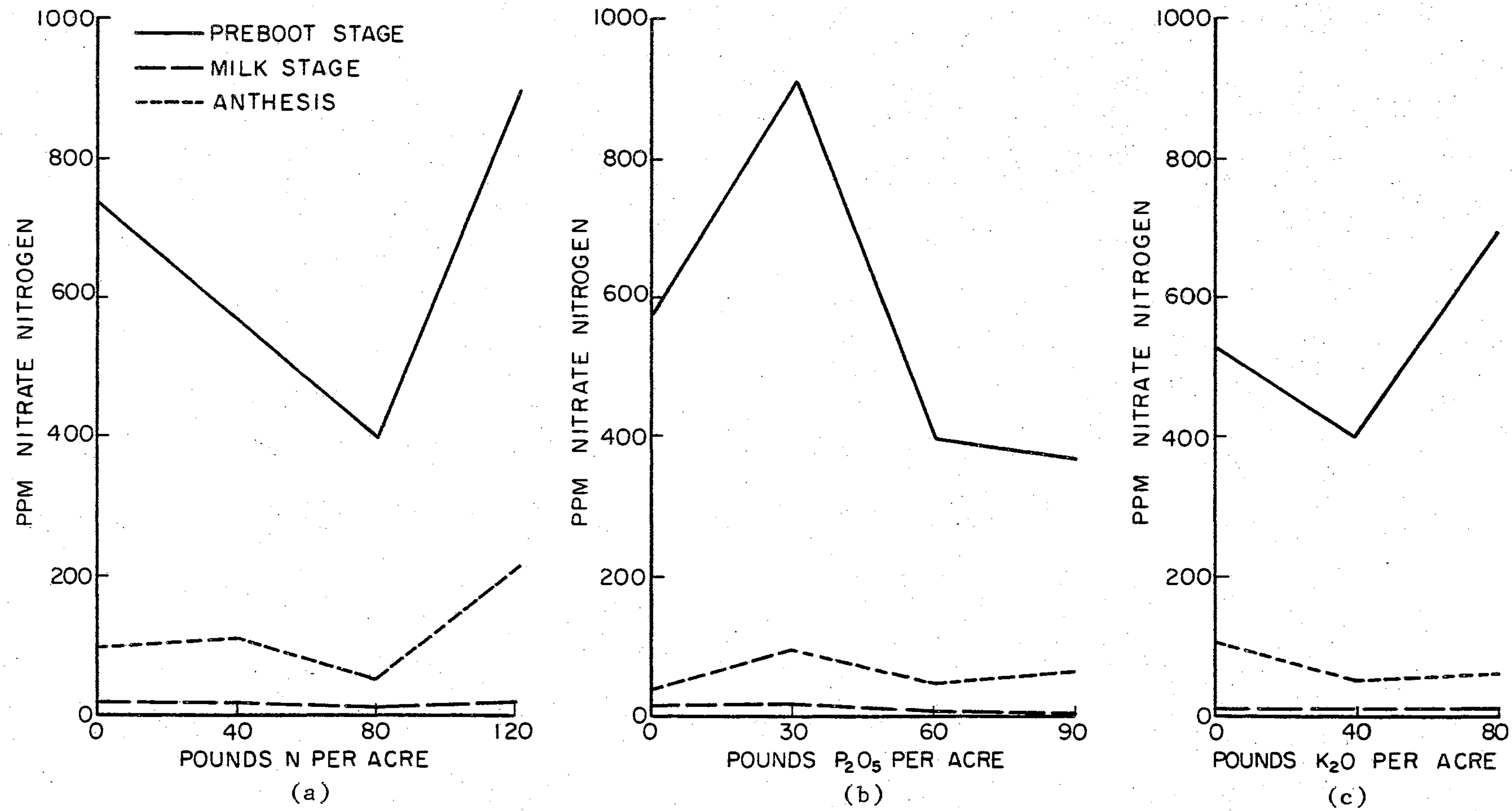

Figure 13. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Nitrate Nitrogen Content of Grain Sorghum Sap, 1966

