A CORRELATION STUDY OF SOIL TEST RESULTS WITH FERTILIZER EXPERIMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The objective of soil fertility studies is to gain knowledge of soil-plant relations. One approach to this problem is the development and improvement of chemical soil tests and the correlation of yield response from fertilizer and the results of the soil test. The first step towards the determination of the nutrient element requirement of a soil is to measure the "available" forms and to calculate nutrient element requirement in terms of the percentage yields. However the amount of nutrient element needed to achieve a balanced fertility at maximum yield level depends not only on the soil type but also on plant type and variety.

Chemical tests for determining available nutrient elements in the soil were started over a century ago, and there has been some progress in the development of these tests. Nevertheless, a more precise correlation with plant response is needed if methods and techniques are to be developed that are suitable for a wide range of soil types. The usefulness of soil testing depends upon the accuracy with which the results obtained will remove a constant proportionate part of a certain element from the soil.

The objective of this study was to study possible correlations between chemical soil tests in the laboratory with plant yield data, with soils from locations in the State of Oklahoma on which fertility experiments had been conducted.[1] The soil types are shown in the appendix.

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[1]Samples were supplied by Mr. O. H. Brensing. These soils were Red and Yellow Podzolic, Reddish Prairie, Prairie soils, or Reddish Brown soils.

The crops studied were corn, cotton, oats, wheat, sorghum, peanuts, barley and alfalfa.

REVIEW OF LITERATURE

Due to lack of knowledge of both soil chemistry and plant physiology, investigators in the nineteenth century made very little progress in the effective use of chemical analyses in soil research. Another drawback was their preconceived idea that chemical methods should emulate "plant feeding" and measure the absolute nutrient availability. Bray (7) pointed out these faults and set up concepts as guides for planning research to measure fertility with chemical methods. Chemical tests and methods to predict soil fertility have been improved since 1930.

According to Baver and Bruner (2) one of the most difficult phases in the development of any chemical method for determining readily soluble nutrient elements is to calibrate the extracted amounts of a given nutrient in terms of the quantity available to the plant. However, some recent experimental data (2) have shown a close correlation between exchangeable cations and plant growth; the amounts of Calcium, Magnesium, Potassium and Manganese, readily soluble in extracting reagents were correlated with the amounts of these cations on the exchange complex.

Bray (8) formulated three requirements for a successful soil test. The first requirement is that the extracting solution should extract the total amount or the proportionate part of the available forms of a nutrient from soils with variable properties. This is accomplished by first knowing the nature of the available forms of a nutrient in a soil. The second requirement calls for reasonable accuracy in the measurement of the amount of the nutrient in the extract. The third requirement is to correlate the amount extracted with plant growth, and the response of different crops to that nutrient under various conditions.

Mitscherlich and Baule (27) proposed an equation by which these three values could be expressed. This was later confirmed by Bray (7) for exchangeable potassium and the absorbed and easily acid-soluble forms of phosphorus in corn belt soils. The Mitscherlich equation in its logarithmic form is:

$$\text{Log } (A-y) = \log A - c\ (b + x)$$

where A is maximum yield, y is the yield obtained when b units of nutrient are in the soil, and x is the units of the same nutrient element added as fertilizer, while c is the proportionality factor.

Mitscherlich (27) and his co-workers, believed that the constant c varies with the kind of plant, element studied, and fertilizer pattern as well as planting rate. Bray (1), therefore, modified the original equation as follows:

$$\text{Log } (A-y) = \log A - C.b - cx$$

where C and c are the efficiency factors of the soil-borne element and the added fertilizer element, respectively. The equation is generally used to calculate the yield of dry matter.

Balba and Bray (1) pointed out that most of the discrepancies were due to certain experimental circumstances. In experiments designed for calibration of soil tests, a group of soils are selected which range from low to high in the element being studied. The crop is grown, and the growth, yield and element uptake measures are taken. Different chemical methods are used and a study is made to determine which method will best predict response. The most common procedure to accomplish calibration of the soil test is to correlate soil test values with the percentage yield of plant material or total uptake of the nutrient element from treated and untreated plots. The A values which were developed by Fried and Dean (12) have been used to correlate soil test values. They conducted many experiments and found that a plant having two sources of a nutrient element will absorb from each of the sources in different proportion to the total amount available. The quantity of available nutrient in the soil can, therefore, be determined by application of a simple equation as shown below:

$$A = \frac{B(1-y)}{y}$$

where A is the amount of nutrient available from the soil, B is the amount of nutrient element in the fertilizer and y is the proportion of the nutrient in the plant derived from the fertilizer.

Correlation of nutrient uptake versus yield curves shows promise in estimating the amount of a fertilizer element available to the plant from the soil and hence may be used to standardize soil tests. This method was used by Fried and Dean (12) for phosphorus and the measurements obtained from field studies were approximately the same as the A values obtained in greenhouse studies.

A recent soil test report (37) has shown that better correlations between soil tests and yield percentages could be obtained under greenhouse conditions than from field studies. In the greenhouse such factors as rainfall, and temperature can be controlled and most variables other than soil fertility can be eliminated. Correlation statistics (37) have been used to present the results of the relationship between percentage yields, A values and soil test values. If the correlation coefficient is an index for expressing the degree of linear relationship between two variables then the scatter diagram for a number of samples consists of a cluster of points which is roughly elliptical in shape. The values of the correlation coefficient between +1 and -1 whereby +1 indicates on the average that increase in one variable is accompanied by an increase in the other and -1 indicates that an increase of one variable is accompanied by a decrease of the other, are convenient techniques to use for an evaluation of soil test procedures.

The correlation coefficient for soil tests is expected to have a positive value. However, it is possible to have statistical significance and still have a method of little value in predicting the nutrient status of the soil. In many instances, the relation between response and soil test value is a curvilinear rather than a linear function. Statistically significant values of r in correlation of a soil test may be misleading in evaluating the merits of such a procedure.

Although it is quite simple to make an inventory of the total plant-nutrient resources of a soil by means of chemical analyses, it is a known fact that a close relationship between the total quantities of the soil-borne nutrient element and the supply available to plants does not always exist. Consequently, the amount of various nutrient elements removed from the soil by water, by plants or by some extracting solution is not necessarily an infallible index of the total amount of a certain element present.

The quantity of different elements ordinarily added to a soil in a fertilizer in one season is so small compared with the total normal supply in the soil that a chemical analysis for total constituents would ordinarily fail to detect the nutrient added.

A high degree of correlation was found between exchangeable potassium and crop response data obtained from field experiments according to Bray (5). He found that the exchangeable potassium values were closely equivalent to the Neubauer values (25), therefore, no significant release of potassium from other forms in the soil was noted during the growing season. Other reports (37) indicate that the correlation coefficients of soil test results for potassium determined by ammonium acetate leaching were higher than test results correlated with Neubauer values. In all tests it was found that a higher correlation was obtained when the ammonium ion was used to replace potassium than in tests which employed other cations.

Salomon and Smith (35) found that potassium extraction by Amberlite IR-120[2] method of Peech and English (30) and extraction by ammonium acetate, removed more potassium than other methods studied. These two methods also gave a better correlation between soil test potassium and hay yields than the other methods which extracted less potassium. Lawton *et al.* (21) could not correlate yield of sugar beets and peppermint with rapid soil tests due to the nature of the plant, climatic conditions, and response of the crops to different fertilizer ratios as well as experimental variations. Harper (17) listed the following six conditions that affect response of plants to potassium fertilization; soil type, rate of plant growth, relation between successive crops, average rainfall, probable yield and method of fertilization.

