A CORRELATION STUDY OF SOIL TEST PHOSPHORUS VALUES AND WHEAT PRODUCTION

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A CORRELATION STUDY OF SOIL TEST PHOSPHORUS

VALUES AND WHEAT PRODUCTION

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CHAPTER I

INTRODUCTION

The study of soil characteristics is an important area of study in agriculture. A major portion of the supply of nutrient elements for plant growth comes from the soil. These facts have been known for almost one-hundred years, but due to their importance they should be constantly re-emphasized if the study of soils is to be remunerative.

Among the major elements, nitrogen, phosphorus and potassium are usually deficient in agricultural soils; therefore, these deficiences are overcome by the use of fertilizers to improve the fertility of the soil. It has long been known that phosphorus is a most important nutrient element for plant growth, and the rate of phosphorus absorption by the plant is often the first limiting factor of plant nutrition. Phosphorus in a highly soluble form and available for plant use is usually not stable, and is found in the soil as a soluble ion in very small amounts because it readily changes from a soluble to an insoluble form by combining with other elements.

The levels of soil fertility have been diagnosed and predicted according to the content of soil phosphorus soluble in dilute acid, base or salt solutions. These techniques are essentially the totality of those used in soil testing. Probably each soil test procedure removes more of one soil phosphorus fraction than some other technique.

The purposes of this study were:

1. To compare methods for the determination of easily soluble soil phosphorus.

2. To determine the correlation coefficients between wheat grain yield and the phosphorus extracted from soils by three different soil test methods.

3. To compare the response of the wheat plant to different levels of phosphorus fertilizers that had been applied to a Grant-Pond Creek soil for several years.

CHAPTER II

LITERATURE REVIEW

There are many methods used to extract easily soluble phosphorus from the soil. Most extracting solutions are mineral acids. The suitability of the extracting solutions is dependent on the types of soil and forms of phosphorus present in each soil type. It may be assumed that the quantity of available phosphorus in the extract is increased with the acidity of the extracting solution; however, side reactions often limit the ability of stronger acid solutions to extract more phosphorus. Substantial variations of the content of phosphorus in extracting solutions has occurred when the same soil is extracted with different extracting solutions; i.e., by different soil tests.

For paddy soils according to Samonite and Mamaril (22)[1] the Ayers and Hagihara (1) method (0.002 N H_2SO_4) extracted the largest quantity of phosphorus among several methods studied which included the Bray #1 (2, 8), Bray #2, (2, 8), Olsen (17) and the Morgan and Peech (16) methods. Robinson and Holmes (20) found that there was more phosphorus in the colloidal soil fraction than was present in the remainder of the whole soil. Susuki et al. (25) determined the correlation between the soil phosphorus fractions and easily soluble phosphorus as a measure of the efficiency of the different extractants. Sillanpaa (23) reported

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[1] Numbers in parentheses refer to literature cited.

that the phosphorus extracted from the soil was a linear function of the amount of phosphorus added as a fertilizer. He concluded that the increase of phosphorus extracted from the soil was due to phosphorus fertilizer application alone. Breland and Nesmith (4) reported on the concentrations of sulfuric acid, ammonium molybdate and stannous chloride as they affected the development of the "Dineges Blue" color and which combination of reagents gave the maximum color development for soil phosphorus. Reagent concentrations of 1.0 N sulfuric acid, 0.3 - 0.5% ammonium molybdate and 0.00625% stannous chloride gave the best results for the soils studied.

Miller and Axley (16) reported that their proposed method extracted the highest quantity of phosphorus compared to the modified Truog (22), Bray #1 (2) and the sodium bicarbonate method of Olsen (17). Smith (24) reported the 0.5 M sodium bicarbonate method of Olsen extracted more phosphorus from the calcareous soils of Western Kansas than the Bray methods. Garboucher (10) studied five methods for the determination of easily soluble phosphorus. He found that all five methods studied gave striking differences in the amounts of soluble phosphorus in the soil; the most sensitive methods studied were the methods where 0.01 M calcium chloride and E.D.T.A. were used as extractants. The Olsen (17) and Egner (9) methods gave differences that were similar to those obtained from anion exchange resins. The Egner-Riehm method was the least sensitive method studied in the experiment.

Many experiments have been performed with the objective to compare phosphorus fertilization and wheat production. All of these experiments tended to correlate the crop yield and the amount of phosphorus fertilizers that had been added to the soil. The results of these experiments have varied from no response to very large response.

Vajragupta, Haley and Melsted (27) reported that the Bray #2 soil phosphorus test method for the determination of easily soluble soil phosphorus gave the highest correlation between grain yield for paddy soils in Thailand and phosphorus fertilization of several methods studied. Samonite and Mamaril (22) studied the forms of phosphorus in Illinois soils. They reported that almost 100% of the fertilizer phosphorus added to these soils was extracted by the Chang and Jackson (6) procedure and gave a high correlation with the amount of phosphorus fertilizers that were added to the soils. Smith (24) found that the Bray #1 method used to extract the calcareous soils of Western Kansas gave the highest correlation between the quantity of phosphorus extracted and the percentage increase in yield of wheat over several methods studied which included the Olsen (17) method and several variations of the Bray methods. Webb, Black, Smith and Pesek (29) conducted a number of experiments concerning an evaluation of the residual effects of phosphorus fertilization, by both the laboratory and plant-response methods in the greenhouse. They studied three soils types and extracted the easily soluble phosphorus by several methods. The best correlation statistic was obtained between plant yield and the Bray method; the second best method was the anion-exchange resin (29) and the third best method was the sodium bicarbonate procedure of Olsen (17).

It has long been known that many factors influence crop yields in addition to the phosphorus fertility of the soil. The major factors are probably climatic and agronomic. These factors control the utilization of phosphorus fertilizers.

Power, Grunes, Reichman and Willis (18) conducted an experiment on the fertilization of two soils with temperature control as a variable. They reported that the extractable soil phosphorus was lower at temperature above 59°F. than below this temperature. Mack and Barber (15) studied the effect of temperature on release of phosphorus from several soil phosphorus fractions. They found that phosphorus released at 30°C. was higher than that released at lower temperatures and that leaching at 32°C. resulted in loss of acid soluble phosphorus and an increase in alkali soluble phosphorus (iron phosphate). Robertson and Hutton (19) studied the retention of fertilizer elements by soil and the effect of cropping on the forms of phosphorus in soil.

Griffin (11) reported on the placement of phosphorus fertilizer as affected by soil moisture conditions. He reported soil moisture played a major role in the solubility of soil phosphorus. Dev (7) conducted an experiment to study the effect of nitrogen fertilizer on the efficiency of fertilizer phosphorus. He reported that urea fertilizer increased the solubility of phosphorus fertilizers.

Walker and Adams (28) found that the total and organic phosphorus in a soil decreased with depth. This was found to be most important for explaining the higher phosphorus levels in a grassland soil. Bates and Baker (3) also found that large amounts of the total phosphorus in a soil tended to be accumulated in the surface soil.