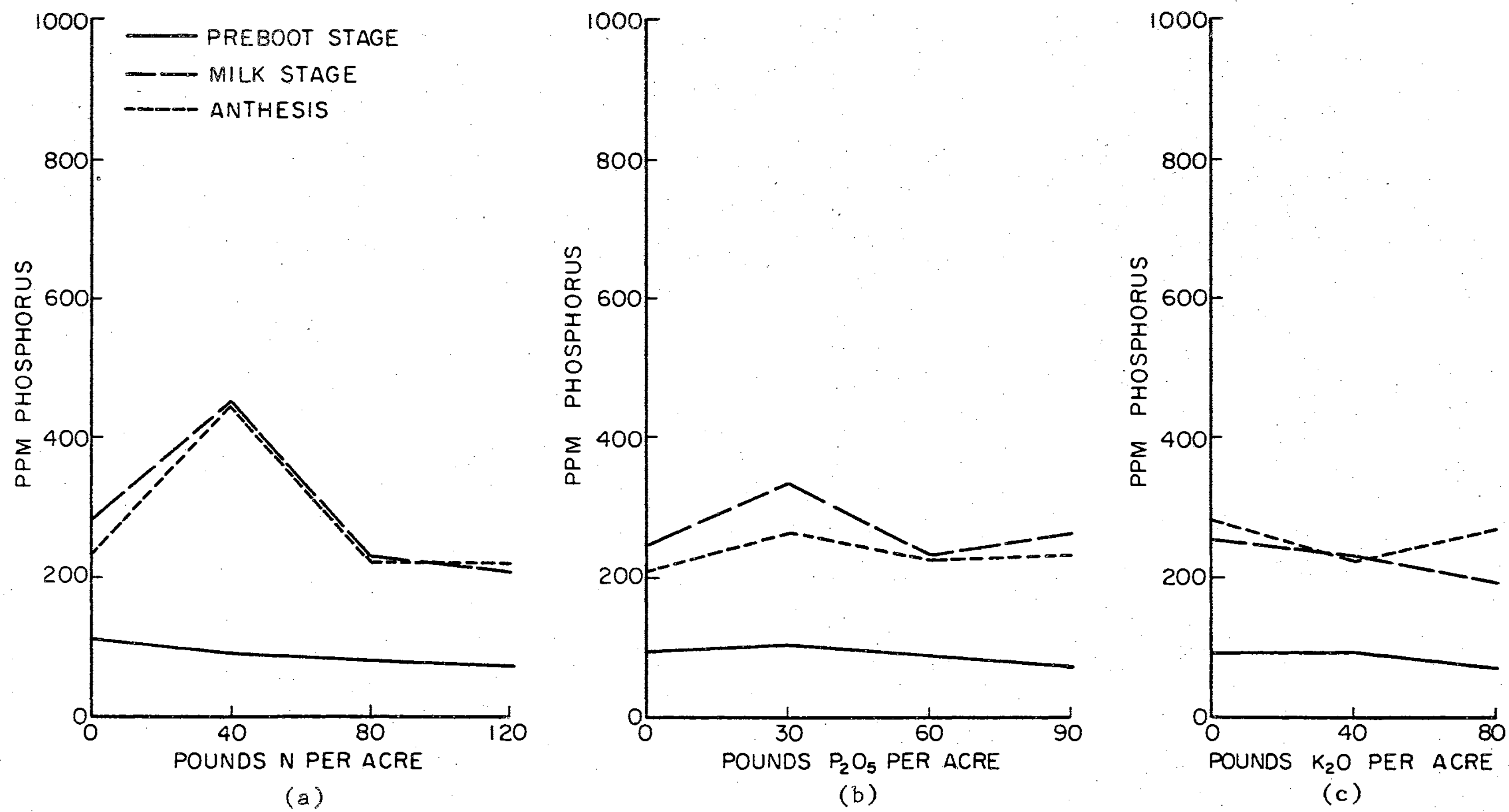

Figure 14. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Phosphorus Content of Grain Sorghum Sap, 1966

No differences due to fertilizer applications were found.

Phosphorus concentrations increased with succeeding sample dates. The concentrations ranged from 128 to 66 ppm at preboot stage, 448 to 209 ppm at anthesis, and 451 to 189 ppm at milk stage.

Potassium level. Potassium concentrations in the plant sap are shown in Table XXXIII, appendix. No significant differences between potassium concentrations due to fertilizer applications were found.

The concentrations of potassium in the sap were inconsistent with the applications of varied rates of nitrogen (Figure 15a), phosphate (Figure 15b), and potash (Figure 15c). Concentrations of potassium were lowest at preboot stage and highest at anthesis. Concentrations varied from 4000 to 2200 ppm at preboot stage, 4400 to 3333 ppm at anthesis, and 4233 to 2767 ppm at milk stage.