Correlation of soil test values for phosphorus and plant growth response was reported by an investigator in Scotland (40) who found that the Truog method (39) was best for soils derived from slate and basic igneous rocks, acetic acid was best for soils derived from granitic rocks and ammonium fluoride plus hydrochloric acid was best for soils derived from old sandstones. Pratt (31) and other workers in Ohio found that the availability of phosphorus was different among soils with different pH values and that some soil series had larger amounts of phosphorus in their lower horizons than in the top soil.

Spurway and Lawton (38) stated that reversion of phosphorus applied

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[2]Strongly-acidic cation exchange resin manufactured by the Rohm and Haar Company of Philadelphia, Pennsylvania.

in fertilizer varied in magnitude between soils. They concluded that the "fixation capacity" must be satisfied before a considerable amount of phosphorus can be detected in soil extracts. The results obtained by Long and Seatz (23) showed that corn response to phosphorus fertilization gave the poorest correlation with the soil test, while fertilization of permanent pasture resulted in the best correlation. They concluded that the poor correlation between fertilizer response as measured by corn growth and the soil tests was due to lack of responsiveness of corn to fertilizer phosphorus on the soil type studied, regardless of soil phosphorus levels. Some investigators (14), (20), have shown that available phosphorus is influenced by soil pH, type of soil phosphorus compound, and type and quantity of clay minerals in soil. It can be implied that no one extraction solution can be expected to give perfect correlations of phosphorus fertilizer response and phosphorus availability under all conditions. It is clear that in order to obtain satisfactory correlations, the factors that contribute significantly to variation in yield due to soil phosphorus must be expressed through the soil test. Bishop and Barber (3) found heterogeneous soils with the respect to types of soil phosphate compounds do not give results with high correlation coefficients between plant response and phosphate fertilizer regardless of the extracting solution used.

Miller and Axley (26) proposed a method employing sulphuric acid and ammonium fluoride as an extractant because it showed the best correlation of several methods studied with crop response. The advantages of ammonium fluoride were believed to be due to its ability to remove sorbed phosphorus, its ability to decrease the solubility of rock phosphate in the presence of an acid extractant, and its reduction of phosphorus fixation by hydrous oxides in an acid extract.

Richer and White (33) concluded that significant correlations of "available" phosphorus with crop yields are not possible. They analyzed soil from plots fertilized with superphosphate, rock phosphate, basic slag and bone meal. They found that plots receiving double or triple amounts of super phosphate showed only small increases in "available" phosphorus extracted by soil test methods.

Nitrogen deficiency probably limits plant growth more than any other element. Black (4) points out that the plow layer of most cultivated soils contains between .04 and .20 percent nitrogen, and the amounts present in the soil are determined by climate, vegetation, topography, and soil parent material.

Pack and Gomez (29) attempted to correlate the results of plant analyses and soil nitrogen content. They found that the concentration of nitrogen in cotton was significantly correlated with either soil organic matter or total soil nitrogen. Results of work by Munson and Stanford (28) showed that the correlation between crop yield and the total soil nitrogen was poor.

METHODS AND MATERIALS

This study is an attempt to correlate soil chemical analyses with fertilizer response obtained in several field fertility experiments. Many soil types from different parts of Oklahoma and the response of corn, wheat and oats to fertilizer were studied. Soil samples from 0 to 6" deep were collected from soil types listed in the Appendix. The fertilizer response on some of the soils studied has been reported by Brensing and Lynd (9).

All soil samples were crushed and sieved through a 20-mesh sieve and stored for analysis. The cation exchange capacity and exchange cations were determined according to the methods of Metson (24) and Jackson (19). The amount of magnesium, potassium, calcium, and sodium were determined on the neutral normal ammonium acetate extract with the Beckman Flame Spectrophotometer with photomultiplier. The pH of the soil studied was determined with a glass electrode in three different ways as described below: (a) Soil-water ratio 1:2 by placing 5 grams of soil in a 50 ml. beaker and adding 10 ml. of distilled water; (b) Soil-water paste by placing 5 grams of soil in a 50 ml. beaker and adding sufficient distilled water to make a thin paste, and allowing the paste to stand for 10 minutes, and (c) Soil-salt solution 1:2, by placing 5 grams of soil in a 50 ml. beaker with 10 ml. 0.1N KCL, and allowing to stand for ten minutes before measuring the pH.

The available phosphorus was determined by three methods: (a) 0.1 N acetic acid, suggested by Harper (15), (b) 0.1 N hydrochloric acid plus

.03 N ammonium fluoride, Bray (6), (c) .02 N H_2SO_4, "County Agents Method,"[3]. The data obtained were treated by correlation statistics according to methods outlined by Ezekiel and Fox (11).

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[3]Method developed by W. Garman and H. J. Harper, Agronomy Department, Oklahoma State University. 1948

RESULTS AND DISCUSSION

The data obtained in this study are shown in Tables I and II and Figures I through IX. The results of the soil tests were correlated by regression analysis against grain yield of corn, oats and wheat. For corn a significant correlation was obtained between soil phosphorus and yield. In an attempt to evaluate soil test methods, three methods were used on each soil sample. The Bray #2 method or 0.1 N hydrochloric acid plus 0.03N ammonium fluoride and 0.1N acetic acid were significantly correlated with yield of corn as shown in Table I and Figures I and II. It is unimportant that a particular soil test procedure fails to measure all of the phosphorus or other elements in a soil, but that the method should measure a proportionate part of the phosphorus that may be expected to become available to a plant during the growing season. Rubins and Dean (34) found a wide range of phosphorus values by using different extractants for soil phosphorus. The values obtained by any particular method should not be used as indices of the particular soil to supply the element.

All three soil test methods gave significant correlation coefficients between corn yield and soil phosphorus where forty pounds of fertilizer phosphorus were used. For corn on both the fertilized and unfertilized soil, the 0.1N acetic acid method gave the highest correlation coefficient with the Bray test next and the sulfuric acid method in third place. It may be of interest to note that Miller and Axley (26) proposed a method employing 0.02N sulfuric acid and 0.03N ammonium fluoride for soil phosphorus.

This method gave the highest correlation coefficient of all methods used in their studies and may combine the better features of the dilute sulfuric acid and Bray methods reported here.

Correlation coefficient obtained between phosphorus and wheat yields are reported in Table I and Figures III and IV. The Bray method gave significant correlation coefficients for both fertilized and unfertilized wheat while the dilute sulfuric acid and acetic acid methods gave highly significant correlations on unfertilized soils and no significance on the fertilized soils. Miller and Axley (26) method for soil phosphorus gave low correlation coefficients between soil phosphorus and wheat yield particularly on soils high in acid soluble phosphorus. Long (22) reported low correlation coefficients between soil phosphorus and wheat and cotton yields. Smith and Cook (36) reported that phosphorus extracted by Bray method gave more significant correlation with plant yield than other methods studied. Miller and Axley (26) found that wheat grown on soils that were high in acid soluble phosphorus did not respond well to application of additional phosphorus. Harper (16) has reported similar results. The experiments reported here on correlation between wheat grain yield and soil test phosphorus agree with the results of other investigators in that the Bray method appears to be the best method studied.

The only soil test method for phosphorus to give a significant correlation between oat yield and soil phosphorus was the dilute acetic acid extractant as shown in Tables I and II and Figures 5 and 6. The slope of the regression lines indicate a relation between yield and soil phosphorus, but the scatter of the data did not show a significant relation. The acetic acid method, however, was significantly correlated with oat grain yields from the non-fertilized soil. These data indicate that more careful selection of soils, soil sampling, laboratory techniques and other sources of error might result in a significant correlation between soil phosphorus and oat grain yield. Harper (15) concluded that climatic conditions particularly precipitation was the chief limiting factor for plant growth during many seasons and that it would be difficult to detect the maximum amounts of available soil phosphorus required for plant response to fertilizer. These data appear to agree with this observation in that the yield data may have been influenced more by rainfall and other climatic variations than soil phosphorus. Rich and Attoe (32) with more nearly optimum conditions reported significant correlations between phosphorus uptake by oats and phosphorus content of the soil on both fertilized and non-fertilized land. Several methods for estimating the proportion of the soil phosphorus that may be correlated with plant growth have been discussed. However, each of the methods reported in this study have shown some weak point, but the best method insofar as consistent results are concerned is the Bray #2 method. Although this method did not give as high results as one of the other methods for a particular plant the overall evaluation based on this study indicates that the Bray method may be significantly correlated with phosphorus response on wheat, corn, and oats.

