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Prediction accuracy evaluation of five soil test methods

William D. Bishop

To the Graduate Council:

I am submitting herewith a thesis written by William D. Bishop entitled "Prediction accuracy evaluation of five soil test methods." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters, Major Professor

We have read this thesis and recommend its acceptance:

L. N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

2nd copy

May 24, 1954

To the Graduate Council:

I am submitting herewith a thesis written by William D. Bishop entitled "Prediction Accuracy Evaluation of Five Soil Test Methods." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Eric Winters

Major Professor

We have read this thesis and recommend its acceptance:

H. G. Spitzer

L N Skold

Accepted for the Council:

E. G. Winters

Dean of the Graduate School

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PREDICTION ACCURACY EVALUATION OF FIVE SOIL TEST METHODS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

William D. Bishop

June 1954

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CHAPTER I

INTRODUCTION

How much fertilizer should farmers use to produce economical crop yields? Crop response to fertilization is one of the important factors to be considered in arriving at the answer. Farmers look to agricultural scientists to supply this information. The expense and the time of running field experiments make it desirable to employ other less expensive and less time-consuming methods for predicting crop responses to fertilizer applications. To supplement field fertilizer experiments, scientists have developed rapid chemical tests for the purpose of supplying farmers needed information about the fertility levels of their soils. The chemical tests are used to predict crop responses on soils not studied.

Many different laboratory tests have been developed in this and other countries. Every state in the United States and many foreign countries are using one or more of these methods in a soil testing program. The University of Tennessee Agricultural Extension Service initiated a state-wide soil testing service in 1944. The central laboratory was located in Nashville, Tennessee. Farmers are using the service at an increasing rate each year. During March 1954, 24,005 soil samples were analyzed for pH, available phosphate, and available potash as compared to 5,251 during March of 1953. Specific lime and fertilizer recommendations are made for crops to be grown on the field from which each soil sample was taken.

The information supplied by these rapid laboratory tests is no better than the correlation between results from field experiments and the soil testing methods used. When one considers the number of farmers using this service and the amount spent for lime and fertilizers by these farmers, it is apparent that the soil testing methods used should be as reliable as possible. The purpose of this investigation is to determine the extent to which crop response to fertilization correlates with different levels of soil phosphorus and potassium as determined by the various soil test methods and to select the most reliable method for Tennessee conditions.

CHAPTER II

REVIEW OF LITERATURE

Peech (13) reported that many different types of extracting solutions are being used in the United States. These include pure and carbonated water; dilute inorganic and organic acids; dilute alkaline solutions; and neutral or acid, highly buffered, salt solutions. He further stated that no one extracting solution can be expected to correlate best with crop response to both phosphate and potash under all conditions. Bray and Kurtz (2) and Bray (4) concluded that the soil extracting solution used is the main important difference among methods for determining the available forms of phosphorus in soils. They stated that absorbed phosphorus is measured by their No. 1 method and that the acid soluble forms of soil phosphorus is measured by their No. 2 method. Results obtained by the No. 2 method correlated better with crop response to fertilization on soils in the corn belt area of Illinois than the results from the No. 1 method.

Correlations of soil tests with crop response to fertilization have been made in Tennessee (6, 9, 10, 12, 16). Mooers (12) concluded that the Cunninghamella blakesleeana method for available phosphorus and the Aspergillus niger method for available potassium were more reliable than the Neubauer method except on Memphis silt loam soils. He also reported a wide degree of inherent error in each method. Long (9) compared the Cunninghamella blakesleeana and Aspergillus niger methods with the sodium perchlorate-perchloric acid method and found no advantage in one over the other in predicting wheat and cotton response to fertilization. He did advocate the use of the sodium perchlorate-perchloric acid method since tests could be made more rapidly by this method than by the biological method. In a later investigation Long (10) obtained the following prediction accuracies with the sodium perchlorate-perchloric acid method: (1) for response to phosphorus - corn 64 per cent, cotton 54 per cent, small grain 70 per cent, legume hay 63 per cent, permanent pasture 100 per cent, and corn on West Tennessee soils 17 per cent; and (2) for response to potassium - corn 44 per cent, cotton 60 per cent, small grain 47 per cent, legume hay 33 per cent, and permanent pasture 57 per cent. Ewing (6) indicated that chemical soil tests were valuable in predicting response of alfalfa, corn, and Irish potatoes to fertilization in Carter County. Winters (16) was able to establish the following approximate levels of exchangeable soil potassium above which certain crops would no longer respond to potash fertilization: corn 155 pounds per acre, alfalfa 160 pounds per acre, cotton 185 pounds per acre, tobacco 190 pounds per acre, and Irish potatoes 220 pounds per acre. He urged that the use of soil tests for fertilizer recommendations should be supported with adequate correlation studies.

Lawton _et al._ (8) compared four soil testing methods for predicting response of legumes to fertilization and found that all methods gave approximately the same degree of accuracy. The first year he obtained a 60 per cent prediction accuracy for potash fertilization and 80 per cent for phosphate fertilization. The second year the accuracy with respect to potash had increased slightly and the phosphate accuracy had declined to approximately 65 per cent. Chandler et al. (5) found a significant yield increase from potash fertilization on alfalfa when the soil potassium level fell below 80 pounds per acre as determined by chemical soil analysis.

Peech and English (14) concluded that even though chemical soil tests provide only a part of the information needed for intelligent fertilization recommendations, they can provide valuable and otherwise unobtainable information when properly correlated with crop response. Bray (1, 3) obtained good correlation between soil tests and crop response to potash fertilization. He stated that chemical soil tests are valuable tools in predicting nutrient deficiencies and even the degree of such deficiencies.

Many of the above workers emphasized that the amount of correlation data is limited and stressed the need for well-planned field experiments to be used for correlating crop response to fertilization and soil test results.

CHAPTER III

METHODS AND PROCEDURES

A survey was made of the data on crop response to fertilizer applications available from field fertilizer experiments conducted by Mr. O. H. Long, Associate Agronomist, University of Tennessee Experiment Station. The author was given access to stored soil samples which had been collected from these field experiments. The topsoil samples from the four unfertilized check plots from each field experiment on corn, cotton, small grain, alfalfa, and permanent pasture were used in the study. Several of the soil samples were tested by all of the following methods: (1) Sodium perchlorate-perchloric acid, (2) Ammonium sulfate, (3) Bray No. 1, (4) Bray No. 2, and (5) Hydrochloric-sulfuric acid. A brief description of each method follows:

Sodium Perchlorate-Perchloric Acid Method

This method is a modification of the methods of Bray (2), and Peech and English (14) and was used in the Tennessee soil testing program from 1944 until the initial phases of this investigation were completed in November 1953. The exact procedures are as follows:

Reagents

1. Extracting solution. Dilute 158 ml. of 70% perchloric acid to 400 ml. with distilled water. Dissolve 109.5 gm. monohydrate sodium carbonate in 400 ml. of distilled water. Mix the two solutions, driving out the CO_2 by heating and vigorously stirring. Dilute to one liter. Adjust the acidity to .1 N. This solution is approximately 25% sodium perchlorate and .1 N free $HClO_4$.