La Mare (14) studied plant response on cultivated and uncultivated soils in an attempt to prepare a response curve for yield versus soil phosphorus. He reported that phosphorus fertilizer caused large increases in yield on both soils studied. The maximum yield increases were obtained from uncultivated soil as compared to cultivated soils. Jordan _et al._ (12) reported that the uptake of soil phosphorus from fertilizer was greater at low moisture tension than at high moisture tension.

Rod and Vondracer (21) studied the plot edge effect on some plant yield variables. Their report concerned the experimental and treatment and they determined that the distance between field plots affected the yield response. Brown et al. (5) studied phosphorus fertilization of dryland spring and winter wheat on soils of the Brown Soil zone.

Smith et al. (24) studied the effect of fertilizer on the yield and quality characteristics of Hard Red Winter Wheat. They reported that the source of phosphorus did not cause significant variation in the per cent of yield increase.

This review has attempted to show some of the variables that have been studied in the development of soil testing for phosphorus. It has also attempted to review some of the pertinent reports that have been published on the response of crop plants to phosphorus fertilizers and native soil phosphorus grown on different soils.

CHAPTER III

MATERIALS AND METHODS

The soil studied in this report is known as the Pond Creek Silt Loam, however, it may be closer to a Grant-Pond Creek complex. A detailed description of the Pond Creek Silt Loam soil is included in the Appendix of this report. The soil samples for this study were collected from the Oklahoma Wheatland Conservation Experiment Station of the Oklahoma State University Department of Agronomy Farm at Cherokee, Oklahoma. A detailed description of physical and chemical properties of this soil is given in Tables I and II.

This experiment was established in 1963[1] and yield data has been collected each year. The size of the experimental plots is 20 x 110 feet and the treatments were replicated four times in a randomized block experimental design. For the study reported here each replicate plot was divided in ten sub-plots as shown in Figure 1. For each sub-plot ten samples were taken at random to make a composite. Each sub-plot was sampled at two depths namely from 0-15 cm. and from 15-30 cm. The soil samples were collected with a 2 x 25 cm. soil tube at random locations within each sub-plot. Ten topsoil samples and ten subsoil samples were collected from each sub-plot and each of these samples represented ten borings. A total of four hundred soil samples were collected

[1]Plots established by Dr. B. B. Tucker. The author is grateful for his permission to sample this experiment.

TABLE I

CHEMICAL PROPERTIES OF GRANT-POND CREEK SILT LOAM
FROM THE WHEATLAND RESEARCH STATION
CHEROKEE, OKLAHOMA[1]

Lab No.	3219	3220	3221	3222	3223
Depth, Cm.	0-13	13-30	30-50	50-90	90-120
Horizon	Ap	A_{12}	A_3	B_2	C
pH, Paste	6.15	6.00	6.60	7.40	7.50
pH, 1:1 KCl	5.50	4.95	5.80	6.60	6.60
CEC, m.e./100 gm.	8.24	8.57	10.76	11.42	10.24
Extractable Cations					
m.e./100 gm.	10.43	12.94	17.11	22.34	21.10
Calcium	5.00	6.20	8.65	11.10	9.85
Magnesium	4.25	5.50	7.66	10.41	10.41
Potassium	1.00	0.76	0.61	0.56	0.53
Sodium	0.08	0.08	0.13	0.17	0.21
% Base Saturation	125.36	146.32	158.46	194.75	205.09
% Organic Matter	1.46	1.33	1.24	1.01	0.63
% Carbon	0.85	0.77	0.72	0.59	0.37
% Nitrogen	0.07	0.07	0.07	0.06	0.06
% Free Fe_2O_3	0.43	0.45	0.53	0.66	0.06
PPM, Total P	300.00	295.00	300.00	220.00	156.00
PPM, Organic P	115.00	115.00	125.00	80.00	36.00
PPM, Al-P	18.75	7.47	2.81	2.20	4.06
PPM, Fe-P	13.75	9.38	6.88	5.00	7.81
PPM, Ca-P	107.50	97.50	87.50	44.50	22.50
PPM Reductant					
Soluble Fe-P	46.25	60.26	81.25	85.94	78.75
PPM Occluded Fe					
and Al-P	3.75	5.00	6.25	7.81	8.75

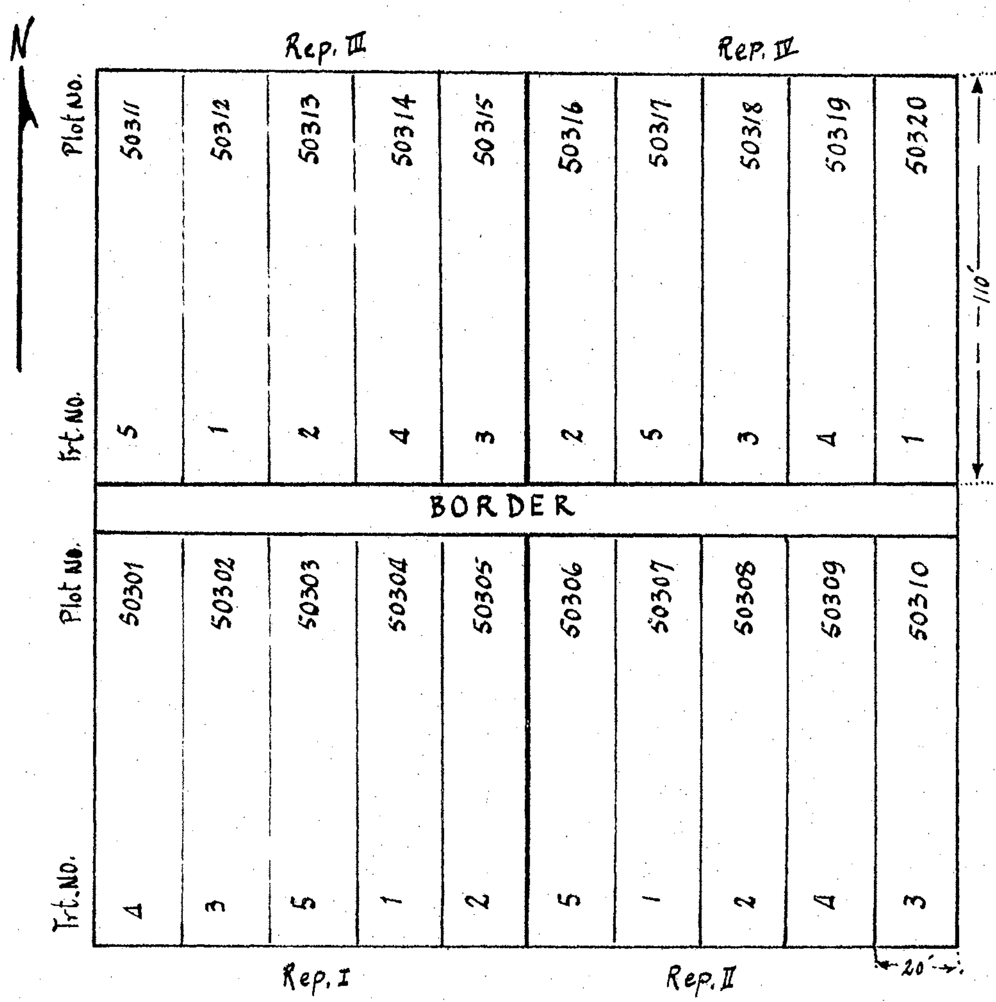
[1]Ohiaeri, G. E. C. The Distribution of Soil Phosphorus Compounds in Some Representative Soils of Oklahoma. Master of Science Thesis, Oklahoma State University, 1963.