The exchangeable soil potassium was determined by leaching the soil with ammonium acetate and estimating the quantity of potassium on the Beckman Flame Spectrophotometer with photomultiplier attachment. These data are reported in Table II and Figures VII, VIII and IX. Correlation coefficients of 0.432 and 0.357 were obtained between soil potassium and yield on corn and oats respectively, where potassium had not been applied as a fertilizer. These values were significant correlations, however, where potassium had been applied in the fertilizer the correlation coeffients were not significant for corn, wheat, and oats. Long and Seatz (23) obtained correlation coefficient of 0.435 from the study of sixty-three fertilizer experiments with potassium on corn in Tennessee. This low correlations may be explained by a postulate reported by Hoagland and Martin (18) who believed that some soils have the power to supply potassium at a rate sufficient for maximum plant growth, although, the soil test value may be quite low. Winters (41) in Tennessee found that the correlation obtained between soil potassium levels and corn grain yields were more variable than those obtained for other crop plants. He believed, however, that the variability was due to lack of adequate rainfall during the summer months and not due to a real difference resulting from plant variability.

The correlation between soil potassium and plant growth response reported in these investigations was not usually significant, but the negative slopes of the regression lines were difficult to explain. For example, the slope of the regression line for oats appears too steep to be real. This may be due to several factors. It is generally known that the finer textured soils are higher in cation exchange capacity and exchangeable cations than more coarse textured soils. This is particularly true for the shallow claypan soils where most of the data for these correlations were collected. Therefore, as the pound per acre of soil test potassium increased drought susceptibility also increased.

The results reported in this study indicate that soil potassium content and plant growth response were not sufficiently related for making a valid conclusion. Despite the inconclusiveness of these data in regard to potassium fertilization there is an indication of a real need for a critical examination of soil fertility studies currently in progress and recommendations that may eventually be expected based on these studies. The need for potassium by the plant is universally recognized, but the potassium status of Oklahoma soils has not been sufficiently correlated with plant growth.

Despite the extensive research efforts to correlate soil test data with plant growth response to fertilizers in many countries for almost one-hundred years, many agronomists still rely on field response to fertilizer as the most dependable means to establish the fertility needs of a soil. Although, this method is reliable it is expensive and time consuming and is not flexible enough to meet the requirements of a rapidly changing technology. Therefore, the need for intensive research in soil testing procedures and correlations is needed to obtain more reliable information between the total quantity of a particular element in the soil, the quantity that may be available to plants, and the growth of plants on the soil.

The successful use of a soil test depends upon a careful calibration of soil test results with increases in crop yield due to fertilizers and lime. Other factors, such as climate, soil properties, plant species, stand, cultural practices, insects and diseases influence the level of response. These factors should be eliminated if possible.

The soil test is widely used to ascertain the quantity of any one element in the soil. The inadequancy of the soil test is not generally recognized by the general public. Therefore, the public as well as the professional agriculturist is often surprised to learn about the limitations of a soil test. The soil scientist has the dual responsibility of improving his methods for interpreting soil test results and explaining to the public and his colleagues how the soil test may be successfully used for problem solving and its limitations.

It has been the objective of this study to present some quantitative aspects of the fertility status of the 190 soils studied based on phosphorus and potassium availability as determined by several chemical procedures. Soil fertility research must continue to be concerned with seeking quantitative expression of the soil plant relation and it is hoped that more intensive effort than reported here will be carried on in the future.

SUMMARY AND CONCLUSIONS

One objective of this study was to measure the soil phosphorus and potassium levels on a wide range of soil types by several methods of analysis. The second objective was to correlate these results with yields of corn, wheat, and oats obtained during the course of field fertility experiments. The experiments studied had been established in various parts of Oklahoma in the course of soil fertility investigations conducted by personnel of the Agricultural Experiment Station during the period of 1947 to 1959.

The results from this study may be summarized as follows:

1. Of the three methods used to measure soil phosphorus, the Bray #2, and .1N acetic acid gave significant correlations with corn yields. Corn yields were responsive to addition of the nutrient element. The highest significant correlation between soil test phosphorus and yield was shown by the Bray #2 method.
2. The correlation coefficients obtained between soil phosphorus and wheat yields were significant with the Bray #2 method showing the highest significance for both fertilized and unfertilized soils. Dilute sulfuric acid and acetic acid gave high significance on unfertilized soils but were not significant on fertilized soils.
3. Only the dilute acetic acid method gave a significant correlation between soil phosphorus and oat yields on the non-fertilized soils. None of the soil tests used were significantly correlated with yields on the fertilized soil.
4. Where potassium had not been applied to the soil, high correlation

coefficients were obtained between soil potassium and yields of corn and oats. With application of potassium the correlation coefficients were not significant for corn, wheat, and oats. Lack of rainfall during the growing season may have been the cause of such results.

5. The correlations between fertilizer potassium with small grain growth response, or grain yields were not significant as shown by this investigation. It may be concluded that factors other than potassium might have been the limiting factors for the lack of response of small grain crops.