2. Phosphorus test solutions.

A. Ammonium molybdate-hydrochloric acid solution. Dissolve 15 gm. ammonium molybdate in 300 ml. distilled water by heating to 60°C. Filter and cool. Then add slowly with constant stirring 300 ml. of concentrated hydrochloric acid, cool to room temperature, dilute with distilled water to one liter. Store in a brown glass stoppered bottle. Prepare a fresh supply every three months. This solution contains 1.5% ammonium molybdate in 3.5 N HCl.

B. Amino-naphthol-sulfonic acid reagent. Mix 2.5 gm. of 1-amino-2-naphthol-4-sulfonic acid (Eastman 360), 5.0 gm. sodium sulfite (Na_2SO_3) and 146.25 gm. sodium bisulfite (meta, $Na_2S_2O_5$) thoroughly and grind the mixture to a fine powder. Dissolve 8.0 gm. of the powder mixture in 50 ml. of warm distilled water. If possible, allow this solution to stand overnight before using. Upon long standing some material may crystallize from the solution. This does not interfere with the action of the reagent. Fresh solution should be made from the dry powder every three weeks.

C. Phosphorus standard - (25 ppm). Dissolve 0.1098 gm. of KH_2PO_4 in one liter of extracting solution.

3. Potassium test solutions.

A. Formaldehyde, 40 per cent.

B. Cobaltinitrite solution. Dissolve 6.25 gm. of $Co(NO_3)_2 \cdot 6H_2O$ and 75.0 gm. of $NaNO_2$ in 175 ml. of distilled water. Add 5 ml. of 99.5% acetic acid and mix, gently at first to prevent loss by foaming; cover with a beaker and allow to stand overnight. Dilute to 250 ml., mix and filter. Store in refrigerator in glass-stoppered bottle. This reagent is good for one month.

C. Isopropyl alcohol (C. P.).

D. Standard potassium solution (50 ppm). Dissolve 0.0954 gm. of KCl in one liter of extracting solution.

Procedure

1. Extraction. Measure (or weigh) 5 gm. of air-dry soil into a 25 x 100 mm. flat bottom vial; add approximately .1 gm. activated carbon (phosphate and potash free) and 10 ml. of extracting solution. Shake vigorously for 3 minutes on shaking machine and filter through a medium qualitative paper (Whatman No. 1).

2. Phosphorus determination. Measure out 2 ml. of the clear soil extract into a 16 x 58 mm. flat bottom vial; add 0.5 ml. of the ammonium molybdate solution and mix immediately. Add 5 drops of amino-naphthol-sulfonic acid reagent and again mix immediately. Compare the colors of the unknown to those of a series of standards prepared simultaneously in the same manner. The concentration of the standards may be varied from 1 to 10 ppm phosphorus by diluting the standard phosphate solution with extracting solution.

3. Potassium determination. Transfer 2 ml. of the soil extract into a 16 x 58 mm. flat bottom vial. Add 5 drops of formaldehyde, mix and allow to stand a few minutes before adding 1 ml. of the cobaltinitrite solution. Again mix, then add 2 ml. of the isopropyl alcohol carefully down the side of the tube so as to form an alcohol layer on top of the solution. After alcohol has been added to all tubes, mix the two layers rapidly and uniformly. This mixing can be accomplished either by a swirling motion or by inverting the tube about ten times. It is important that the method of mixing be uniform. Compare the turbidities with a series of standards prepared simultaneously in the same manner. The concentration of the standards should range between 0 and 50 ppm potassium.

Ammonium Sulfate Method

The ammonium sulfate method was developed by Dr. Lloyd F. Seatz, Associate Agronomist, University of Tennessee Experiment Station, but has not been published. The method is similar to the Truog test for phosphate except that (1) the extracting reagent is almost two and one-half times as concentrated as that used in the Truog test and (2) the soil-solution ratio is narrower (1-4) to permit potassium determination in addition to phosphorus determination from the same soil extract. This method was developed primarily out of a need for a soil extracting solution which could be used in a state soil testing program where a single extracting reagent could be utilized for both phosphorus and potassium determinations, when using a flame photometer for the potassium determinations. The exact procedure for this method is as follows:

Reagents

1. Extracting solution. A solution of 1% $(NH_4)_2SO_4$ in .05 N NH_2SO_4.

2. Phosphorus test solutions. The phosphorus test solutions used in this method are identical to those used in the sodium perchlorate-perchloric acid method above.

3. Potassium test solution. Standard KCl solution (50 ppm). Dissolve 0.0954 gm. of KCl in one liter of extracting solution.

Procedure

1. Extraction. The extraction procedure for this method is the same as for the sodium perchlorate-perchloric acid method above except that 20 ml. of extracting solution is used instead of 10 ml.

2. Phosphorus determination. The procedure for phosphorus determination for this method is the same as for the sodium perchlorate-perchloric acid method above except that 5 ml. of the soil extract is used instead of 2 ml.

3. Potassium determination with Perkin & Elmer Model 53 flame photometer by direct method.

   A. Instrumentation.

      (1) Turn on switch 30 minutes prior to taking any readings.

      (2) Light burner 10 minutes before taking readings.

(3) Turn on air to 10 pounds pressure.

(4) Fuel - use propane gas at 5 pounds pressure.

B. Standardization of flame photometer.

(1) Set instrument to read 100 on maximum standard.

(2) Establish potassium curve by using standard solutions containing 0, 12-1/2, 25, 37-1/2, and 50 ppm K. .

C. Determining potassium in soil extract.

(1) After a 5 ml. aliquot has been removed for phosphorus determination, the remaining soil extract is used for potassium determination. A four-way stopcock may be connected to the atomizer which will avoid the necessity of removing the filter tubes from the rack. This arrangement is shown in Figure 1.

(2) Run one standard solution about every tenth determination to be sure instrument is still standardized. Air pressure and gas pressure should be kept constant. Slight variations may cause faulty readings.

Bray No. 1 Method

The extracting reagent used in the Bray No. 1 method is a solution of .03 N ammonium fluoride in .025 N hydrochloric acid. The exact procedures described by Bray (2) were followed.

Bray No. 2 Method

The extracting reagent used in the Bray No. 2 method is a solution of .03 N ammonium fluoride in .1 N hydrochloric acid. The exact procedures described by Bray (2) were followed.

Hydrochloric-Sulfuric Acid Method

The extracting solution used in the hydrochloric-sulfuric acid method is a mixture containing approximately .05 N HCl and .025 N H_2SO_4. It is prepared by adding 14 ml. of concentrated H_2SO_4 and 83 ml. of concentrated HCl to 19 liters of distilled water. The extraction procedure is the same as that described above for the ammonium sulfate method. The ammonium molybdate-ammonium vanadate mixture is the only phosphate reagent used in this method and is made by mixing equal volumes of the following solutions: (1) 25 gm. ammonium molybdate dissolved in 500 ml. of distilled water and (2) 1.25 gm. ammonium vanadate dissolved in 500 ml. of 1:1 HNO_3. This mixture should be prepared fresh each week. The phosphorus determination is made by adding and mixing 1 ml. of the ammonium molybdate-ammonium vanadate mixture to 4 ml. of the soil extract. Allow to stand 20 minutes before making readings. Phosphate standards are used as indicated in the other methods.