TABLE II

SOME PHYSICAL PROPERTIES OF GRANT-POND CREEK SILT LOAM FROM THE WHEATLAND RESEARCH STATION CHEROKEE, OKLAHOMA[1]

Lab No.	32.9	3220	3221	3222	3223
Depth, Cm.	0-13	13-30	30-50	50-90	90-120
Horizon	Ap	A_{12}	A_3	B_2	C
Particle Size Distribution in %					
Clay 2u	10	14	18	25	23
Silt 2-50u	36	37	39	32	29
Sand 50u	54	49	43	43	48
Textural Class	S. loam	loam	loam	loam	loam

[1]Ohiaeri, G. E. C. The Distribution of Soil Phosphorus Compounds in Some Representative Soils of Oklahoma. Master of Science Thesis, Oklahoma State University, 1963.



Treatment of Phosphorus Fertilizer Application
Trt. No. 1 = zero (check plot)
2 = 20 lbs/A
3 = 40 lbs/A
4 = 80 lbs/A
5 = 600 lbs N. 300 lbs P_2O_5 and 100 lbs K_2O lbs/A

Figure 1. Plot Plans for Experiment 503 on Which the Wheat Experiments Were Conducted.

immediately after the wheat was harvested in June of 1967. The soil samples were air dried, crushed, passed through a twenty mesh sieve and stored in one-half pint paper cartons.

The fertilizer treatments for these plots were started in 1963. Plots 1, 2, 3 and 4 received variable annual applications of phosphorus fertilizer and an annual application of fertilizer nitrogen applied at the rate of 40 pounds of nitrogen per acre per year applied as ammonium nitrate. The variable in these treatments was as follows:

1. Treatment # 1 - no phosphorus.
2. Treatment # 2 - 8.8 pounds elemental phosphorus applied as treble superphosphate.
3. Treatment # 3 - 17.6 pounds of elemental phosphorus applied as treble superphosphate.
4. Treatment # 4 - 35.2 pounds of elemental phosphorus applied as treble superphosphate.
5. Treatment # 5 - 600 pounds of nitrogen as ammonium nitrate, 134 pounds of elemental phosphorus applied as treble superphosphate and 83 pounds of elemental potassium applied as muriate of potash. This treatment was applied at the beginning of the experiment in 1963 with no further additions of fertilizer made on this plot.

It is to be noted that treatment five was radically different from the other treatments and consisted of only one treatment made at the beginning of the experimental period in 1963. All other plots received an annual application of nitrogen and variable amounts of phosphorus each year.

The three soil test procedures studied were the "Weak Bray" or

Bray #2, (2), "Strong Bray" or Bray #1 (2), and the Olsen (13) or sodium bicarbonate method. The detailed procedure for these three soil test methods is given in the Appendix.

Wheat yield data were obtained for the six year interval 1963-1968[2]. These yields were used as a basis for comparing soil test values with yield.

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[2]The author is grateful to Mr. Eldon Greer, Superintendent of the Wheatland Experiment Station, for supplying wheat yield and weather data.

CHAPTER IV

RESULTS AND DISCUSSION

The variation of available phosphorus test values reported in this experiment was probably caused by many factors. The major factors causing variation between soil test values and plant yield (grain yield of wheat) were probably climatic and agronomic factors such as variety, time of tillage, and disease and insect infestation. Other factors were probably field sampling errors, laboratory manipulation and sampling errors and instrumentation errors. Other factors which may influence variation might be method of fertilizer treatment application and erosion, etc.

The analysis of variance for the easily soluble phosphorus soil test values is given in Table III and Figure 2. The variation in soil phosphorus test values among replicate plots were significant at the 5% level. The variation for treatments were significant at the 5% level which indicates that phosphorus by soil test increased with phosphorus fertilization. The data on soil phosphorus treatments versus soil test values varied significantly at the 5% level and approached a higher level of significance than the variation among replicates. The variation between surface-soil and sub-soil were significant at the 5% level which indicate that phosphorus fertilizer does not move into the sub-surface layer of the soil except by tillage. These plots were never plowed except by stubble mulch tillage which involves a sweep

TABLE III

ANALYSIS OF VARIANCE OF AVAILABLE PHOSPHORUS DISTRIBUTION ON THE WHOLE LAYOUT OF THE WHEATLAND EXPERIMENT NO. 503

Source	d.f.	M.S.	Calc. F
Replicate (R)	3	23.3491	5.2854*
Treatment (A)	4	55.5523	12.5752*
Error (a)	12	4.4176	
Depth (B)	1	97.6753	17.3447*
Treatment X Depth (A X B)	4	0.5982	0.1062NS
Error (b)	15	5.6314	
Method (C)	2	388.4775	162.4257*
Method X Treatment (A X C)	8	2.2074	0.9229NS
Method X Depth (B X C)	2	8.3367	3.4858*
Method X Treatment X Depth (C X A X B)	8	0.1612	0.0674NS
Error (C) Exp.	60	2.3916	
Sampling Error	1080	0.5759	
Total	1199		

*Significant at the 5% level.
NS-Not significant at the 5% level.