TABLE I

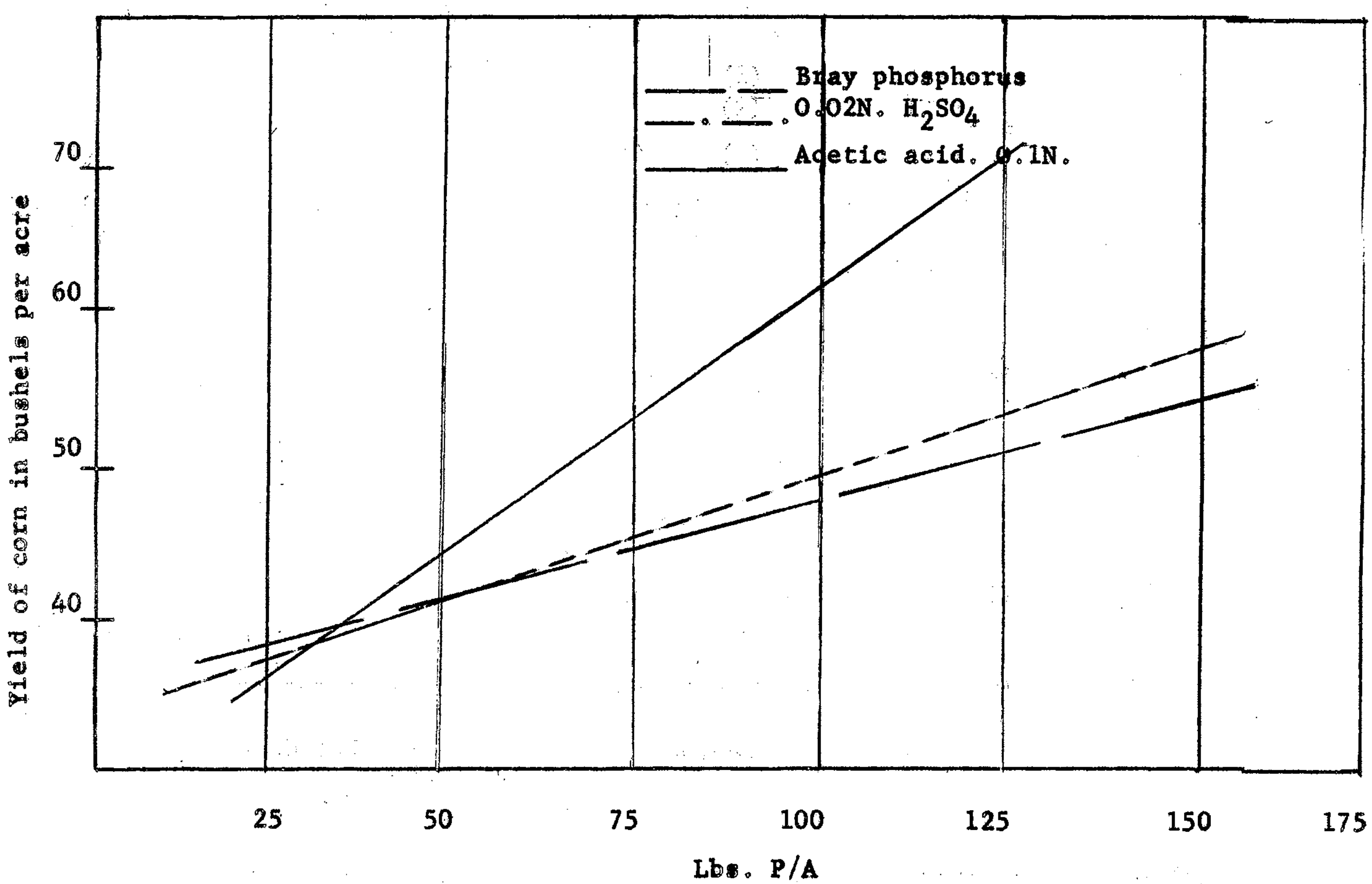
STATISTICAL DATE FOR SOIL PHOSPHORUS

X YIELD, REGRESSION ANALYSIS

	Fertilizer Treatment	Soil Test	Plant	Y = a + bx	rxy		S yx
1.	No Phosphorus	Bray	Corn	19.25 + .183x	.451	**	12.28
2.	No Phosphorus	0.02 N H_2SO_4	Corn	22.73 + .109	.320	NS	13.04
3.	No Phosphorus	.1N H. Ac.	Corn	15.55 + .314	.516	**	11.79
4.	40# P_2O_5/Acre	Bray	Corn	36.7 + .123x	.381	*	6.49
5.	40# P_2O_5/Acre	.02 N H_2SO_4	Corn	34.5 + .175x	.441	*	15.28
6.	40# P_2O_5/Acre	.1 N H Ac.	Corn	32.51 + .333x	.468	*	15.06
7.	No Phosphorus	Bray	Oats	26.28 + .374x	.363	NS	20.52
8.	No Phosphorus	.02 N H_2SO_4	Oats	31.11 + .355x	.259	NS	21.96
9.	No Phosphorus	.1 N H Ac.	Oats	26.21 + .402x	.444	*	20.38
10.	40# P_2O_5/Acre	Bray	Oats	54.43 + .032x	.078	NS	22.33
11.	40# P_2O_5/Acre	.02 N H_2SO_4	Oats	44.39 + .228x	.276	NS	8.85
12.	40# P_2O_5/Acre	.1 N H Ac.	Oats	45.90 + .161x	.209	NS	29.66
13.	No Phosphorus	Bray	Wheat	18.16 + .066x	.606	**	5.22
14.	No Phosphorus	.02 N H_2SO_4	Wheat	16.56 + .203x	.593	**	5.11
15.	No Phosphorus	.01 N H Ac	Wheat	18.26 + .069x	.530	**	4.57
16.	40# P_2O_5/Acre	Bray	Wheat	20.15 + .454x	.423	*	9.70
17.	40# P_2O_5/Acre	.02 N H_2SO_4	Wheat	33.08 + .034x	.083	NS	10.67
18.	40# P_2O_5/Acre	.1 N H Ac.	Wheat	25.77 + .362x	.312	NS	10.19

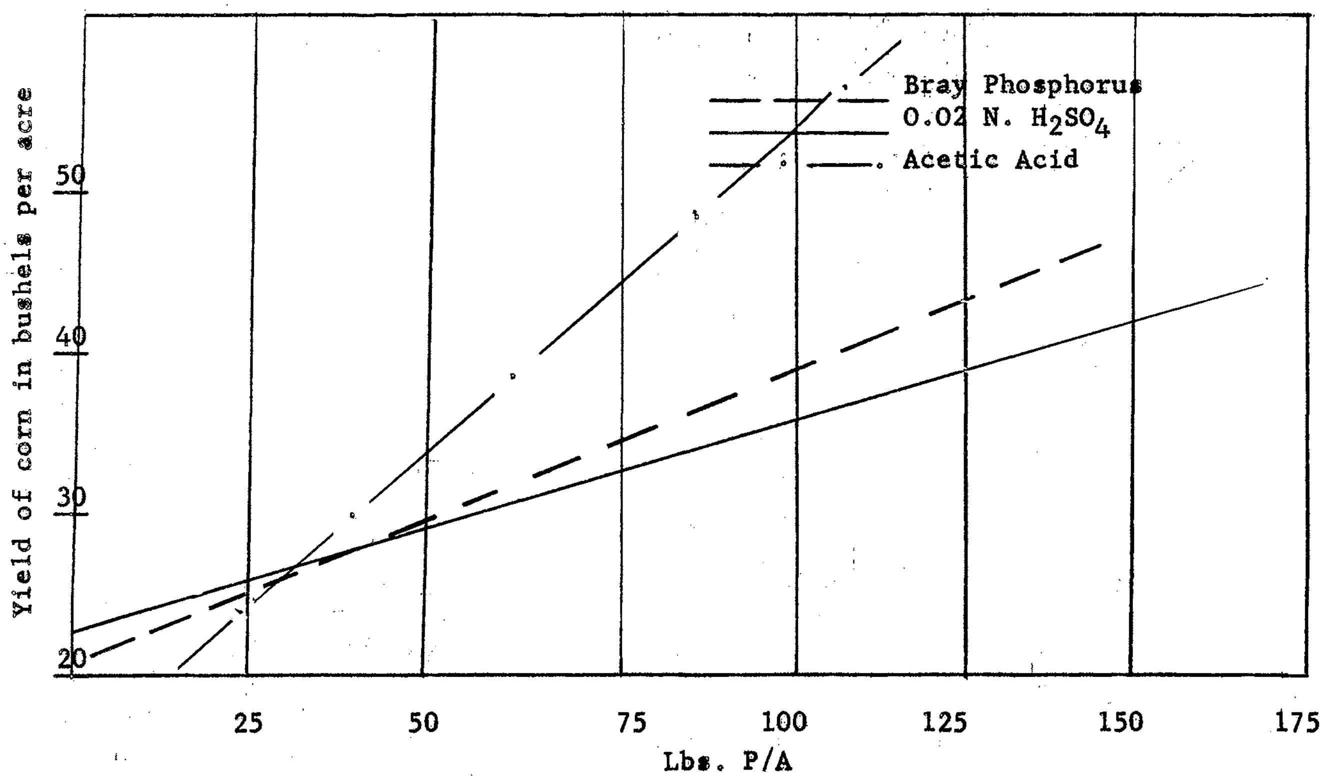
** Correlation Coefficient, 1% Level of Significance
* Correlation Coefficient, 5% Level of Significance
NS Not Significant