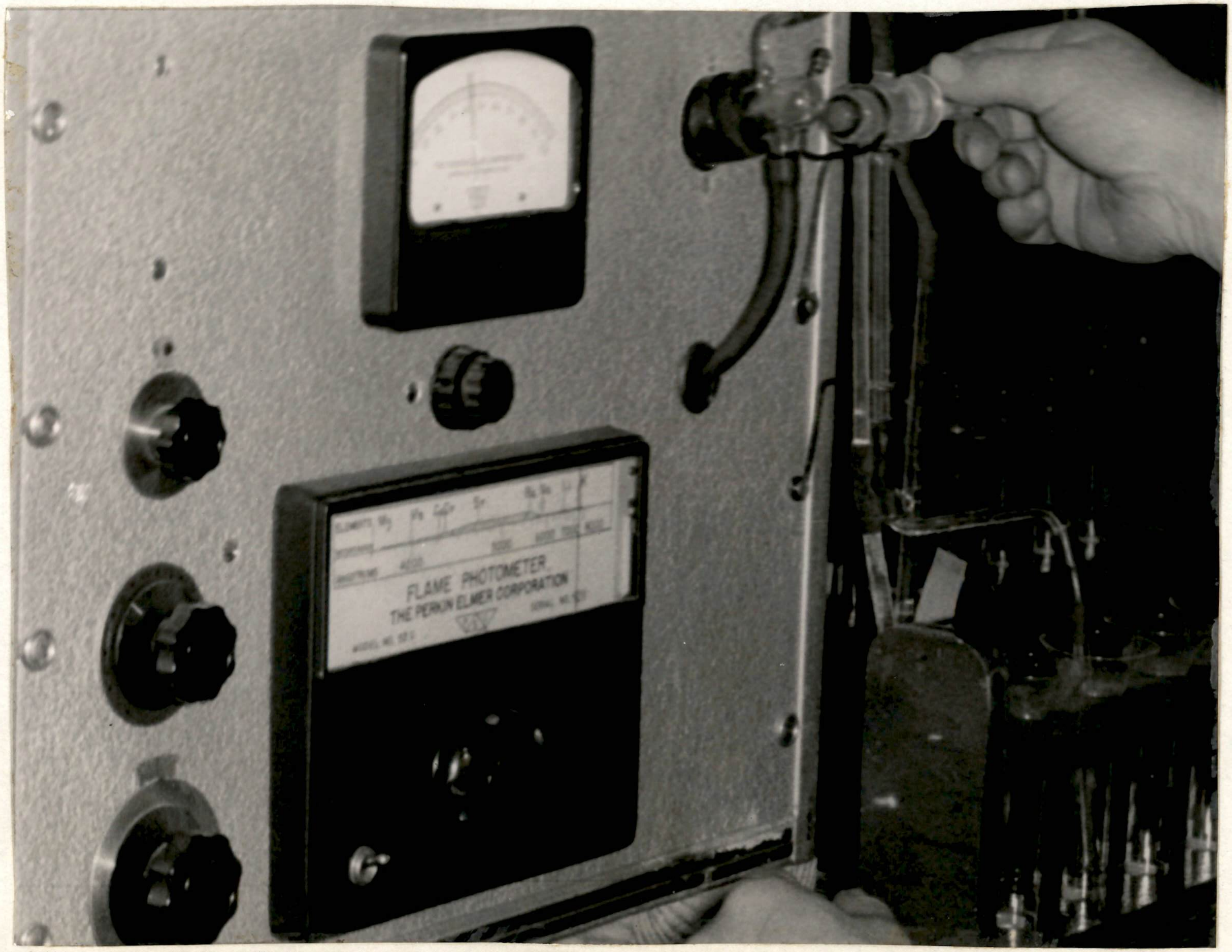

Figure 1. Potassium determinations made direct from soil extract in filter tubes by using four-way stopcock connected to atomizer on flame photometer.

CHAPTER IV

PRESENTATION OF DATA

The following terms will be used throughout this report as defined:

Relative yield. The yield of the no-phosphate treatment (NK) or no-potash treatment (NP) computed as a percentage of the complete treatment (NPK).

Critical nutrient level. That level of available soil phosphorus or potassium above which crops do not normally respond to phosphate or potash fertilization. (i.e. relative yields are above 90 per cent).

Prediction accuracy. The number of experiments that behaved as expected, based on the critical nutrient level, computed as a percentage of the total number of experiments considered.

Soil Test Results and Crop Response to Phosphate Fertilization

Available phosphorus values in pounds per acre as determined by five soil testing methods are presented in Table I for soil samples from fields where crop response to phosphate fertilization has been determined. The relative yield values are also included. Experiments in which crop response to phosphate fertilization is significant at the five per cent level are indicated.

Available phosphorus values in pounds per acre as determined by three soil testing methods are presented in Table II for soil samples from fields where corn response to phosphate fertilization has been determined. The relative yield values are also included. Experiments in which crop response to phosphate fertilization is significant at the five per cent level are indicated. Yield data were obtained from Mr. O. H. Long. Similar data are presented in Table III for small grain and in Table IV for cotton, alfalfa, and permanent pasture.

The relationship between available soil phosphorus as determined by the sodium perchlorate-perchloric acid method and the relative yield is shown graphically in Figure 2 for all experiments included in Tables II, III, and IV. The available phosphorus in pounds per acre is shown on the X axis and the relative yield in per cent on the Y axis. Ten pounds per acre has been selected as the critical phosphorus level for the sodium perchlorate-perchloric acid method. A line has been drawn at the 90 per cent relative yield level on the assumption that 10 per cent may be considered a rough approximation of experimental error. Experiments with relative yields of 90 per cent or less are considered as responsive to phosphate fertilization, and those with relative yields of more than 90 per cent are considered as non-responsive.

The relationships between available soil phosphorus as determined by the ammonium sulfate method using 1-4 and 1-8 soil-solution ratios and relative yields are presented in Figures 3 and 4 respectively in a manner similar to that described above for the sodium perchlorate-perchloric acid method. Critical nutrient levels of 15 and 30 pounds per acre respectively have been assigned to these methods.

Soil Test Results and Crop Response to Potash Fertilization

Available potassium values in pounds per acre as determined by three soil testing methods are presented in Table V for soil samples from fields where corn response to potash fertilization has been determined. The relative yield values are also included. Experiments in which crop response to potash fertilization is significant at the five per cent level are indicated. Yield data were obtained from Mr. O. H. Long. Similar data are presented in Table VI for small grain and in Table VII for cotton, alfalfa, and permanent pasture.

The relationship between available soil potassium as determined by the sodium perchlorate-perchloric acid method and the relative yield is shown graphically in Figure 5 for all experiments included in Tables V, VI, and VII. The available potassium in pounds per acre is shown on the X axis and the relative yield in per cent on the Y axis. One hundred fifty pounds per acre has been selected as the critical potassium level for the sodium perchlorate-perchloric acid method. A line has been drawn at the 90 per cent relative yield level on the assumption that 10 per cent may be considered a rough approximation of experimental error. Experiments with relative yields of 90 per cent or more are considered as non-responsive.

The relationships between available soil potassium as determined by the ammonium sulfate method using 1-4 and 1-8 soil-solution ratios and relative yields are presented in Figures 3 and 4 respectively in a manner similar to that described above for the sodium perchlorate-perchloric acid method. Critical nutrient levels of 125 and 150 pounds per acre respectively have been assigned to these methods.