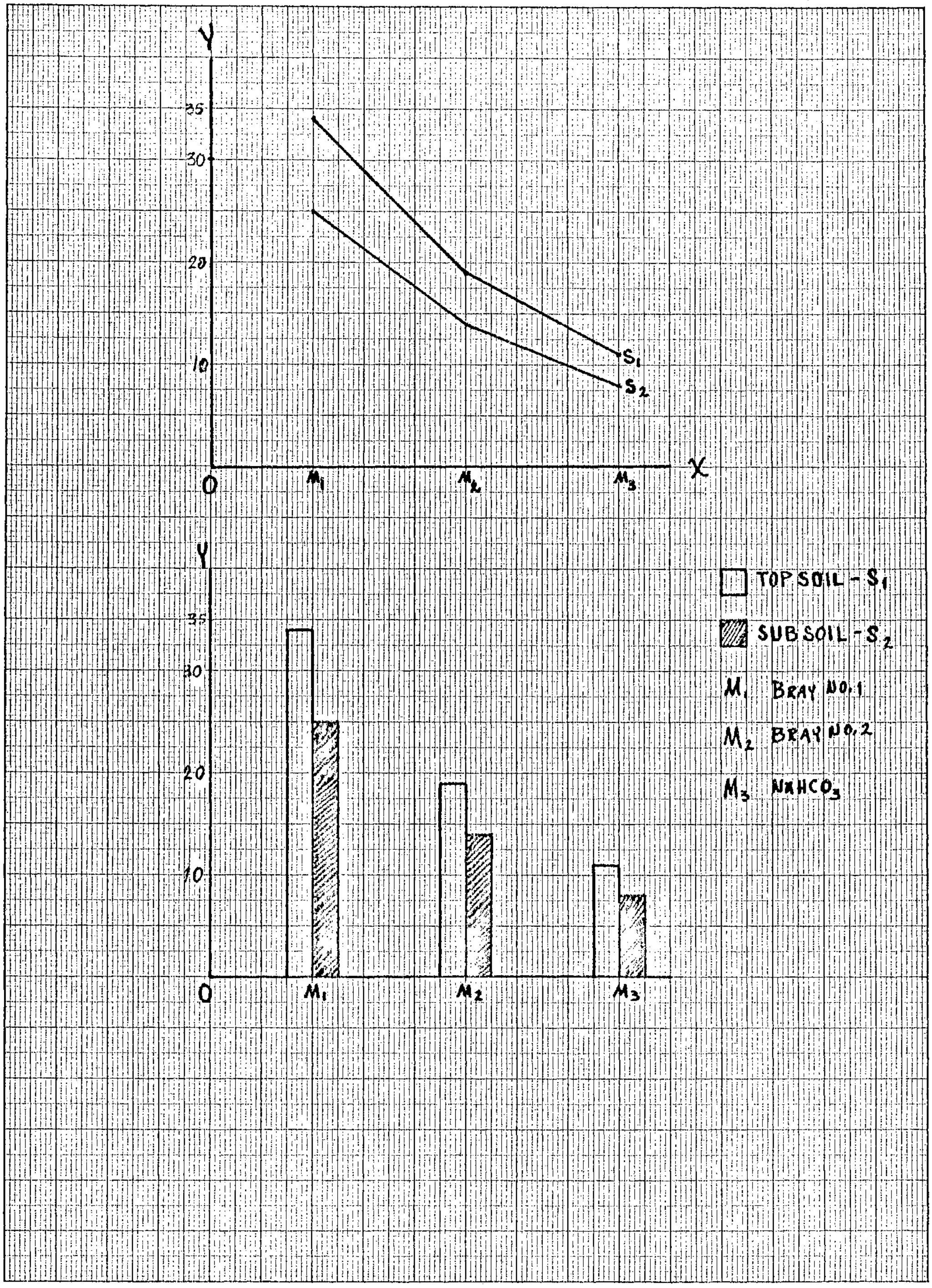

Figure 2. Comparison of Phosphorus Content at Topsoil, Subsoil Between Bray No. 1 Method, Bray No. 2 Method and Sodium Bicarbonate Method.

type knife to kill weeds, therefore, phosphorus had little opportunity to move into the subsurface except through soil cracks and drainage. Some plant roots may absorb phosphorus from the surface soil and translocate it to roots in the sub-surface soil layer and when the plant dies these roots would add to the phosphorus in these soil layers. However, this would be a very slow process and it is doubtful it if would be of any significance in this experiment.

In a comparison of the three methods studied the variations were significant at the 1% level as shown in Table III. The three methods did not vary significantly within treatments. However, the three methods studied differed in the magnitude of significance as shown in Tables IV, V, VI and in Figures 3 through 6. The values for significance at the 5% level of confidence were highest for the sodium bicarbonate extract, next highest for the "Weak Bray" or 0.025 N hydrochloric acid and lowest for the "Strong Bray" or 0.1 N hydrochloric acid. The factor of soil depth is most interesting in that the "Strong Bray" and the sodium bicarbonate extraction gave very high "F" values significant at the 1% level of confidence while the "Weak Bray" was significant at a much lower confidence level for soil depths. This indicates that the "Strong Bray" and the bicarbonate extraction remove a larger amount of phosphorus in regard to treatment from this lower pH layer of the soil. When all data is pooled for the three methods versus yield, the correlations obtained were not significant as shown in Table VII. When all methods were compared with each other there was a highly significant correlation between the "Weak Bray" or Bray #2 and the sodium bicarbonate extraction as shown by Table VIII. The "Strong Bray" or Bray #1 and the "Weak Bray" or Bray #2, did not correlate significantly and

TABLE IV

ANALYSIS OF VARIANCE OF AVAILABLE PHOSPHORUS OBTAINED FROM METHOD NO. 1, BRAY NO. 1

Source	d.f.	M.S.	Calc. F
Total	399		
Rep. (R)	3	41.9342	8.7971*
Treatment (A)	4	17.3970	3.6496*
Error RA (a)	12	4.766884	
Soil Depths (B)	1	75.977	154.3306*
Treatment X Depths (A X B)	4	0.545	1.1070NS
Error (b); RA + RAB	15	0.4923	
Sampling (C)	360	0.4	

*Significant at the 5% level.
NS-Not significant at the 5% level.

TABLE V

ANALYSIS OF VARIANCE OF AVAILABLE PHOSPHORUS
ANALYZED BY BRAY NO. 2 METHOD

Source	d.f.	M.S.	Calc. F.
Rep. (R)	3	7.563	2.2576**
Treatment (A)	4	29.909	8.9280*
Error (a) R X A	12	3.35	
Soil Depths (B)	1	29.609	8.2453*
Treatment X Depths (A X B)	4	0.277	0.0771NS
Error (b) RA + RAB	15	3.591	
Sampling Error (c)	360	0.07	
Total	399		

*Significant at the 5% level.
NS-Not significant at the 5% level.
**Significant at the 1% level.
For soil depths at 1 and 15 d.f., Cal. F. 8.2453 significant at the 5% level but not significant at the 1% level.

TABLE VI

ANALYSIS OF VARIANCE OF AVAILABLE PHOSPHORUS OBTAINED FROM METHOD NO. 3, SODIUM BICARBONATE METHOD

Source	d.f.	M.S.	Calc. F
Rep. (R)	3	1.737	2.212NS
Treatment (A)	4	12.660	16.1273*
Error (a) R X A	12	0.785	
Soil Depths (B)	1	8.761	172.8007*
Treatment X Depths (A X B)	4	0.097	1.9132NS
Error (b) RA + RAB	15	0.507	
Sampling Error (c)	360		
Total	399		

*Significant at the 0.05 level.
NS-Not significant.