Figure 1



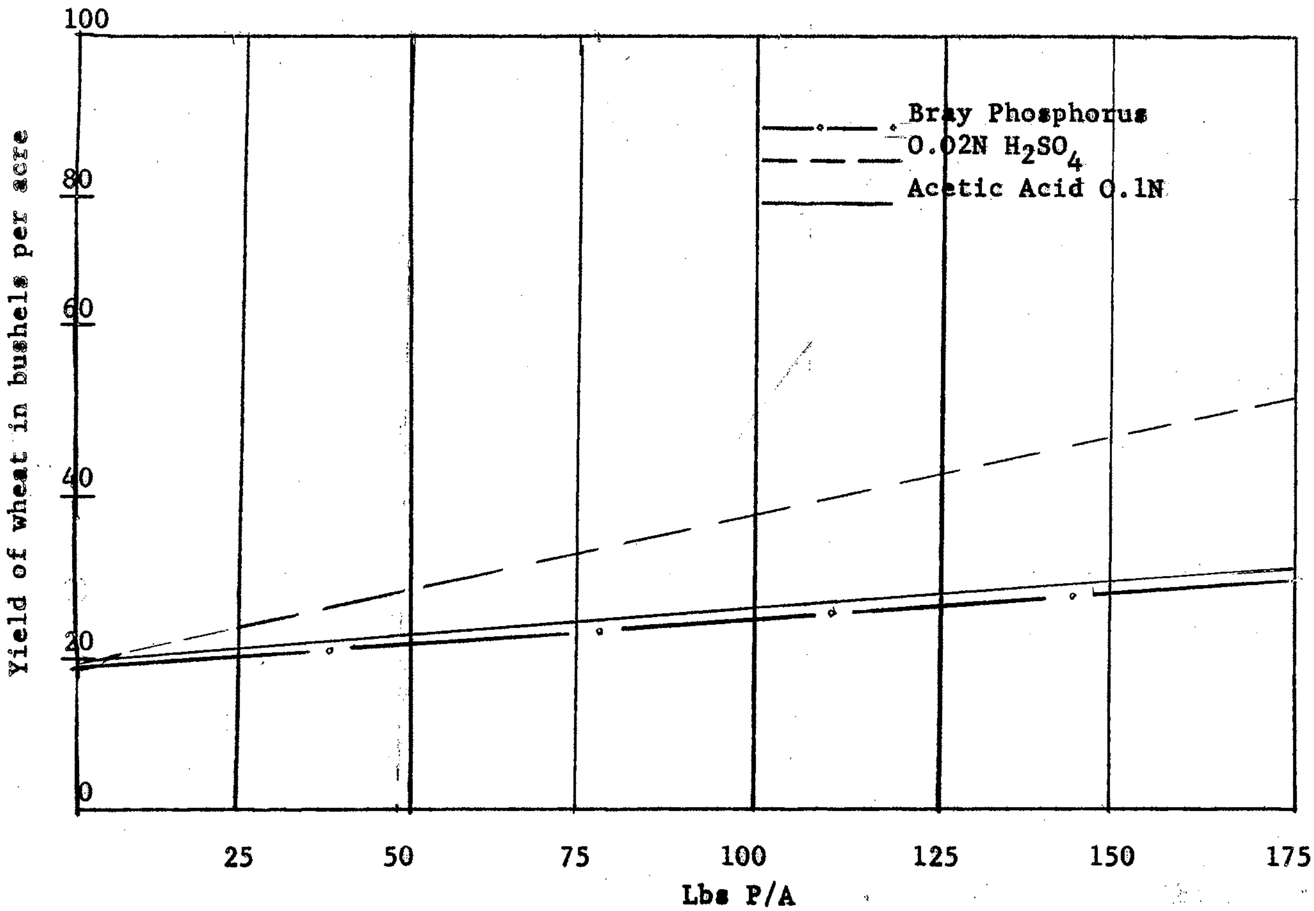
Regression of soil phosphorus on yield of corn with 40 lbs of P_2O_5 per acre with and without nitrogen and potassium.

Figure 2



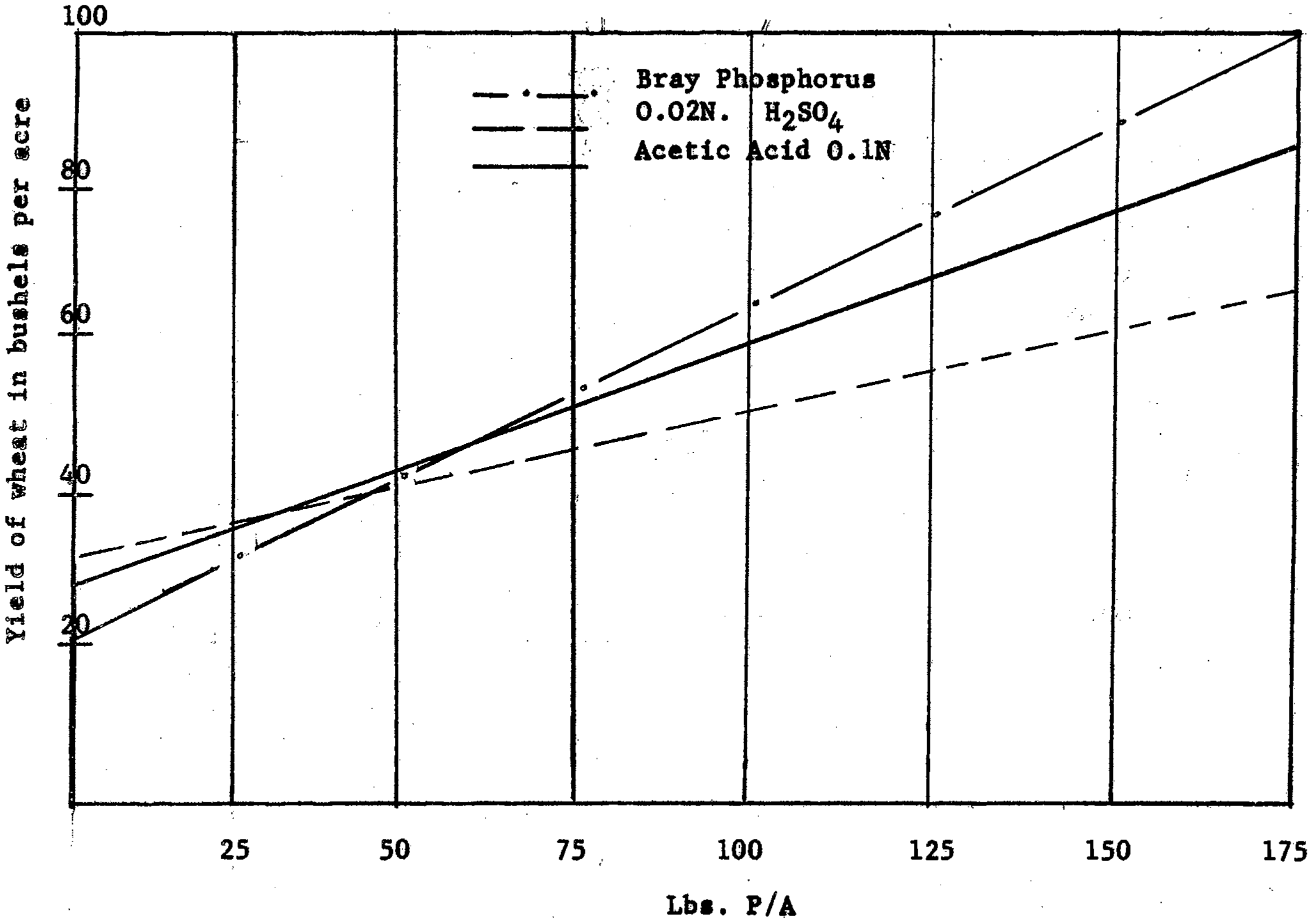
Regression of Soil Phosphorus on yield of corn with no Phosphorus treatment and without Nitrogen and Potassium.