TABLE I

AVAILABLE PHOSPHORUS BY FIVE METHODS ON SOIL SAMPLES FROM FIELDS WHERE CROP RESPONSE TO PHOSPHATE FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Phosphorus lb./acre					Relative Yield
		Na $HClO_4$	Amm. Sul.	Bray No. 1	Bray No. 2	HCl-H_2SO_4 Acid	
264	Lintonia	2	16	4	48	22	94
265	Memphis	7	26	4	73	33	101
266	Center	2	23	2	47	36	107
268	Obion	15	24	1	54	44	96
270	St. Catherine	20	40	7	126	80	92
272	Loring	6	15	3	45	20	99
275	Grenada	3	10	3	28	14	81*
296	Lintonia	1	9	3	18	9	88
327	Talbott	1	13	2	28	17	107
328	Decatur	1	8	2	20	11	81*
329	Tilsit	7	23	5	68	33	103
331	Fullerton	2	8	3	29	13	81
332	Sequoia	1	6	2	22	9	85*
333	Alcoa	2	15	2	36	25	116
345	Bolton	6	21	3	56	36	95
346	Fullerton	7	13	4	44	19	71*
347	Fullerton	14	34	5	67	43	103
348	Leadvale	7	13	1	28	21	57*

* Crop response significant at the 5 per cent level.

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TABLE II

AVAILABLE PHOSPHORUS BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE CORN RESPONSE TO PHOSPHATE FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Phosphorus lb/acre			Relative Yield
		Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio 1-4	Ammonium Sulfate Soil-Solution Ratio 1-8	
264	Lintonia	1.8	16	22	94
265	Memphis	7.8	26	33	101
266	Center	1.8	23	36	107
268	Obion	20.0	24	44	96
270	St. Catherine	15.3	40	80	92
272	Loring	6.8	15	20	99
275	Grenada	3.5	10	14	81*
326	Decatur	3.8	26	54	102
336	Emory	5.3	24	39	116
338	Leadvale	0.5	7	10	89
339	Sequoia	0.3	4	6	80*
340	Dewey	1.9	16	24	73*
383	Decatur	2.0	6	9	96
384	Fullerton	2.3	6	7	70*
385	Leadvale	1.5	5	9	56*
407	Dewey	3.3	11	18	99
408	Leadvale	4.8	12	19	84*
409	Leadvale	4.5	9	17	92
411	Dewey	5.0	11	16	83
412	Fullerton	10.0	12	17	71*
414	Sequoia	4.3	9	13	79*

* Crop response significant at the 5 per cent level.

TABLE III

AVAILABLE PHOSPHORUS BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE SMALL GRAIN RESPONSE TO PHOSPHATE FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Phosphorus lb./acre			Relative Yield
		Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio 1-4	Ammonium Sulfate Soil-Solution Ratio 1-8	
296	Lintonia	0.3	9	9	88
327	Talbott	1.1	13	17	107
328	Decatur	0.6	8	11	81*
329	Tilsit	7.0	23	33	103
331	Fullerton	1.4	8	13	81
332	Sequoia	0.3	6	9	85*
333	Alcoa	2.1	15	25	116
345	Bolton	6.0	21	36	95
346	Fullerton	7.8	13	20	71*
347	Fullerton	14.5	34	43	103
348	Leadvale	7.3	14	21	57*
378	Dewey	3.8	13	22	79*
379	Dewey	2.5	13	21	65*
380	Sequoia	4.0	19	30	83*
405	Hartsell	5.0	13	18	63*
407	Dewey	3.3	11	18	82*
412	Fullerton	10.0	12	17	65*
415	Fullerton	4.3	8	15	69*
416	Fullerton	4.0	7	14	64*
417	Fullerton	5.0	12	16	80*

* Crop response significant at the 5 per cent level.

TABLE IV

AVAILABLE PHOSPHORUS BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE COTTON, ALFALFA, AND PERMANENT PASTURE RESPONSE TO PHOSPHATE FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Phosphorus lb./acre			Relative Yield
		Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio 1-4	Ammonium Sulfate Soil-Solution Ratio 1-8	
		- Cotton -			
360	Dulac	5.0	13	19	84
361	Loring	1.8	3	8	60*
362	Memphis	2.8	8	17	82
391	Memphis	2.0	6	9	77
421	Dickson	2.3	10	13	46*
422	Dickson	3.3	6	10	52*
		- Alfalfa -			
407	Dewey	3.3	11	18	51*
P.E.S.	Hartsell	4.0	10	18	55*
WTES	Lintonia	14.0	36	61	102
HRES	Dickson	5.0	15	24	90
BCES	Decatur	2.0	8	18	51*
GTES	Shackelton	11.0	21	28	74*
		- Permanent Pasture -			
351	Dewey	3.0	10	16	70*
352	Sequoia	3.5	7	11	42*
353	Leadvale	3.8	9	14	66*

* Crop response significant at the 5 per cent level.

TABLE V

AVAILABLE POTASSIUM BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE CORN RESPONSE TO POTASH FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Potash lb./acre			Relative Yield
		Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio		
			1-4	1-8	
264	Lintonia	180	120	140	98
265	Memphis	155	160	170	94
266	Center	131	120	140	80
268	Obion	140	90	100	85*
270	St. Catherine	139	120	140	94
272	Loring	116	140	170	106
275	Grenada	139	90	110	70*
336	Emory	121	110	100	107
338	Leadvale	78	80	80	88
339	Sequoia	132	130	150	100
340	Dewey	148	140	170	80
383	Decatur	165	140	140	105
384	Fullerton	119	90	100	100
385	Leadvale	101	60	70	80*
407	Dewey	75	60	70	55*
408	Leadvale	68	50	70	30*
409	Leadvale	158	90	100	83*
411	Dewey	220	240	230	80*
412	Fullerton	58	70	70	50*
414	Sequoia	168	110	120	83*

* Crop response significant at the 5 per cent level.

TABLE VI

AVAILABLE POTASSIUM BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE SMALL GRAIN RESPONSE TO POTASH FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Potash lb./acre			Relative Yield
		Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio 1-4	Ammonium Sulfate Soil-Solution Ratio 1-8	
296	Lintonia	66	70	90	93
327	Talbott	149	140	150	95
328	Decatur	135	120	150	85*
329	Tilsit	85	80	100	104
331	Fullerton	86	100	120	89
332	Sequoia	84	80	100	94
333	Alcoa	161	150	150	108
345	Bolton	225	300	300	98
346	Fullerton	170	130	140	97
347	Fullerton	196	140	160	102
348	Leadvale	125	70	90	85
378	Dewey	174	210	190	92
379	Dewey	205	380	390	70*
380	Sequoia	163	120	120	100
405	Hartsell	145	110	150	104
407	Dewey	75	60	70	89
412	Fullerton	58	70	70	111
415	Fullerton	163	370	390	97

* Crop response significant at the 5 per cent level.