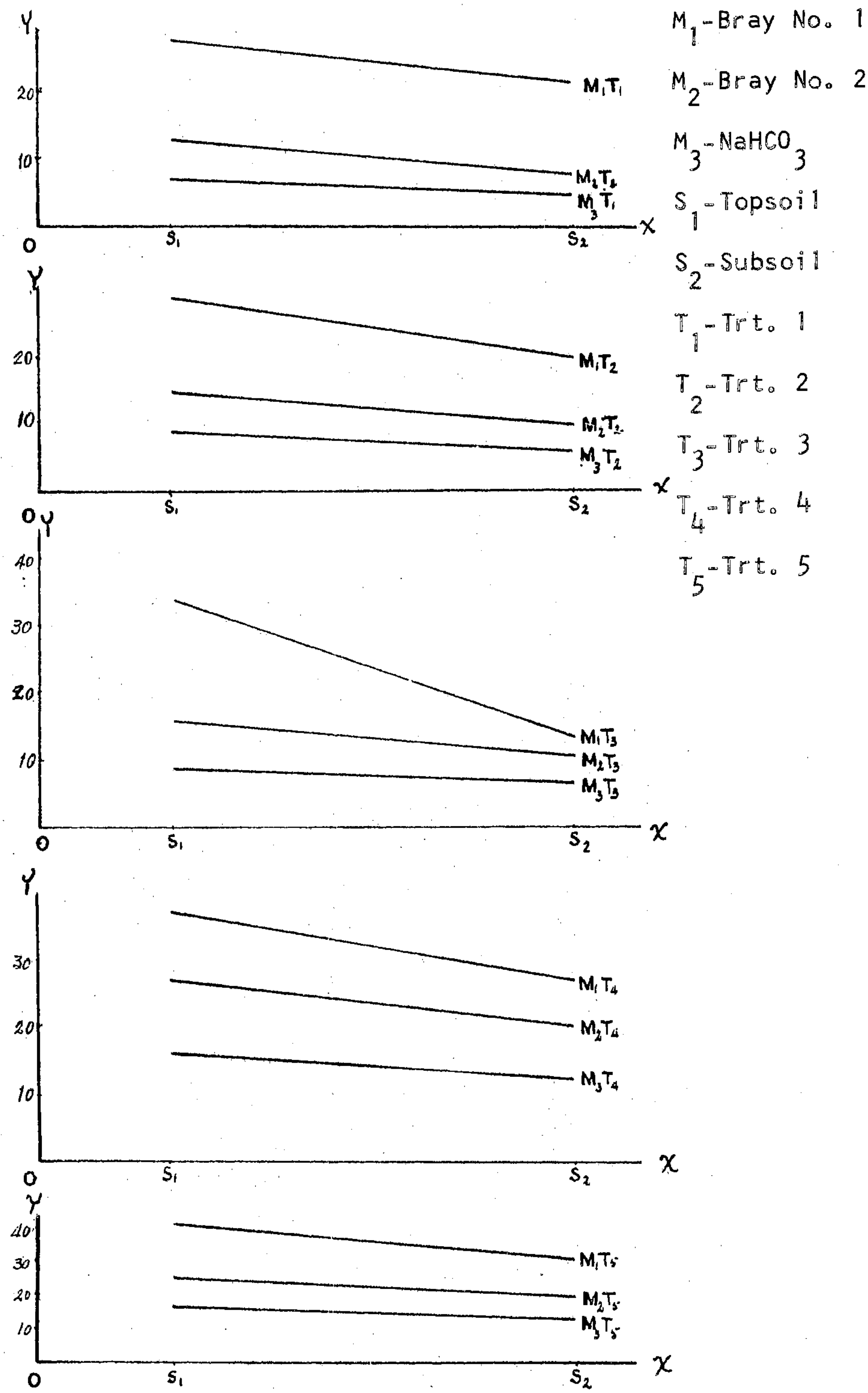

Figure 3. Comparison of P Test Values Between Methods Within Treatment.

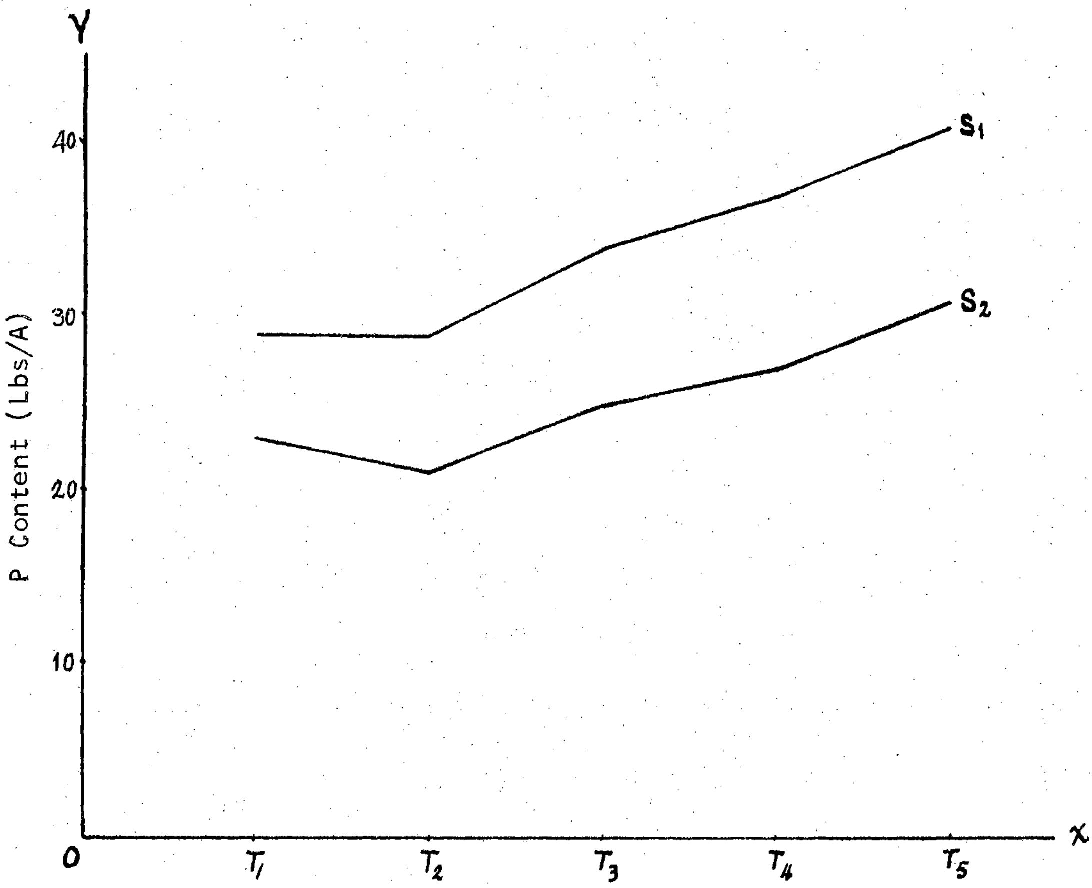

Figure 4. Bray No. 1 Method Soil Phosphorus Test Values Obtained in Five Treatments Versus Soil Depths.