Correlation coefficient. The correlation coefficient (r) values for tissue testing in 1966 are shown in Table VIII. In Table IX are shown the correlation coefficient (r) values calculated from data selected to minimize interactions between nutrients.

No significant correlations between grain yields and nitrate nitrogen concentrations in sorghum sap were found. Correlation coefficient (r) values were .099 at preboot stage, -.008 at anthesis, and -.185 at milk stage. A positive correlation between nitrate nitrogen and potassium concentrations in sorghum sap at anthesis was shown to exist. Correlation coefficient (r) values between nitrate nitrogen and yields, calculated from data in which only nitrogen fertilizer applications were varied, were -.393 at preboot stage, .071 at anthesis, and .346 at milk stage.

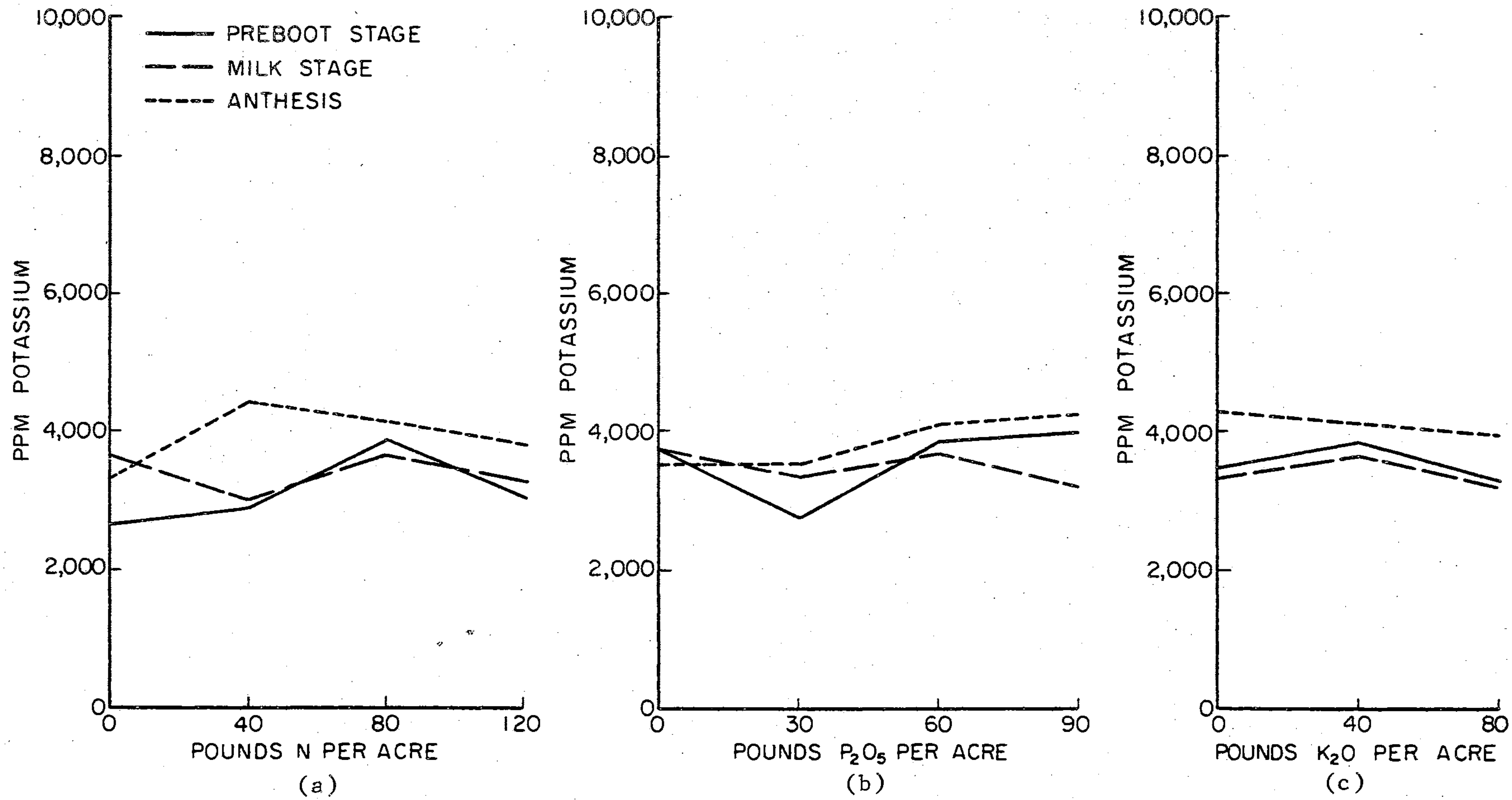

Figure 15. The Effects of Nitrogen, Phosphate and Potash Fertilizer Applications on the Potassium Content of Grain Sorghum Sap, 1966