TABLE VII

AVAILABLE POTASSIUM BY THREE METHODS ON SOIL SAMPLES FROM FIELDS WHERE COTTON, ALFALFA, AND PERMANENT PASTURE RESPONSE TO POTASH FERTILIZATION HAS BEEN DETERMINED

Field No.	Soil Series	Av. Available Potash lb./acre: Na $HClO_4$	Ammonium Sulfate Soil-Solution Ratio: 1-4	Ammonium Sulfate Soil-Solution Ratio: 1-8	Relative Yield
		- Cotton -			
360	Dulac	146	130	130	100
361	Loring	181	160	160	112
362	Memphis	218	270	270	111
391	Memphis	138	190	230	100
421	Dickson	45	80	80	71*
422	Dickson	83	120	130	100
		- Alfalfa -			
407	Dewey	75	60	70	55*
P.E.S.	Hartsell	150	120	130	75*
WTES	Lintonia	100	90	90	97
HRES	Dickson	120	80	90	76
BCES	Decatur	140	100	140	80*
GTES	Shackelton	220	200	220	96
		- Permanent Pasture -			
351	Dewey	173	250	240	111
352	Sequoia	185	200	200	73*
353	Leadvale	110	80	90	84

* Crop response significant at the 5 per cent level.

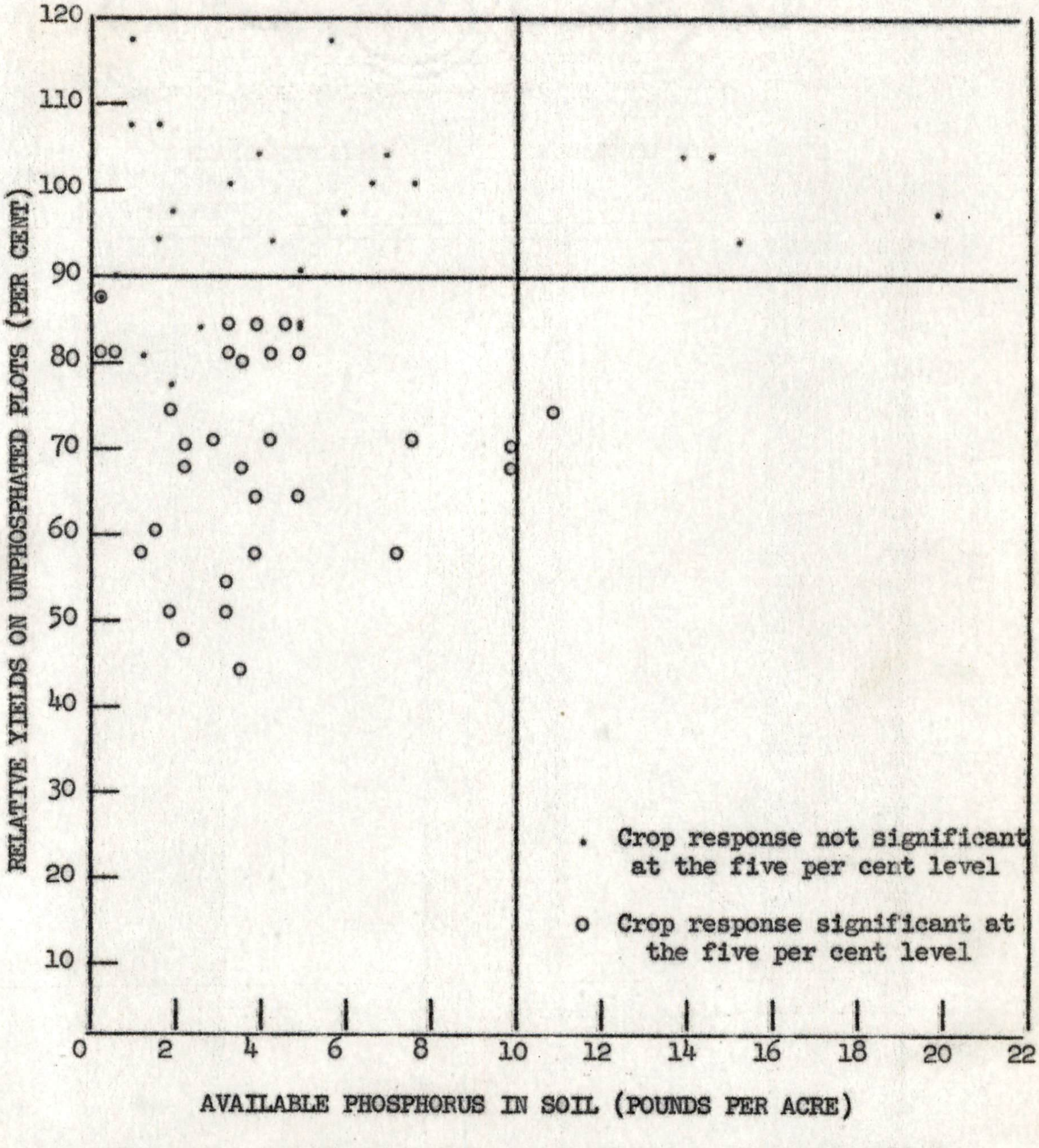

Figure 2. Relationship between available soil phosphorus as indicated by the sodium perchlorate-perchloric acid method and relative yields of crops on plots receiving no phosphate (data from Tables II, III, and IV).