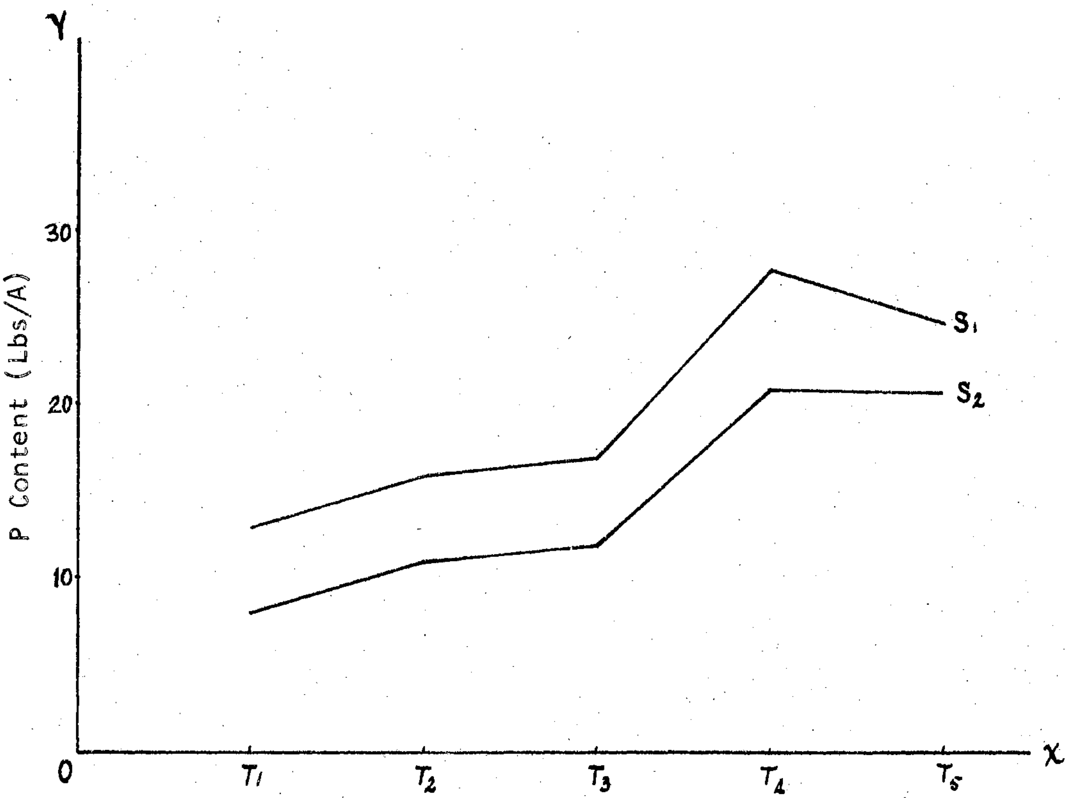

Figure 5. Bray No. 2 Method Soil Phosphorus Test Values Obtained From Five Treatments Versus Soil Depths.

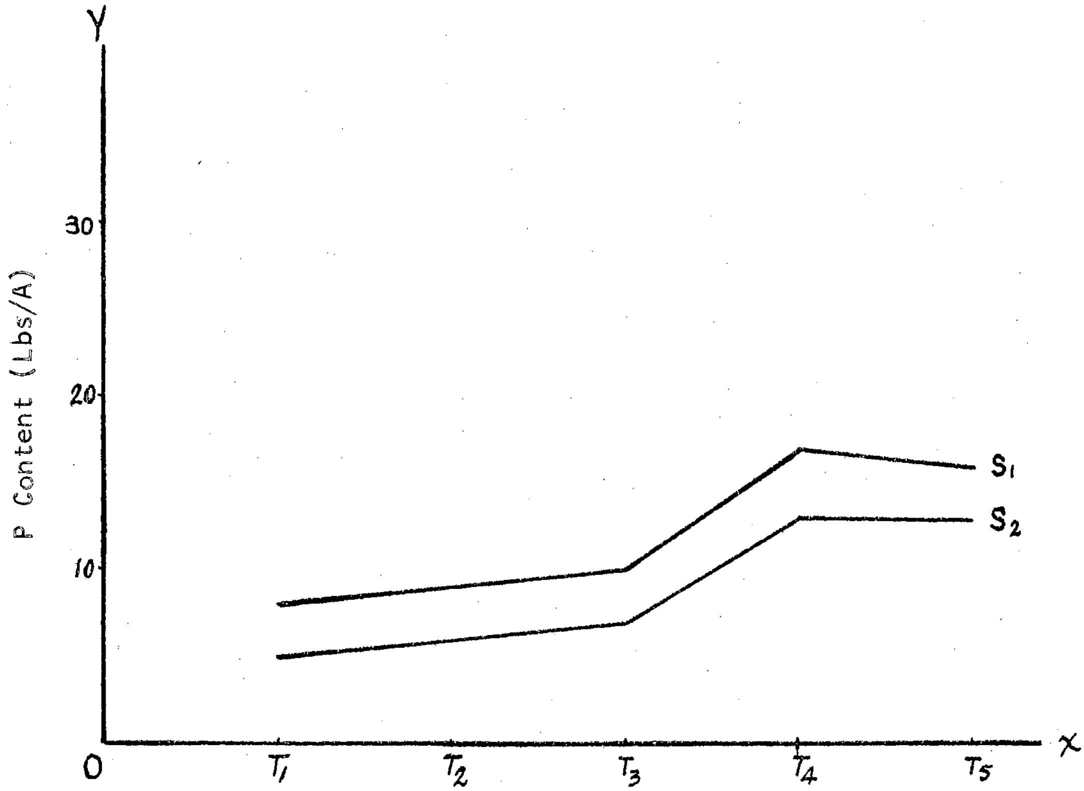

Figure 6. Sodium Bicarbonate Method Soil Test Values Obtained From Five Treatments Versus Soil Depths.

TABLE VII

THE CORRELATION COEFFICIENTS BETWEEN SOIL TEST VALUES OF AVAILABLE PHOSPHORUS AT THE SURFACE SOIL (DEPTH 0"-6") AND THE AVERAGE YIELD OF WHEAT GRAIN

Variables Correlated	Correlation Coefficient Values
Replicate X Treatment X P with 1963 yield	-0.2419
Replicate X Treatment X P with 1964 yield	0.0954
Replicate X Treatment X P with 1965 yield	0.3357
Replicate X Treatment X P with 1966 yield	-0.0140
Replicate X Treatment X P with 1967 yield	-0.2529
Replicate X Treatment X P with 1968 yield	-0.5042

TABLE VIII

CORRELATION COEFFICIENTS OF ANALYSIS OF AVAILABLE PHOSPHORUS BETWEEN BRAY NO. 1 METHOD, BRAY NO. 2 AND SODIUM BICARBONATE METHOD*

Variables Correlated	Correlation Coefficient Values
Bray No. 1 Method X Bray No. 2 Method	0.226692
Bray No. 1 Method X Sodium Bicarbonate Method	0.136230
Bray No. 2 Method X Sodium Bicarbonate Method	0.9320308

*Bray 1, 0.1N HCl + 0.030N NH_4F; Bray 2, 0.025N HCl + 0.030N NH_4F; Sodium carbonate, 0.5M Sodium carbonate.

the "Strong Bray" and the sodium bicarbonate extraction did correlate significantly as shown in Table VIII.

It is also interesting to note that the sodium bicarbonate extraction gave an "F" value below the 5% confidence level for variation between replicates, Table VI and Figure 5, while the two Bray procedures gave a variation between replicates at the 5% level of confidence. However, the difference between the "Weak Bray" and sodium bicarbonate significance for replication was so small that it is probably not meaningful, that is "F" values of 2.2576 and 2.2120 are very close and if one is significant at the 5% level the other is probably significant at the 5.001 level, etc.

The data presented in this report confirms the conclusion that this soil was adequate in phosphorus fertility before fertilizer phosphorus was added. The correlation coefficients between the soil phosphorus test values for the surface soil and wheat yield were highest for 1968 of the years (1963-68) reported. These coefficients are shown in Table VII. However, the correlation obtained had a negative slope. The negative slope was probably due to yields obtained under drought conditions where soil treatment had little or no effect on yield, therefore, the cause of the variation was not one of the factors studied in this report.