Figure 3



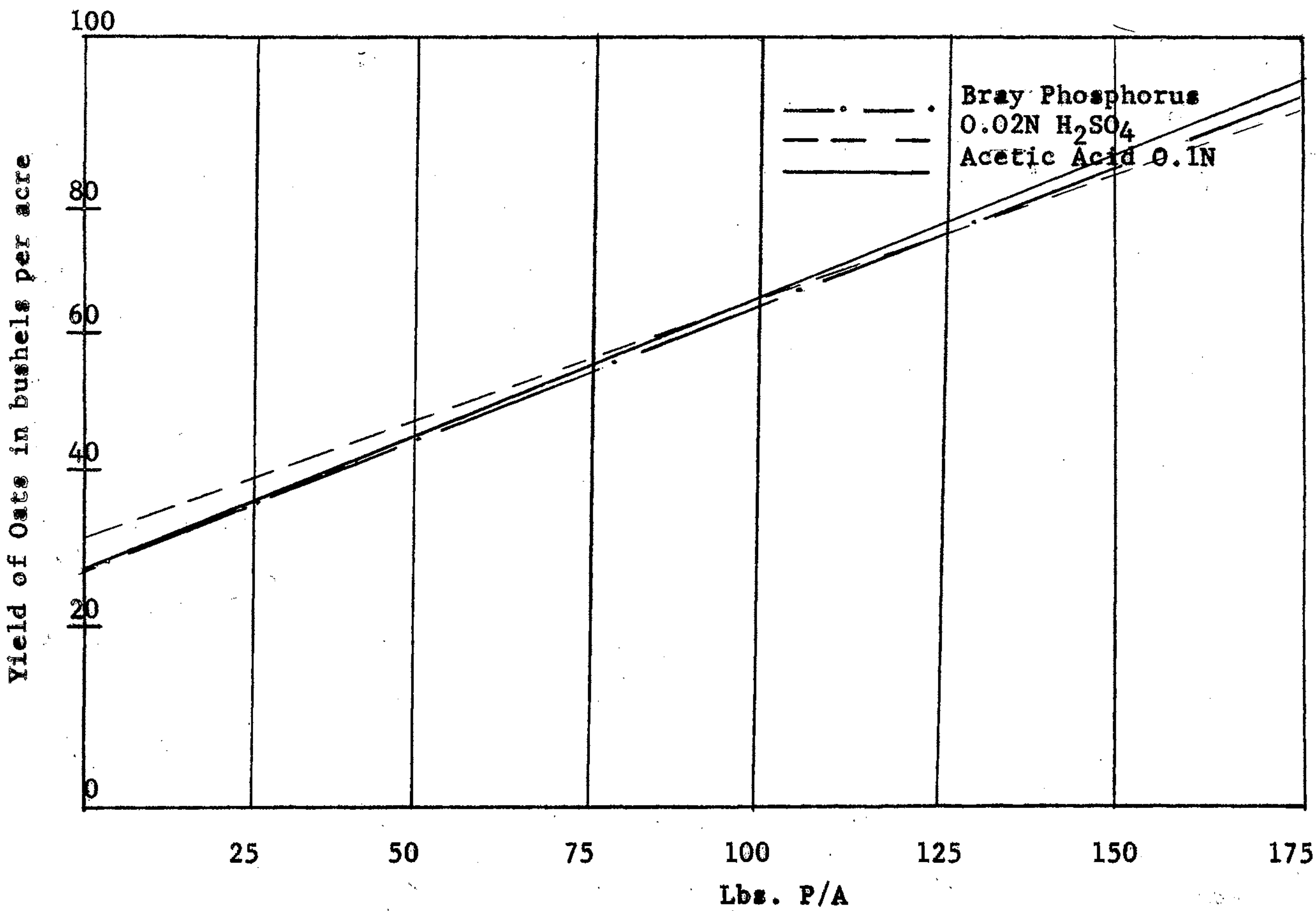
Regression of soil phosphorus on yield of wheat with no Phosphorus treatment, with and without Nitrogen and Potassium.

Figure 4



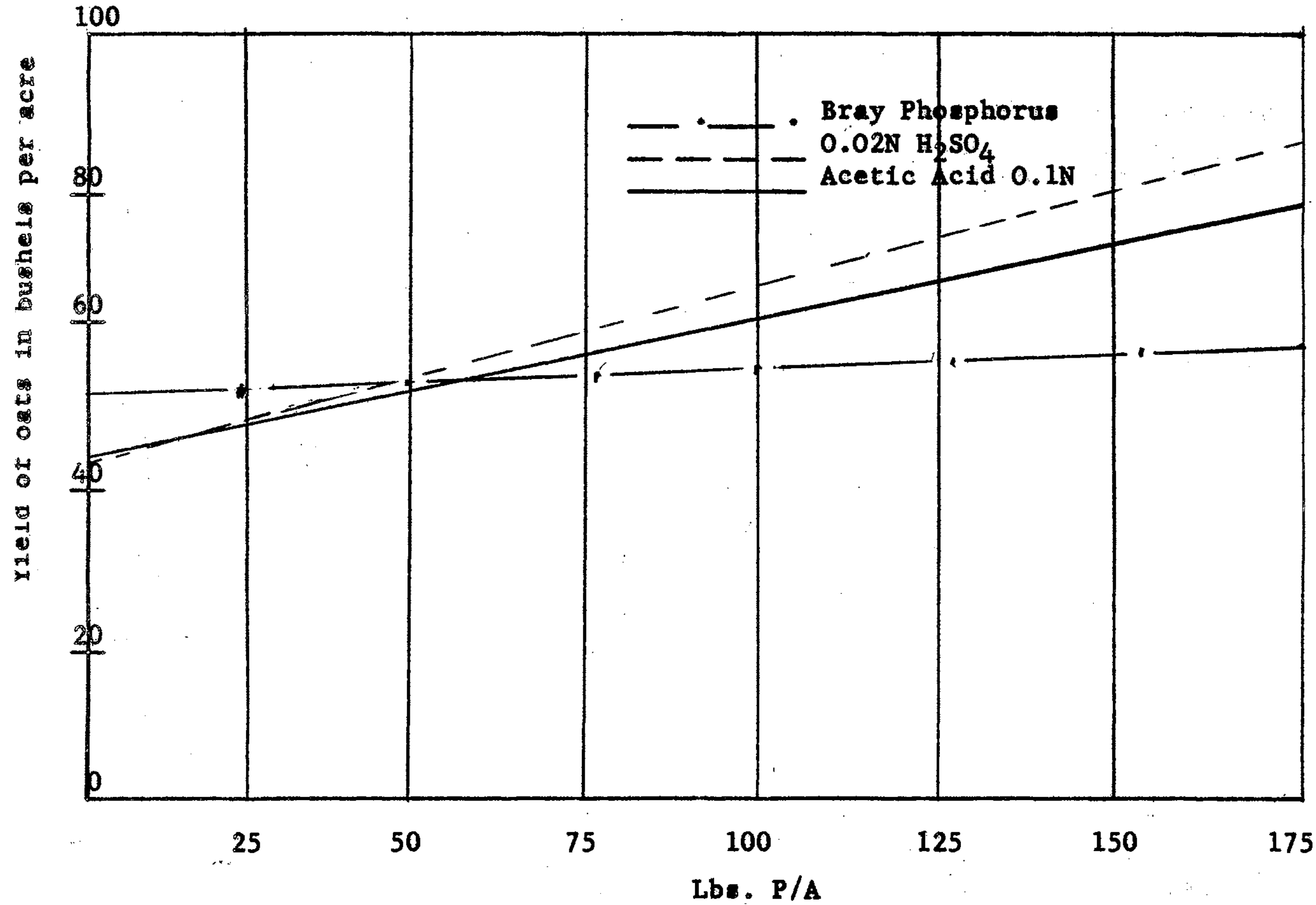
Regression of soil phosphorus on yield of wheat with 40-60 lbs. of P_2O_5 fertilizer per Acre with and without Nitrogen and Potassium.