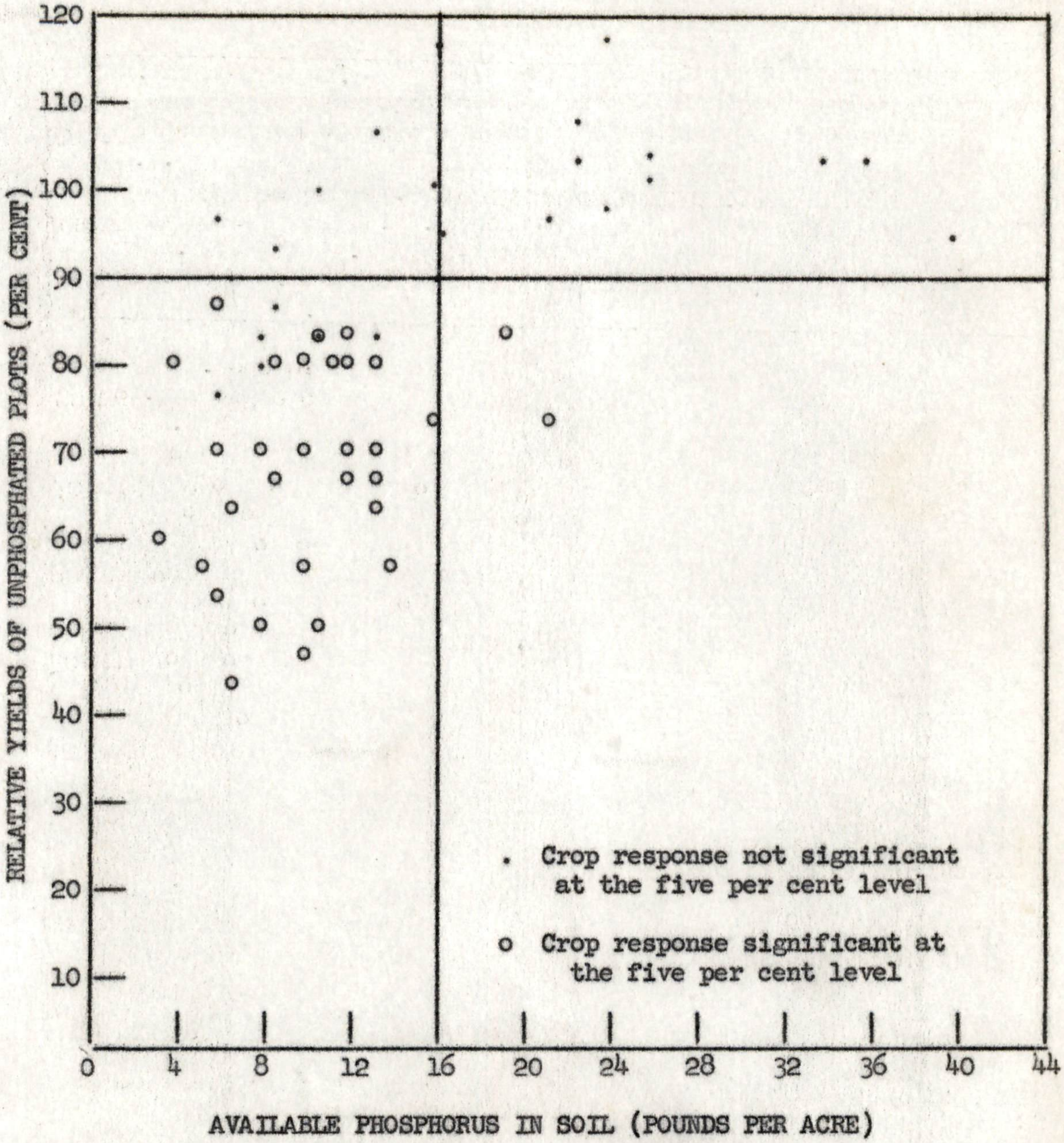

Figure 3. Relationship between available soil phosphorus as indicated by the ammonium sulfate method using 1-4 soil-solution ratio and relative yields of crops on plots receiving no phosphate (data from Tables II, III, and IV).

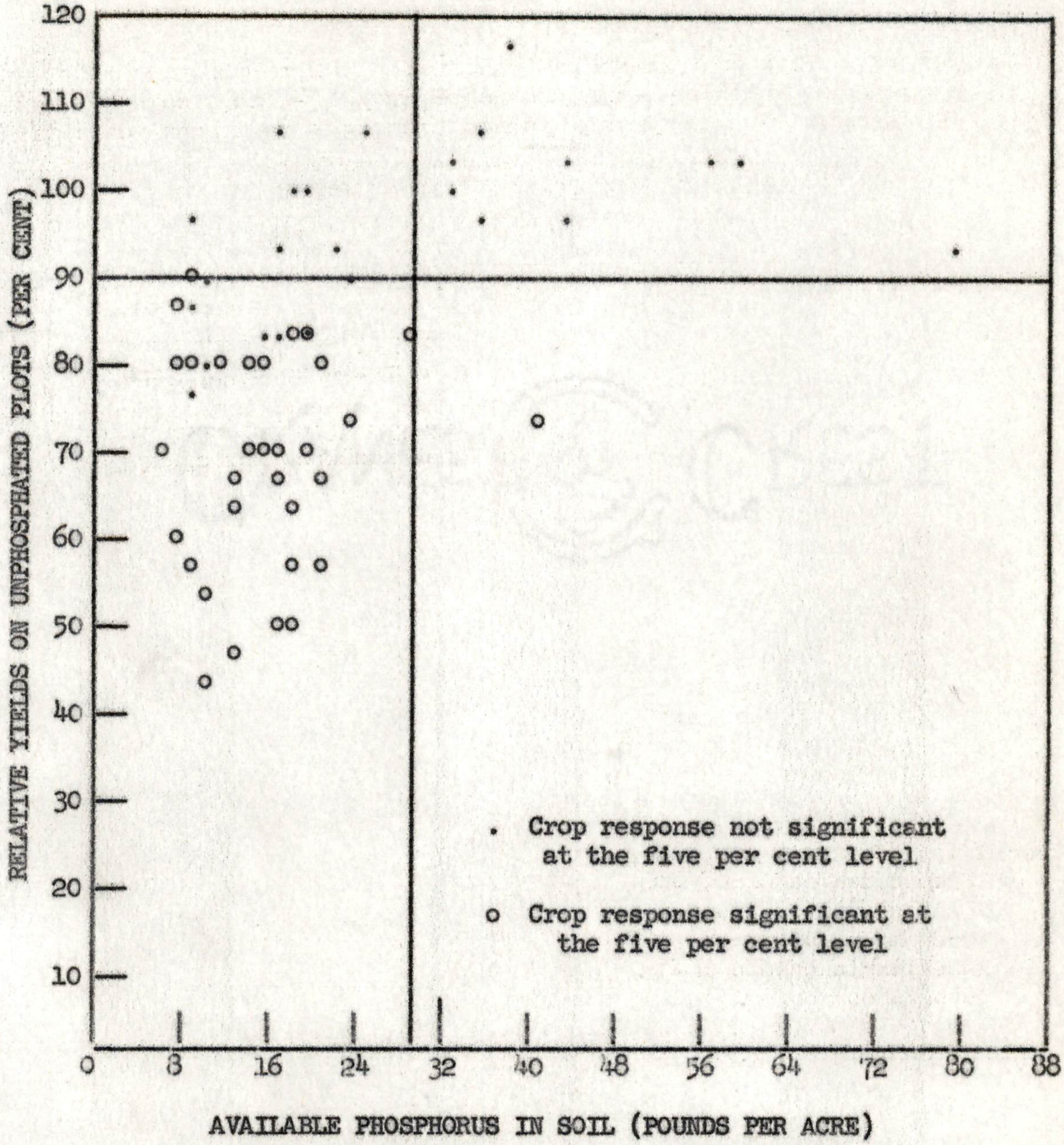

Figure 4. Relationship between available soil phosphorus as indicated by the ammonium sulfate method using 1-8 soil-solution ratio and relative yields of crops on plots receiving no phosphate (data from Tables II, III, and IV).