CHAPTER V

SUMMARY AND CONCLUSION

In the study reported here about the easily soluble phosphorus content of soil a comparison was made between three soil test methods. Variation between the methods was determined by the use of correlation statistical procedures. A correlation study was also made between the three soil test procedures and yield of wheat grain. The study also attempted to correlate the results obtained by the three soil test procedures studied and soil depth. Variation within plots was also studied by sub-plot soil sampling with the result that a significant statistical variation was obtained.

From this investigation it may be concluded that:

1. Of the three soil test methods for phosphorus studied the sodium bicarbonate and Bray #2 (0.025 N hydrochloric acid + 0.03 N ammonium fluoride) correlated best with soil treatment.
2. The easily soluble phosphorus was high for all methods studied.
3. Large additions of phosphate fertilizer to soil may not always increase crop yields. This is particularly so for soils judged to be adequate to high in soil test phosphorus content.
4. High chemical soil test values for easily soluble phosphorus did not give a high correlation with crop yield.

5. A high chemical analysis soil test value for easily soluble soil phosphorus does not guarantee a high crop yield.
6. Maximum yield is not necessarily guaranteed by supplying one or two deficient nutrient elements. There is a required suitable combination of factors for maximum yield and these factors may include nutrient element supply, rainfall or climatic factors, soil physical or edaphic factors and the proper selection of species and varieties of plants.
7. Small plots of soil may vary considerably in soil test values within a few meters. Therefore, the necessity for composite soil samples is obvious.

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APPENDIX

SOIL PROPERTIES OF EXPERIMENT NO. 503 PLOTS

The soil that was used for this experiment is 3-A Pond Creek Silt Loam, 0 to 1 per cent slopes.

This unit comprises brown and grayish-brown soils with moderate development which occurs on nearly dead flat upland areas. B_2 horizons are non-calcareous and may range in texture from clay loam to silty clay loam. The B_2 horizon is less reddish, heavier, and has a stronger, more blocky structure than the B_2 of the Grant silt loam. Small areas of Grant silt loam occur in this unit. The Pond Creek soils are well drained, but their permeability is slower than in the Grant soils.

		Representative profile of Pond Creek silt loam (cultivated S62-OKLA-2-4(4), was described 300' east of center of section 16.
A_1	0" - 18"	Dark brown (10 YR 3/3) silt loam. Brown (10 YR 4/3) dry; weak fine and medium plates crush easily to weak granules; friable, pH 6.5; plowed boundary.
B_1	18" - 26"	Dark brown (7.5 YR 3/4) light silty clay loam, brown (7.5 YR 4/4) dry; compound, moderate medium prismatic and subangular blocky; friable, pH 6.8, clear boundary.
B_2t	26" - 48"	Dark brown (7.5 YR 4/4) silty clay loam; brown (7.5 YR 5/4) dry; moderate medium cubical blocky; firm, ped faces have dark, continuous clay films; a very few gravel particles have been observed; pH 7.0; gradual boundary to next layer.
B_3	48" - 54"	Color as above; silty clay loam; weak medium and coarse blocky; friable.
B_3		pH 7.8; non-calcareous.

Range in Characteristics:

Surface soil depths vary from 14 to 20 inches. B_2 horizons encompass clay loams and silty clay loams and vary from dark brown and brown to dark reddish brown. Surface soil had few gravels.

(STRONG) BRAY #1 SOIL PHOSPHORUS (2) PROCEDURE

Chemical Reagents Used:

1. Extracting solution

   0.1 N HCl = 144 ml. HCl dissolved in 18 liters of dist. H_2O:
   0.03 N NH_4F = 20 gm./18 liters

2. Molybdate solution

   15 gm. $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ dissolved in 300 ml. H_2O + 291 ml. HCl make up to 1 liter.

3. $SnCl_2$

   10 gm. $SnCl_2 \cdot 2H_2O$ + 25HCl

4. Diluted $SnCl_2$ - ½ml. $SnCl_2$ diluted to 165 ml. with H_2O

Preparation of Extract:

1. Weigh out 1 gram of soil in a 125 ml. Erlenmeyer flask.
2. Add to the soil 20 ml. extracting solution.
3. Stopper and shake for 5 minutes on wrist action shaker.
4. Filter into test tube using Watman #2 filter paper.

Turn on Bausch and Lomb Spectrophotometer to warm up while samples are filtering. Set scale at 700 mu and a red filter. Optical density (O.D.) will be read for each sample.

Test Procedure - Color Development

(Reagent Blank)	Samples (Unknown)
7 ml. H_2O	2 ml. extract
2 ml. Molybdate Sol.	5 ml. H_2O
1 ml. $SnCl_2$	2 ml. Molybdate Sol.
	1 ml. $SnCl_2$

$SnCl_2$ is a reducing agent. It is not stable for more than 2 to 3 hours so must be made up fresh each time test is run. Dilute ½ml. $SnCl_2$ (stock) to 165 ml. with distilled H_2O. Since the $SnCl_2$ develops the color it must be added last. Read each sample within 5 to 20 minutes after $SnCl_2$ has been added. Calculations: O.D. X 377 = #/A of available phosphorus.

(WEAK) BRAY #2 SOIL PHOSPHORUS (2) PROCEDURE

Chemical Reagents Used:

1. Extracting solution

   0.025 N HCl - 36 ml. HCl/18 liters
   0.03 N NH_4F - 20 gm./18 liters

2. Molybdate solution

   15 gm. $(NH_4)_6Mo_7O_{24} \cdot 4 H_2O$ dissolved in 300 ml. H_2O + 291 ml. HCl. make up to 1 liter.

3. $SnCl_2$

   10 gm. $SnCl_2 \cdot 2 H_2O$ + 25 ml. HCl

4. Diluted $SnCl_2$ - ½ml. $SnCl_2$ diluted to 165 ml. with H_2O

Preparation of Extract:

1. Weigh out 1 gram of soil in a 125 ml. Erlenmeyer flask.
2. Add to the soil 20 ml. extracting solution.
3. Stopper and shake for 5 minutes on wrist action shaker.
4. Filter into test tube using Watman #2 filter paper.

Turn on Bausch and Lomb Spectrophotometer to warm up while samples are filtering. Set scale at 700 mu and a red filter. Optical density (O.D.) will be read for each sample.

Test Procedure - Color Development

(Reagent Blank)	Samples (Unknown)
7 ml. H_2O	2 ml. extract
2 ml. Molybdate Sol$^{\underline{n}}$	5 ml. H_2O
1 ml. $SnCl_2$	2 ml. Molybdate Sol$^{\underline{n}}$
	1 ml. $SnCl_2$

$SnCl_2$ is a reducing agent. It is not stable for more than 2 - 3 hours so must be made up fresh each time test is run. Dilute ½Ml. $SnCl_2$ (stock) to 165 ml. Add Dist. H_2O. Since the $SnCl_2$ develops the color it must be added last. Read each sample within 5 - 20 minutes after $SnCl_2$ has been added. Calculations: O.D. X 377 = #/A of available phosphorus.