Figure 5



Regression of soil Phosphorus on field of oats with no Phosphorus treatment with and without Nitrogen and Potassium.

Figure 6



Regression of soil phosphorus on yield of oats with 40 lbs. of P_2O_5 fertilizer per acre with and without Nitrogen and Potassium.

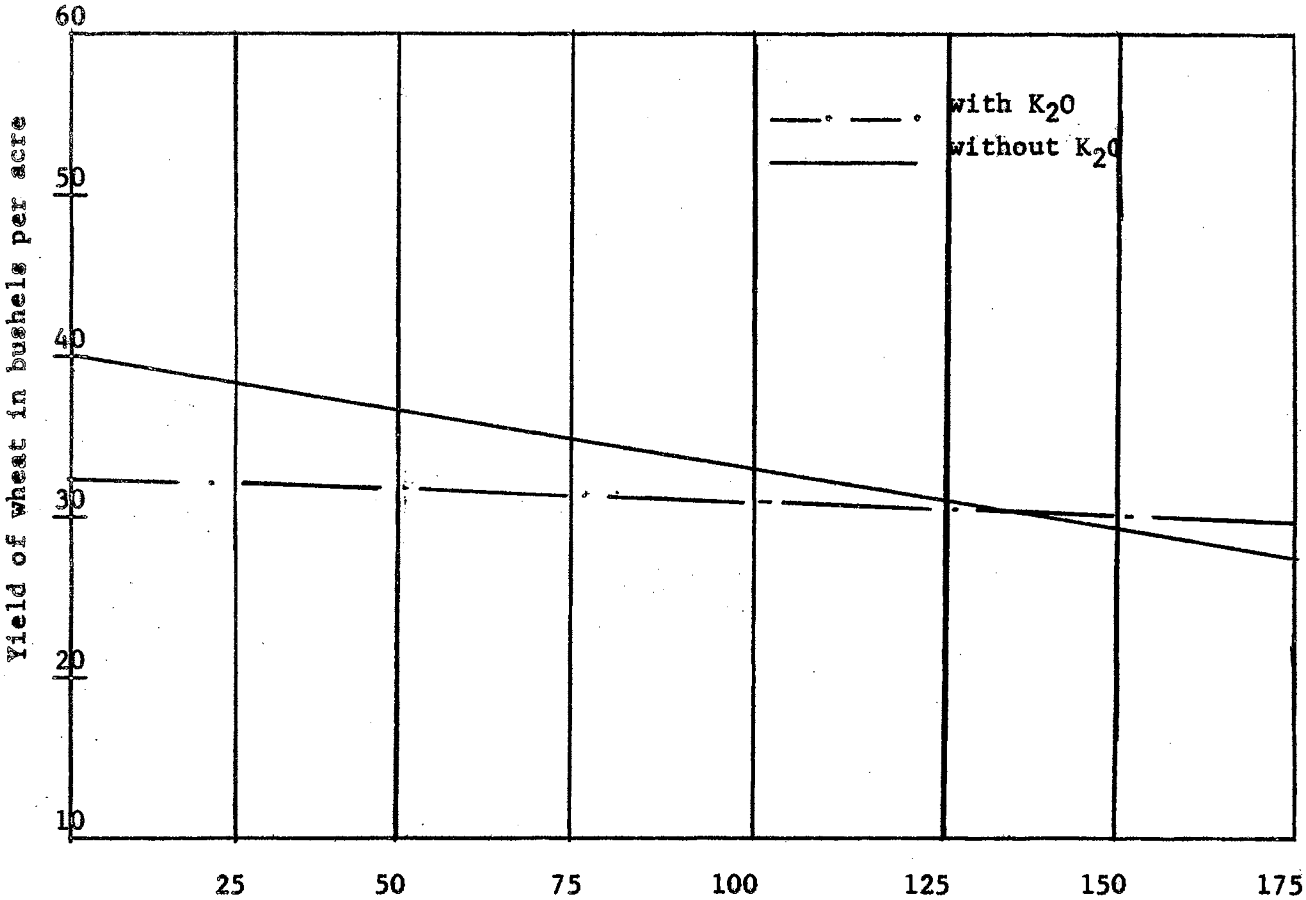
TABLE II

STATISTICAL DATA FOR SOIL POTASSIUM AS DETERMINED BY AMMONIUM ACETATE EXTRACTION VERSUS REGRESSION ANALYSIS

	Fertilizer Treatment	Crop Plant	Y = a + bx	rxy	S yx
1.	No Potassium	Corn	15.95 + .152x	.432 **	14.69
2.	40-60 # K_2O/A	Corn	29.26 + .049x	.109 NS	15.60
3.	No Potassium	Oats	76.73 - .256x	.357 *	24.58
4.	40-60 # K_2O/A	Oats	55.24 - .127x	-.380 NS	15.17
5.	No Potassium	Wheat	37.10 - .074	.148 NS	7.20
6.	40-60 # K_2O/A	Wheat	32.32 - .025	.338 NS	29.21

** Correlation Coefficient, 1% Level of Significance
* Significant Correlation Coefficient, 5% Level of Significance
NS Not Significant Correlation Coefficient