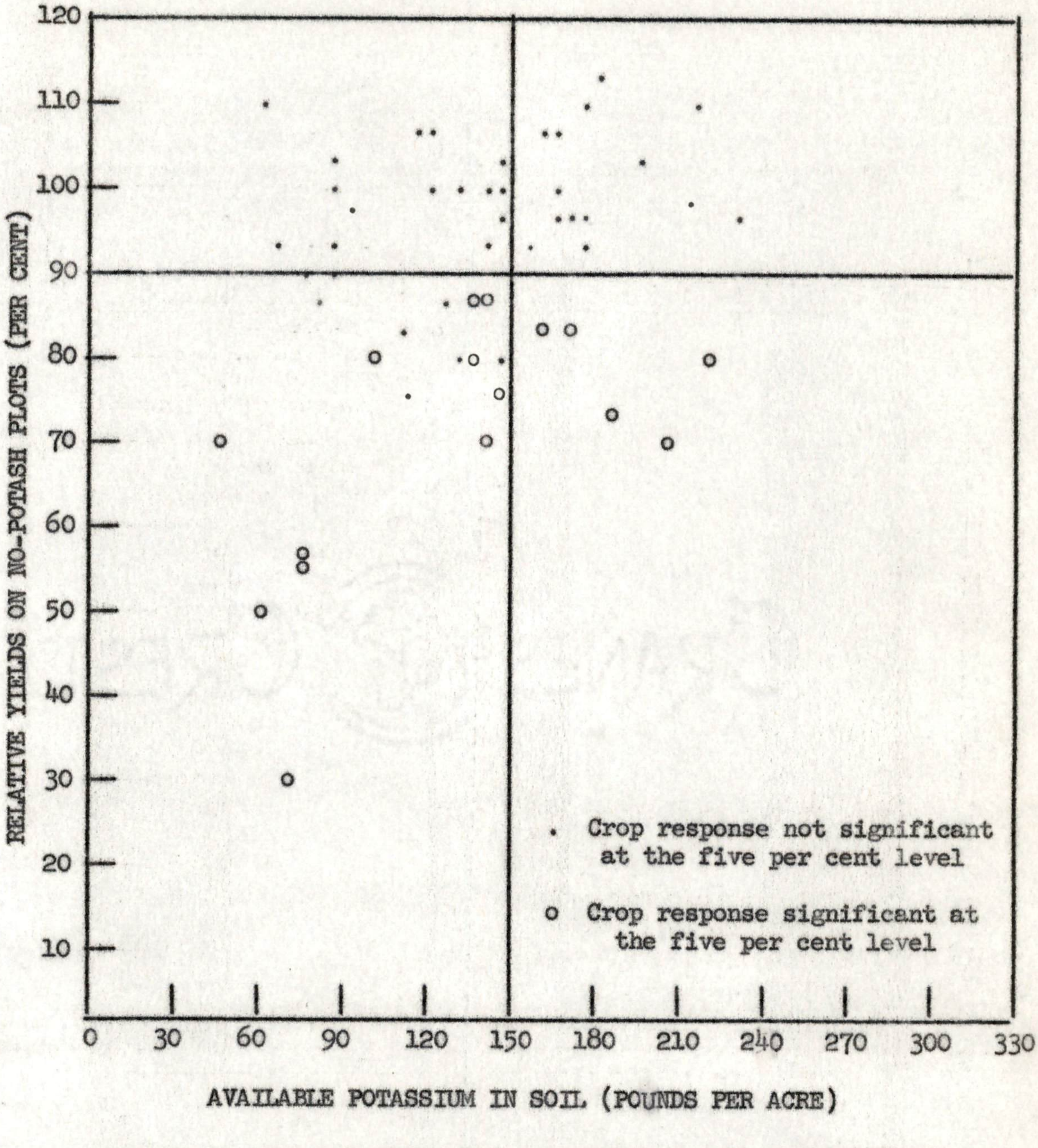

Figure 5. Relationship between available soil potassium as indicated by the sodium perchlorate-perchloric acid method and relative yields of crops on plots receiving no potash (data from Tables V, VI, and VII).

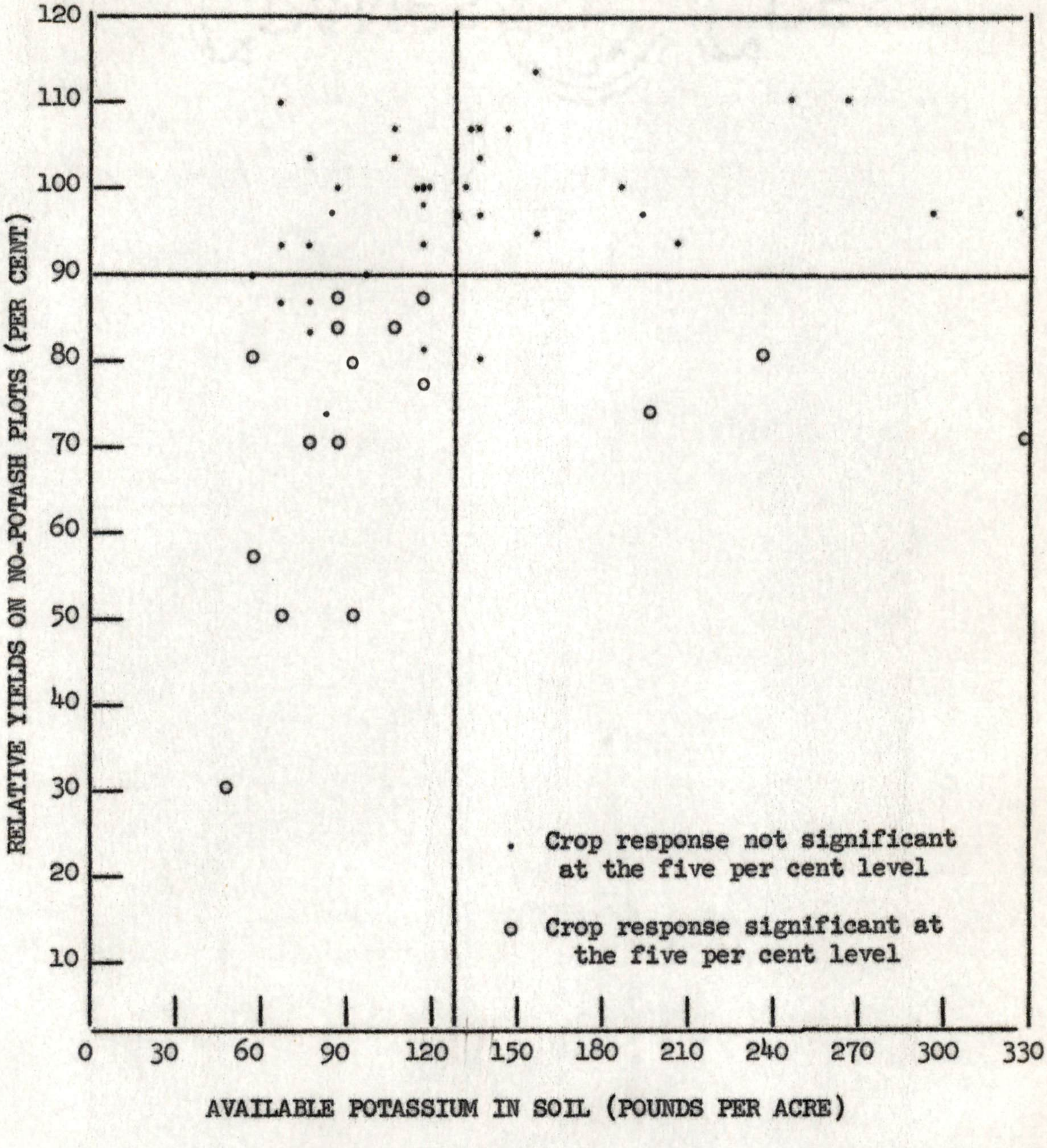

Figure 6. Relationship between available soil potassium as indicated by the ammonium sulfate method using 1-4 soil-solution ratio and relative yields of crops on plots receiving no potash (data from Tables V, VI, and VII).