TABLE VIII

CORRELATION COEFFICIENT (r) VALUES COMPARING SAP ANALYSES WITH YIELDS, MUSKOGEE, OKLAHOMA, 1966

Variables	Correlation Coefficients*		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Phosphorus	.331	-.090	-.440
Nitrate-Potassium	-.276	.563	.452
Nitrate-Yield	.099	-.008	-.185
Phosphorus-Potassium	.455	.183	.150
Phosphorus-Yield	-.254	-.325	-.143
Potassium-Yield	-.240	.109	.030

*Significant r at 5% confidence level = .488

TABLE IX

CORRELATION COEFFICIENT (r) VALUES COMPARING SAP ANALYSES WITH YIELDS, CALCULATED FROM SELECTED DATA, MUSKOGEE, OKLAHOMA, 1966

Variables	Correlation Coefficients		
	Preboot Stage	Anthesis	Milk Stage
Nitrate-Yield*	-.393	.071	.346
Phosphorus-Yield*	-.298	.195	-.011
Potassium-Yield**	.695	.088	-.367

*Significant r at 5% confidence level = .795

**Significant r at 5% confidence level = .881

No significant correlations were found between phosphorus concentrations in sorghum sap and yields. Correlation coefficient (r) values were -.254 at preboot stage, -.325 at anthesis, and -.143 at milk stage. Correlation coefficient (r) values between phosphorus concentrations and grain yields, calculated from data in which only phosphate fertilizer rates were varied, were -.298 at preboot stage, .195 at anthesis, and -.011 at milk stage.

No significant correlations were found between potassium concentrations in sorghum sap and yields. Correlation coefficient (r) values were -.240 at preboot stage, .109 at anthesis, and .030 at milk stage. Correlation coefficient (r) values between potassium concentrations and grain yields, calculated from data in which only potash fertilizer rates were varied, were .695 at preboot stage, .088 at anthesis, and -.367 at milk stage.

Sample Position

In an attempt to determine the effect of position of the sample on nutrient concentrations, leaves and sap samples were collected from the second, fourth, and seventh leaf from the top of the plant. Since the differences among the samples were large and consistent, no statistical analysis was necessary.

Leaf analysis. Nitrate nitrogen concentrations of sorghum leaves increased from top to bottom, nitrogen and phosphorus decreased from top to bottom, while potassium concentrations were essentially unchanged throughout the entire plant. The data for nitrate nitrogen, nitrogen, phosphorus, and potassium content of the sorghum leaves from four different treatments are given in Tables X, XI, XII, and XIII respectively.

TABLE X

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF NITRATE NITROGEN IN GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrate Nitrogen (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	93	175	210
120-60-40	245	393	455
80-90-40	93	187	210
80-60-80	105	257	350

TABLE XI

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF NITROGEN IN GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrogen (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	31,100	32,700	31,000
120-60-40	32,800	31,600	30,100
80-90-40	33,600	31,600	28,900
80-60-80	34,000	32,500	29,100

TABLE XII

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF PHOSPHORUS IN GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Phosphorus (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	2533	2400	2066
120-60-40	2600	1800	1500
80-90-40	3000	2330	2000
80-60-80	2667	2400	1933

TABLE XIII

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF POTASSIUM IN GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Potassium (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	13,067	13,466	13,200
120-60-40	12,933	12,333	14,533
80-90-40	12,200	13,400	14,366
80-60-80	10,933	12,466	11,466

<u>Sap analysis</u>. The nitrate nitrogen concentrations of the sap increased from top to bottom, while phosphorus and potassium content decreased from top to bottom. The data for nitrate nitrogen, phosphorus, and potassium content of the sap from four different treatments are presented in Tables XIV, XV, and XVI, respectively.