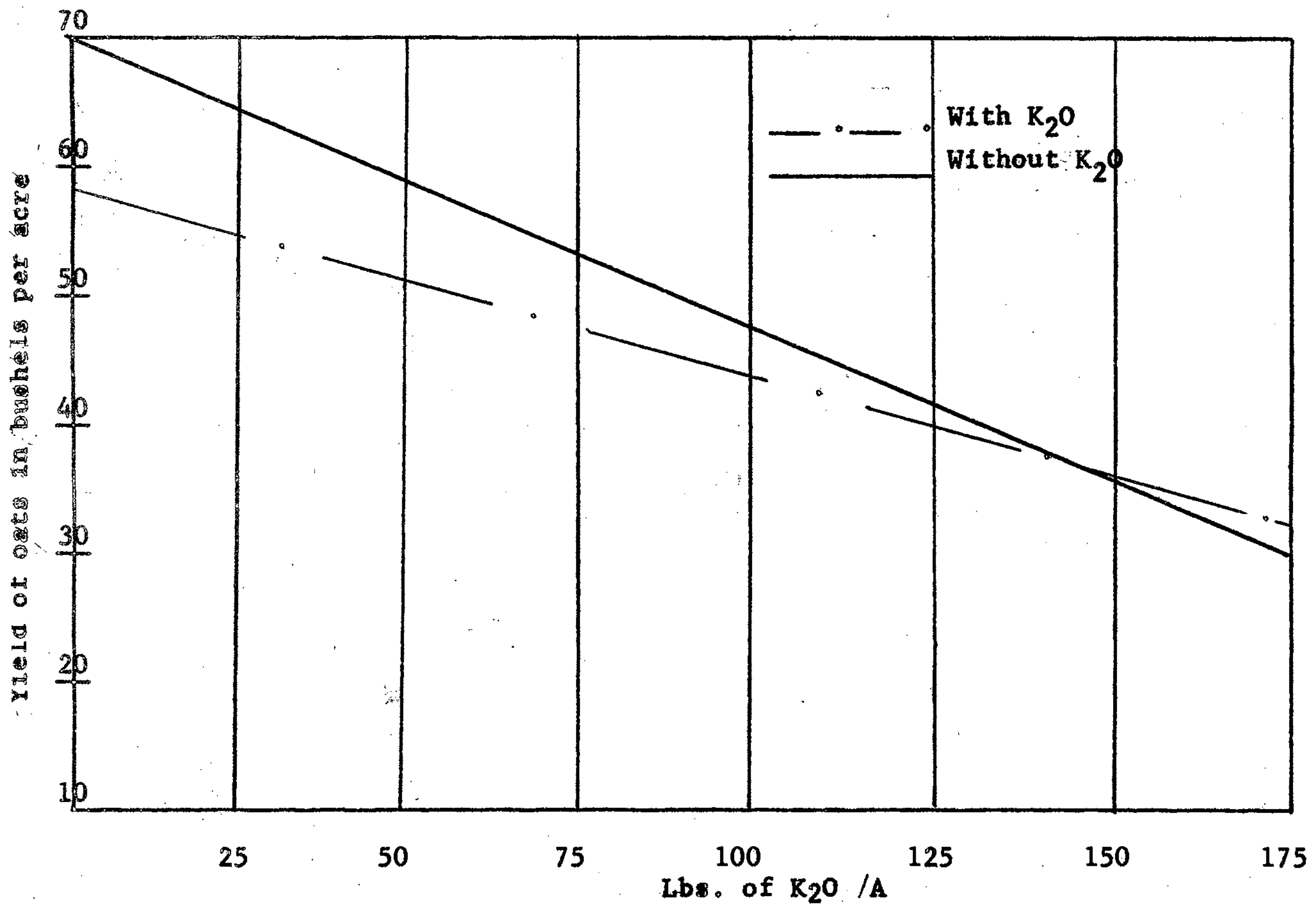
Figure 7



Lbs. of K_2O /A

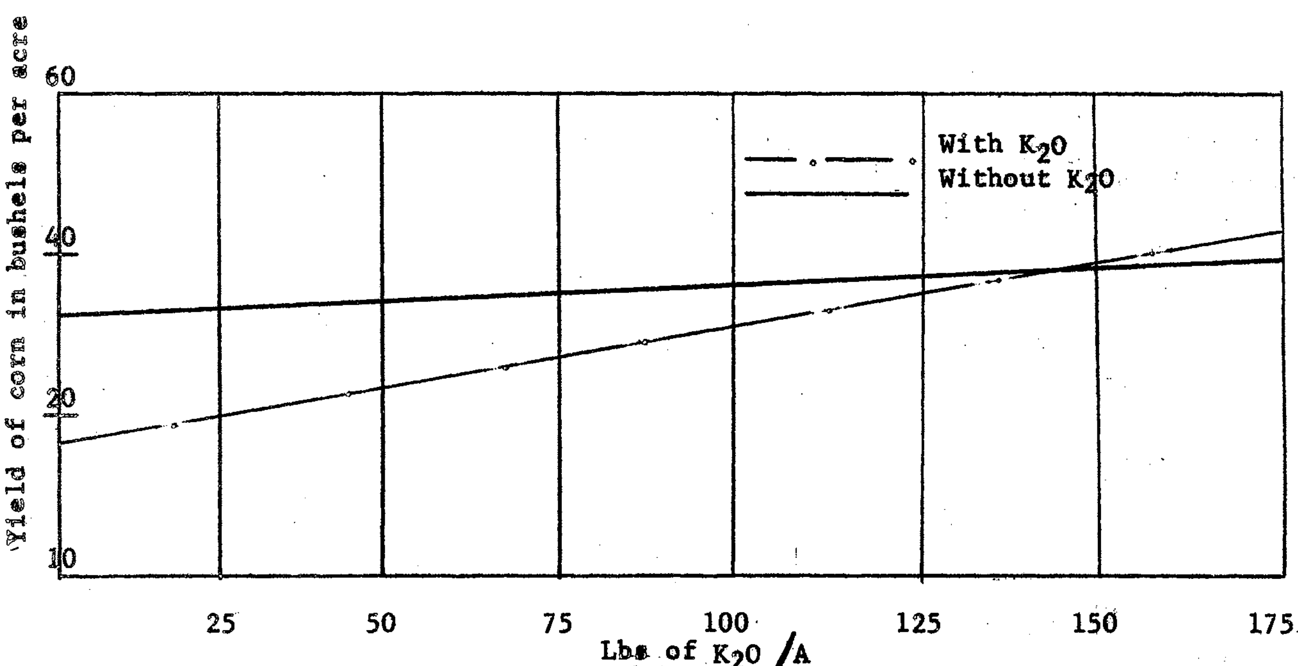
Ammonium Acetate Soluble Potassium of soils versus Wheat yield treated with variable amounts of Nitrogen and Phosphorus. Regression of analysis of K_2O experiment.

Figure 8



Ammonium Acetate Soluble Potassium of soils versus Oat yield treated with variable amounts of Nitrogen and Phosphorus. Regression analysis of K_2O experiment.

Figure 9



Ammonium Acetate Soluble Potassium of soils versus Corn yield treated with variable amounts of Nitrogen-Phosphorus. Regression of analysis of K_2O experiment.

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A P P E N D I X

SOIL TYPES STUDIED, THEIR NUMBER AND LOCATION

	SOIL TYPE	SAMPLE #	COUNTY
1.	Bates very fine sandy loam	75, 109	McClain & Lincoln
2.	Bates silt loam	32, 121	Craig & Pawnee
3.	Bowie fine sandy loam	1-5,131-176,179-181,65	Atoka & Choctaw
4.	Canadian fine sandy loam	49-61	Ellis
5.	Choctaw loam	9-30	Bryan
6.	Choctaw silt loam	91	Mayes
7.	Dougherty fine sandy loam	62	Johnston
8.	Dennis silt loam	34-5, 42, 114-119, 125	McClain, Pawnee Craig, Wagoner
9.	Durant sandy loam	13, 20	Bryan
10.	Miller Clay	66, 73, 76	Lincoln, Johnston
11.	McClain silt loam	78	Lincoln
12.	Norge fine sandy loam	182-190	Payne
13.	Norge silt loam	104	Noble
14.	Okemah silt loam	92	McIntosh
15.	Parsons silt loam	36-41, 86-1, 113, 123, 130	Ottawa, Wagoner Craig, Mayes
16.	Parsons very fine sandy loam	103	McIntosh
17.	Port very fine sandy loam	25, 71, 77, 120 124	Pawnee, Wagoner Bryan, Lincoln
18.	Port silt loam	80-82	Lincoln
19.	Port loam	70, 79	Lincoln
20.	Port silt clay loam	21	Bryan
21.	Port clay loam	22	Bryan

	SOIL TYPE	SAMPLE #	COUNTY
22.	Pratt loamy fine sand	46	Caddo
23.	Pratt fine sandy loam	43	Major
24.	Prague sandy loam	69	Lincoln
25.	Reinach sandy loam	19	Bryan
26.	Reinach very fine sandy loam	23	Bryan
27.	San Saba Clay	26-29	Bryan
28.	Stephenville fine sandy loam	68	Lincoln
29.	Stidham fine sandy loam	98-102	McIntosh
30.	Summit clay loam	43	Craig
31.	Taloka silt loam	90, 128-9	Mayes, Wagoner
32.	Teller fine sandy loam	63	Johnston
33.	Trinity clay	6	Bryan
34.	Verdigris silt loam	106	McClain
35.	Vanoss very fine sandy loam	64	Johnston
36.	Vanoss silt loam	105	McClain
37.	Verdigris very fine sandy loam	127	Wagoner
38.	Wilson sandy loam	7, 15, 17	Bryan
39.	Wilson clay loam	10-12	Bryan
40.	Woodson silt clay loam	122	Tulsa
41.	Yahola very fine sandy loam	18, 24	Bryan

VITA

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Master of Science

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