OLSEN (17) SODIUM BICARBONATE EXTRACTION PROCEDURE FOR SOIL PHOSPHORUS

Preparation of Reagents:

Dissolve 15.0 gms. ammonium molybdate in 300 ml. of warm distilled water. Filter if necessary and add to the solution, after cooling, 342 ml. of concentrated HCl gradually with mixing. Dilute to 1000 ml. This solution contains an extra 50 ml. of concentrated HCl to neutralize the $NaHCO_3$. Dissolve 10 gms. of $SnCl_2 \cdot 2H_2O$ in 25 ml. of concentrated HCl - Stock solution. Prepare fresh every two months or less. Use large crystals rather than fine powder.

Dilute Stock:

Add 0.5 ml. of the concentrated solution to 66 ml. of distilled water. Prepare dilute stock for each set of determination.

Method of Extraction:

1. Prepare 0.5 Molar $NaHCO_3$ Reagent Grade adjusted to pH 8.5 with NaOH. Add mineral oil to avoid exposure to air.
2. Shake 1 gm. soil and one teaspoon carbon black in 20 ml. for 30 minutes, in a 250 Erlenmeyer flask. A suitable shaker is supplied by Burrell Technical Supply Corp., Pittsburgh, Pa.
3. Filter through Watman No. 40. Add more carbon black if necessary to obtain a clear filtrate.
4. Determine phosphorus by Dickman and Bray (5a) method modified to include extra HCl to neutralize the $NaHCO_3$. Add a 5 ml. aliquot of the filtrate into a 25 ml. volumetric flask. Add 5 ml. of molybdate reagent and proceed as indicated under Procedure. Some soil high in extractable phosphorus may require less than a

5 ml. aliquot. If so, the total volume should be made up equivalent to 5 ml. of the $NaHCO_3$ solution in order to maintain the proper acidity for developing the color.

5. The carbon black (Darco-G-60) releases phosphorus when treated with $NaHCO_3$. Therefore, the carbon black is pretreated with the $NaHCO_3$ solution by leaching, washing with water, and drying.

Procedure:

Place an aliquot of unknown in a 25 ml. volume flask. Add 5 ml. of the ammonium molybdate solution to each flask and mix. Wash down the neck of the flask to avoid direct contact of $SnCl_2$ solution with concentrated molybdate solution. Dilute to about 22 ml. Add 1.0 ml. of the dilute stannous chloride solution. Mix immediately. Make to volume and shake thoroughly. Read color intensity in the colorimeter ten minutes after addition of the stannous chloride solution using a 700 mu filter. Prepare the standard curve with 5 ml. of the $NaHCO_3$ solution included with the standard phosphorus solution.

Phosphorus Determination - Dickman and Bray (2) Procedure (Modified)

This procedure is based on the use of hydrochloric acid to develop the acidity instead of sulfuric acid or mixture of sulfuric and hydrochloric acids. The advantages claimed for this method are that it is less subject to interference by iron (tolerates up to 15 ppm Fe) and is more stable (4-20 min.). The conditions under which the color is developed are:

.7 N HCl, 0.3% ammonium molybdate and 0.012% $SnCl_2$.

TABLE IX

SOIL ANALYSIS OF AVAILABLE PHOSPHORUS DATA OBTAINED FROM THREE METHODS FOR 0"-6" AND 6"-12" DEPTH IN POUNDS PER ACRE

Rep. No.	Trt. No.	Bray No. 1		Bray No. 2		Sodium Bicarbonate	
		0"-6"	6"-12"	0"-6"	6"-12"	0"-6"	6"-12"
1	1	25.640*	18.120	09.860	06.080	06.120	03.760
1	2	33.150	22.460	15.960	10.080	10.080	06.000
1	3	41.590	32.460	06.800	03.700	04.320	02.680
1	4	29.980	23.980	23.300	16.760	14.380	12.240
1	5	34.420	26.750	22.510	16.350	15.560	11.520
2	1	35.080	29.780	13.760	09.340	08.040	05.680
2	2	36.900	25.580	17.680	12.900	09.520	07.060
2	3	43.260	32.920	21.300	16.500	11.400	09.440
2	4	54.380	40.480	35.040	26.460	18.600	14.080
2	5	53.940	39.240	23.950	14.480	16.420	12.920
3	1	33.920	25.160	19.280	12.600	11.300	07.920
3	2	23.420	17.580	11.260	06.620	06.980	03.880
3	3	27.440	15.160	16.920	12.810	09.540	07.680
3	4	33.680	21.740	24.840	19.260	15.920	11.920
3	5	41.080	31.440	24.500	23.740	14.700	13.360
4	1	20.620	18.220	09.440	06.320	06.160	04.040
4	2	24.020	18.300	18.740	12.480	11.140	07.520
4	3	24.160	18.800	20.780	13.280	12.880	09.340
4	4	31.720	23.720	28.720	19.540	17.360	12.020
4	5	35.780	28.000	30.940	27.500	18.560	16.720

*According to this individual figure, each one was obtained from the mean of the 10 soil samples in each plot.

TABLE X

RAINFALL DATA FOR WHEATLAND CONSERVATION EXPERIMENT STATION
CHEROKEE, OKLAHOMA
(INCHES)

Year		Average
1963	(January-June)	25.56
1964	" "	24.41
1965	" "	22.55
1966	" "	18.45
1967	" "	20.33
1968	" "	26.61

TABLE XI

WHEAT GRAIN YIELD IN BU/A FROM 1963-1968

Rep.	Trt.	Level of P_2O_5	1963	1964	1965	1966	1967	1968
1	1	Check plot	25.51	39.60	41.20	23.76	04.00	19.43
1	2	20 lbs/A	30.50	39.27	41.20	24.33	03.50	25.96
1	3	40 lbs/A	26.33	35.47	41.20	25.98	04.80	27.05
1	4	80 lbs/A	29.51	32.35	44.20	29.12	09.10	29.41
1	5	300 lbs/A	21.51	34.32	36.90	18.23	09.20	21.15
2	1	Check plot	30.87	26.23	38.80	23.67	04.80	29.69
2	2	20 lbs/A	34.23	33.08	38.00	24.17	03.30	34.23
2	3	40 lbs/A	28.60	30.52	36.70	21.61	04.10	32.86
2	4	80 lbs/A	32.68	33.74	39.50	22.93	03.80	32.32
2	5	300 lbs/A	24.60	41.33	36.50	13.61	05.40	20.52
3	1	Check plot	28.05	31.35	44.10	28.71	07.80	17.88
3	2	20 lbs/A	32.23	24.50	42.00	27.88	07.30	22.79
3	3	40 lbs/A	36.86	30.77	39.90	25.57	05.60	31.50
3	4	80 lbs/A	36.04	29.12	41.60	26.23	04.20	27.69
3	5	300 lbs/A	30.87	32.01	40.50	22.35	10.90	19.97
4	1	Check plot	27.24	35.72	41.70	24.99	04.40	22.51
4	2	20 lbs/A	33.86	21.86	45.00	24.25	02.60	27.14
4	3	40 lbs/A	30.32	38.52	42.80	24.99	02.20	29.87
4	4	80 lbs/A	31.87	37.29	41.20	22.85	02.40	26.60
4	5	300 lbs/A	25.51	32.34	43.30	24.00	08.00	22.88

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