TABLE XIV

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF NITRATE NITROGEN IN GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrate Nitrogen (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	52	55	80
120-60-40	206	333	440
80-90-40	67	107	167
80-60-80	63	61	133

TABLE XV

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF PHOSPHORUS IN GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Phosphorus (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	254	221	117
120-60-40	222	166	76
80-90-40	230	177	73
80-60-80	264	202	142

TABLE XVI

THE EFFECT OF SAMPLE POSITION ON THE CONCENTRATION OF POTASSIUM IN GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Potassium (ppm)		
	Leaf No. 2	Leaf No. 4	Leaf No. 7
80-60-40	4233	4617	3433
120-60-40	3800	3233	2400
80-90-40	4233	4083	3083
80-60-80	3983	2600	2517

Foliar Analysis

The two years data presented on foliar analysis were somewhat contradictory. In 1965, grain sorghum yields and concentrations of nitrate nitrogen and total nitrogen in the leaf samples were increased by the applications of nitrogen fertilizer; grain yields and phosphorus concentrations by phosphate fertilizer; and grain yields and potassium by potash fertilizer. In 1966, this trend was not observed. Grain yields were increased by fertilizer applications, but nutrient concentrations in the leaf samples were not consistent with fertilizer applications. Poor correlations were found between yields and nutrient concentrations in leaf samples in 1965 and 1966. Part of this lack of correlation was attributed to interactions among nitrogen, phosphorus, and potassium within the plant. By selecting data to minimize this interaction, higher correlation coefficient (r) values were obtained, some significant at the 5% confidence level. The best correlations from these selected treatments were obtained in 1965, at preboot stage. The correlation coefficient (r) values were .290 between nitrate nitrogen and yield, .694 between nitrogen and yield, .701 between phosphorus and yield, and .583 between potassium and yield. Correlation coefficient (r) values in 1966 were lower and more variable.

This data left some question as to the use of foliar analysis in helping to make fertilizer recommendations on dryland grain sorghum. Great variability was found between the two years of data. This variability is especially important in dryland grain sorghum production, where few environmental factors are held constant from one year to another. Interactions between nutrients obscured the true nutrient status of the sorghum plant. For these reasons it is apparent that caution must be exercised in the interpretation of foliar analyses on dryland grain sorghum.

Tissue Testing

The two years data on tissue testing were also contradictory. In 1965, increased fertilizer applications resulted in a greater accumulation of nitrate nitrogen, phosphorus, and potassium expressed in the sap. In 1966, however, no effect due to fertility treatments was observed. This difference was attributed to environmental factors which influenced the nutrient availability and uptake of the plant nutrients. This along with interactions among nutrients greatly complicated the interpretation of tissue testing data, and suggests that interpretations of tissue testing results need to be made with caution.

Poor correlations between nutrient concentrations and yields were found over all treatments in 1965 and 1966. By selecting data to minimize nutrient interactions, high correlation coefficient (r) values were obtained between phosphorus concentrations and yields in 1965. The correlation coefficients between the nutrients in plant sap and grain yields were, for the most part, low and quite variable.

CHAPTER V

SUMMARY AND CONCLUSIONS

Grain sorghum foliage and sap were analyzed to determine the feasibility of the use of foliar analysis and tissue testing in evaluating the nutritional status of the sorghum crop. The study was conducted in 1965 and 1966 near Muskogee, Oklahoma. Foliar and sap samples were collected at three stages of growth and analyzed for nitrate nitrogen, total nitrogen, phosphorus, and potassium.

Sorghum grain yields and nutrient content of the leaves and sap were found to increase with increased fertilizer application rates in 1965. In 1966, the grain yields were increased with increased fertilizer applications, but the nutrient concentrations of the leaves and sap did not vary in accord with the fertilizer application rates.

Poor correlations were found between yields and concentrations of nitrate nitrogen, nitrogen, phosphorus, and potassium in the leaf and sap samples when calculated over all treatments. Correlations were found between nutrients and yields when calculated over treatments in which one nutrient was varied. This difference was attributed to interactions among the nutrients. Correlation coefficient (r) values, however, varied between years.

Nutrient levels in the plants were found to vary with the maturity of the grain sorghum sampled. In leaf samples, nitrate nitrogen, total nitrogen, and potassium were found to decrease with maturity. Phosphorus concentrations were highest at the preboot stage and lowest at anthesis. In sap samples, nitrate nitrogen concentrations decreased while phosphorus increased with maturity. Potassium concentrations did not differ consistently with plant maturity.

Nutrient levels varied with the position at which leaf and sap samples were taken. Nitrate nitrogen concentrations increased from top to bottom in the sorghum plant, while nitrogen and phosphorus decreased from top to bottom. The potassium concentrations showed little change with different leaf positions. In sap samples, nitrate nitrogen increased from top to bottom while phosphorus and potassium concentrations decreased.

The conclusion was drawn that caution must be used when employing foliar analysis or tissue testing for the determination of the nutrient status of dryland grain sorghum.

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APPENDIX

TABLE XVII

SOIL TEST VALUES FOR TALOKA SILT LOAM, MUSKOGEE, OKLAHOMA

pH		%	Phosphorus	Potassium
Paste	KCl	OM	(Available*) Lbs/A	(Exchangeable) Lbs/A
5.0	4.1	1.61	13	110

*As measured by Bray #1 extraction

TABLE XVIII

SUMMARY OF TOTAL PRECIPITATION AND DEPARTURE FROM NORMAL AT EASTERN PASTURE EXPERIMENT STATION, MUSKOGEE, OKLAHOMA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1965												
Rainfall	2.29	2.28	0.95	4.52	3.53	5.67	1.51	2.51	2.22	0.05	0.44	2.27
Departure From Normal	-0.01	-0.35	-2.28	-0.02	-2.22	+0.19	-1.64	-0.38	-1.27	-3.37	-1.85	+0.36
1966												
Rainfall	1.31	3.96	1.01	7.35	2.46	1.61	0.61	4.46	0.85	0.95	1.66	1.87
Departure From Normal	-0.99	+1.33	-2.22	+2.81	-3.29	-3.87	-2.54	+1.57	-2.64	-2.47	-1.13	-0.04

TABLE XIX

THE EFFECT OF FERTILIZER APPLICATION ON GRAIN SORGHUM YIELDS, MUSKOGEE, OKLAHOMA, 1965-1966

Treatment	Yield (Lbs/A)	
	1965	1966
0- 0- 0	1045	1704
0-60-40	1431	2124
40-60-40	1542	2381
80-60-40	1483	2613
120-60-40	1901	2618
80- 0-40	850	1680
80-30-40	1353	2223
80-60-40	1483	2613
80-90-40	1908	2883
80-60- 0	1490	2562
80-60-40	1483	2613
80-60-80	1797	2443
120-90- 0	1477	2693
120-90-80	1928	2660
Calculated F Values	4.07	3.46
Significant at	5%	5%
Coefficient of Variation	22.1%	14.6%

TABLE XX

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITRATE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1965

Treatment	Nitrate Nitrogen (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	1558	481	44
0-60-40	385	639	18
40-60-40	1041	586	35
80-60-40	1873	1208	79
120-60-40	2266	1199	70
80- 0-40	2564	1549	280
80-30-40	1461	971	123
80-60-40	1873	1208	79
80-90-40	1943	779	35
80-60- 0	1698	1216	193
80-60-40	1873	1208	79
80-60-80	1794	849	70
120-90- 0	2048	1470	140
120-90-80	2362	936	70
Calculated F Values	2.80	1.77	1.97
Significant at	5%	11%	7%
Coefficient of Variation	40.9%	52.2%	113.2%

TABLE XXI

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1965

Treatment	Nitrogen (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	42,800	33,425	27,775
0-60-40	39,050	29,425	24,875
40-60-40	42,400	33,400	28,625
80-60-40	41,625	35,375	30,675
120-60-40	46,150	37,575	30,525
80- 0-40	38,375	37,100	29,050
80-30-40	42,200	36,425	28,975
80-60-40	41,625	35,375	30,675
80-90-40	42,650	32,950	30,850
80-60- 0	40,650	35,225	28,400
80-60-40	41,625	35,375	30,675
80-60-80	40,625	36,225	30,650
120-90- 0	42,075	36,700	30,825
120-90-80	44,025	34,800	30,475
Calculated F Values	1.36	6.78	3.49
Significant at	25%	5%	5%
Coefficient of Variation	8.6%	5.0%	6.5%

TABLE XXII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE PHOSPHORUS CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1965

Treatment	Phosphorus (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	3000	1625	2250
0-60-40	2825	2275	2450
40-60-40	3375	2100	2200
80-60-40	3700	2500	2650
120-60-40	3600	2350	2550
80- 0-40	1875	1850	2000
80-30-40	2775	2125	2100
80-60-40	3700	2500	2650
80-90-40	4025	2275	2550
80-60- 0	3450	2300	2300
80-60-40	3700	2500	2650
80-60-80	3725	2400	2400
120-90- 0	4200	2800	2775
120-90-80	4125	2675	2675
Calculated F Values	5.33	3.67	3.01
Significant at	5%	5%	5%
Coefficient of Variation	17.2%	14.9%	11.6%

TABLE XXIII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE POTASSIUM CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1965

Treatment	Potassium (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	12,350	9,750	12,200
0-60-40	15,250	15,200	12,150
40-60-40	15,900	16,400	12,050
80-60-40	17,550	13,850	12,250
120-60-40	15,950	14,550	11,800
80- 0-40	16,700	12,450	14,300
80-30-40	15,250	15,300	12,750
80-60-40	17,550	13,850	12,250
80-90-40	16,350	12,500	11,650
80-60- 0	10,850	9,000	9,650
80-60-40	17,550	13,850	12,250
80-60-80	14,700	18,950	13,650
120-90- 0	9,950	9,650	9,600
120-90-80	16,950	15,200	12,100
Calculated F Values	2.51	3.20	4.19
Significant at	5%	5%	5%
Coefficient of Variation	20.9%	24.8%	11.0%

TABLE XXIV

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITRATE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1965

Treatment	Nitrate Nitrogen (ppm) Preboot Stage	Nitrate Nitrogen (ppm) Anthesis Stage
0- 0- 0	150	515
0-60-40	130	410
40-60-40	179	480
80-60-40	122	450
120-60-40	154	495
80- 0-40	176	530
80-30-40	200	465
80-60-40	122	450
80-90-40	119	550
80-60- 0	205	575
80-60-40	122	450
80-60-80	149	520
120-90- 0	199	485
120-90-80	252	445
Calculated F Values	0.58	1.38
Significant at	20%	24%
Coefficient of Variation	61.4%	16.4%

TABLE XXV

THE EFFECT OF FERTILIZER APPLICATIONS ON THE PHOSPHORUS CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1965

	Phosphorus (ppm)		
Treatment	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	165	218	665
0-60-40	193	282	849
40-60-40	190	291	765
80-60-40	210	274	894
120-60-40	246	299	805
80-0-40	112	204	626
80-30-40	210	221	654
80-60-40	210	274	894
80-90-40	327	307	844
80-60- 0	316	455	894
80-60-40	210	274	894
80-60-80	290	302	771
120-90- 0	394	567	1030
120-90-80	263	293	748
Calculated F Values	3.56	13.51	1.73
Significant at	5%	5%	12%
Coefficient of Variation	34.5%	18.2%	22.3%

TABLE XXVI

THE EFFECT OF FERTILIZER APPLICATIONS ON THE POTASSIUM CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1965

Treatment	Potassium (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	4000	1625	3844
0-60-40	5031	3063	3875
40-60-40	5688	2656	3750
80-60-40	4813	2781	3719
120-60-40	5563	2719	4344
80- 0-40	6063	3500	4085
80-30-40	5063	2750	3813
80-60-40	4813	2781	3719
80-90-40	5563	2875	3781
80-60- 0	3094	1156	3188
80-60-40	4813	2781	3719
80-60-80	4500	3219	4250
120-90- 0	3656	1219	2931
120-90-80	6063	2844	3759
Calculated F Values	3.46	6.41	1.31
Significant at	5%	5%	29%
Coefficient of Variation	20.9%	24.0%	18.3%

TABLE XXVII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITRATE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrate Nitrogen (ppm) Preboot Stage	Nitrate Nitrogen (ppm) Anthesis Stage
0- 0- 0	607	105
0-60-40	805	187
40-60-40	817	175
80-60-40	338	93
120-60-40	770	295
80- 0-40	420	105
80-30-40	712	128
80-60-40	338	93
80-90-40	292	93
80-60- 0	560	117
80-60-40	338	93
80-60-80	385	105
120-90- 0	618	93
120-90-80	560	198
Calculated F Values	1.30	2.26
Significant at	30%	5%
Coefficient of Variation	48.5%	42.9%

TABLE XXVIII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrogen (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	36,600	32,633	33,867
0-60-40	35,167	34,300	30,267
40-60-40	36,733	35,000	33,033
80-60-40	34,567	31,100	30,267
120-60-40	35,300	32,800	31,800
80- 0-40	31,800	31,033	29,433
80-30-40	33,967	33,800	32,667
80-60-40	34,567	31,100	30,267
80-90-40	32,667	33,600	30,667
80-60- 0	35,533	33,600	31,000
80-60-40	34,567	31,100	30,267
80-60-80	34,067	33,967	29,567
120-90- 0	35,667	34,933	30,467
120-90-80	35,733	35,300	34,667
Calculated F Values	0.66	1.27	0.40
Significant at	Not Sig.	Not Sig.	Not Sig.
Coefficient of Variation	9.1%	6.4%	15.0%

TABLE XXIX

THE EFFECT OF FERTILIZER APPLICATIONS ON THE PHOSPHORUS CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Phosphorus (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	3200	3133	3200
0-60-40	2800	2800	2267
40-60-40	2600	3333	3133
80-60-40	4400	2533	2467
120-60-40	2867	2600	2600
80- 0-40	4600	2533	2733
80-30-40	3733	2933	3267
80-60-40	4400	2533	2467
80-90-40	2600	3000	3067
80-60- 0	4333	2800	3000
80-60-40	4400	2533	2467
80-60-80	4800	2667	2333
120-90- 0	2733	3133	3267
120-90-80	3400	3133	3633
Calculated F Values	1.59	0.86	2.95
Significant at	18%	Not Sig.	5%
Coefficient of Variation	32.7%	17.4%	14.8%

TABLE XXX

THE EFFECT OF FERTILIZER APPLICATIONS ON THE POTASSIUM CONCENTRATIONS OF GRAIN SORGHUM LEAVES, MUSKOGEE, OKLAHOMA, 1966

Treatment	Potassium (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	13,267	12,533	11,400
0-60-40	11,433	12,133	10,800
40-60-40	12,633	10,800	9,400
80-60-40	12,300	13,067	10,800
120-60-40	12,000	12,933	10,267
80- 0-40	14,000	12,600	11,067
80-30-40	11,067	12,067	10,667
80-60-40	12,300	13,067	10,800
80-90-40	13,233	12,200	11,333
80-60- 0	13,933	11,933	11,133
80-60-40	12,300	13,067	10,800
80-60-80	11,333	10,933	9,867
120-90- 0	12,000	11,867	10,600
120-90-80	10,000	10,500	10,067
Calculated F Values	0.87	1.25	0.65
Significant at	Not Sig.	Not Sig.	Not Sig.
Coefficient of Variation	18.3%	10.7%	12.5%

TABLE XXXI

THE EFFECT OF FERTILIZER APPLICATIONS ON THE NITRATE NITROGEN CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Nitrate Nitrogen (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	588	186	22
0-60-40	733	98	20
40-60-40	567	109	19
80-60-40	397	52	12
120-60-40	895	207	20
80- 0-40	574	39	17
80-30-40	913	97	19
80-60-40	397	52	12
80-90-40	370	67	12
80-60- 0	528	105	10
80-60-40	397	52	12
80-60-80	694	63	13
120-90- 0	737	50	23
120-90-80	971	131	31
Calculated F Values	0.53	1.51	0.91
Significant at	Not Sig.	21%	Not Sig.
Coefficient of Variation	70.4%	74.5%	59.5%

TABLE XXXII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE PHOSPHORUS CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Phosphorus (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	84	395	325
0-60-40	117	240	287
40-60-40	95	448	451
80-60-40	87	224	229
120-60-40	77	222	211
80- 0-40	95	209	247
80-30-40	105	263	336
80-60-40	87	224	229
80-90-40	73	230	262
80-60- 0	88	283	255
80-60-40	87	224	229
80-60-80	66	264	189
120-90- 0	109	290	349
120-90-80	128	223	389
Calculated F Values	0.60	1.88	1.83
Significant at	Not Sig.	11%	13%
Coefficient of Variance	43.9%	34.2%	33.8%

TABLE XXXIII

THE EFFECT OF FERTILIZER APPLICATIONS ON THE POTASSIUM CONCENTRATIONS OF GRAIN SORGHUM SAP, MUSKOGEE, OKLAHOMA, 1966

Treatment	Potassium (ppm)		
	Preboot Stage	Anthesis Stage	Milk Stage
0- 0- 0	3467	3367	4233
0-60-40	2633	3333	3600
40-60-40	2867	4400	3000
80-60-40	3850	4133	3667
120-60-40	3050	3800	3267
80- 0-40	3767	3583	3767
80-30-40	2800	3567	3383
80-60-40	3850	4133	3667
80-90-40	4000	4233	3217
80-60- 0	3500	4300	3350
80-60-40	3850	4133	3667
80-60-80	3300	3983	3200
120-90- 0	2800	4317	3167
120-90-80	2200	3583	2767
Calculated F Values	0.81	0.96	1.15
Significant at	Not Sig.	Not Sig.	Not Sig.
Coefficient of Variation	33.2%	17.8%	18.5%

VITA

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Master of Science

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