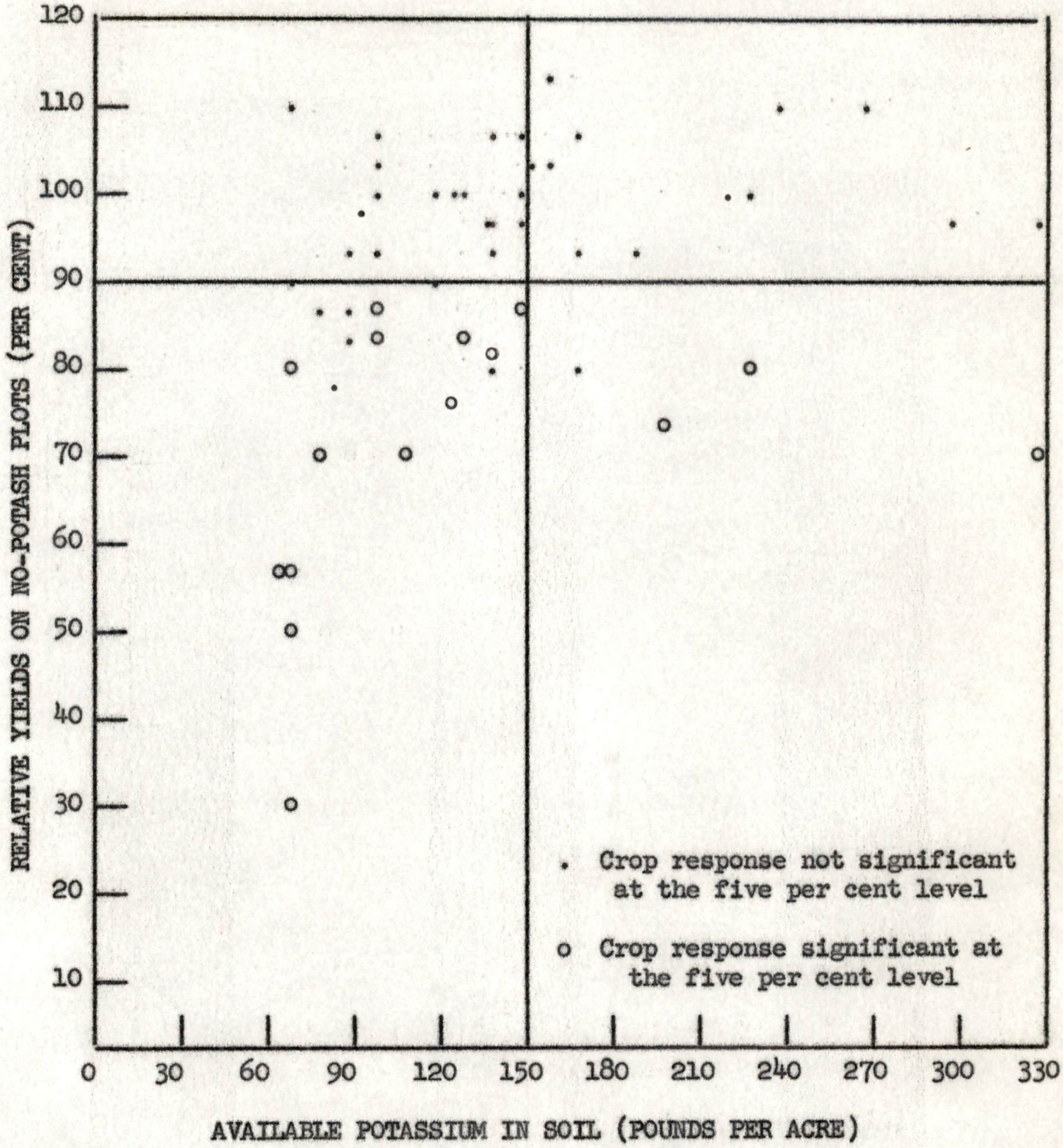

Figure 7. Relationship between available soil potassium as indicated by the ammonium sulfate method using 1-8 soil-solution ratio and relative yields of crops on plots receiving no potash (data from Tables V, VI, and VII).

CHAPTER V

DISCUSSION OF RESULTS

Preliminary Evaluation of Five Soil Test Methods

Prediction accuracy percentages for each of the five soil testing methods were calculated from the data presented in Table I and are given in Table VIII. Prediction accuracy is defined on page 13.

Both the sodium perchlorate-perchloric acid method and the Bray No. 1 method were relatively less satisfactory in predicting crop response to phosphate fertilization than were the ammonium sulfate, Bray No. 2, and the hydrochloric-sulfuric acid methods. Even though the prediction accuracy of the sodium perchlorate-perchloric acid method was relatively low, this method was included in further studies because it was being used in the state soil testing program at the time this investigation was initiated. The ammonium sulfate method also was selected for further study. The Bray No. 1 method was dropped because of the poor correlation obtained. The Bray No. 2 method was not included in the rest of the study primarily because the fluoride ion interferes with the operation of the flame photometer. The hydrochloric-sulfuric acid method was dropped because it extracted less potassium from the soil than the ammonium sulfate method.

Evaluation of Three Soil Test Methods with Crop Response to Phosphate Fertilization

Prediction accuracy percentages for each of the three soil testing methods were calculated from the data presented in Tables II, III, and IV (shown graphically in Figures 2, 3, and 4) and are given in Table IX.

The correlation between available soil phosphorus as indicated by the sodium perchlorate-perchloric acid method and corn response to phosphate fertilization was relatively low. A 53 per cent prediction accuracy was obtained when a critical soil phosphorus level of 10 pounds per acre was used. This is the same critical phosphorus level as was used in preliminary evaluation of the five methods reported in Table VIII. Prediction accuracies of 75 per cent were obtained for small grain, 100 per cent for cotton and permanent pasture, and 83 per cent for alfalfa by the sodium perchlorate-perchloric acid method. The wide variation in prediction accuracy percentages among crops may be due to several factors. Moisture deficiency at critical periods influences corn production more than it does the other crops studied. This is especially true when only the grain yield is considered. Whether or not rain occurs during the tasseling stage may determine whether or not corn responds to phosphate fertilization. Small grain is grown during the winter and spring months when moisture is normally adequate; therefore, small grain yields may reflect the relative soil fertility level better than corn. The sodium perchlorate-perchloric acid method fails to differentiate satisfactorily soils that are responsive to phosphate fertilization on corn or small grain from those that are not responsive.

The correlation between soil phosphorus, as indicated by the ammonium sulfate method using either a 1-4 soil-solution ratio or a 1-8 soil-solution ratio, and crop response to phosphate fertilization was higher than for the sodium perchlorate-perchloric acid method (see Table VIII). From the data, one may conclude that either ammonium sulfate method is equally reliable in predicting crop response to phosphate fertilization. The critical soil phosphorus level used for the ammonium sulfate method with a soil-solution ratio of 1-4 was 15 pounds per acre and for the ammonium sulfate method with a soil-solution ratio of 1-8, 30 pounds per acre. These methods gave prediction accuracies approximately 25 per cent higher for corn and 15 per cent higher for small grain than the sodium perchlorate-perchloric acid method. The prediction accuracy for crop response to phosphate fertilization for cotton, alfalfa, and permanent pasture was the same for all three soil testing methods.

Evaluation of Three Soil Test Methods with Crop Response to Potash Fertilization

Prediction accuracy percentages for each of the three soil testing methods were calculated from the data presented in Tables V, VI, and VII (shown graphically in Figures 5, 6, and 7) and are given in Table X.

The correlation between soil potassium as indicated by the sodium perchlorate-perchloric acid method and corn response to potash fertilization was relatively low. When a critical soil potassium level of 150 pounds per acre was used, a prediction accuracy of 60 per cent was obtained for corn, 56 per cent for small grain, and 60.4 per cent for all crops. The correlation was not improved when the critical soil potassium level was changed to 125 pounds per acre. At the 125 pounds per acre level there were 10 responses to potash fertilization on soils with test values of more than 125 pounds per acre as compared to only 5 cases when the 150 pound per acre level was used.

The ammonium sulfate method using a 1-4 soil-solution ratio gave a higher prediction accuracy. A prediction accuracy of 70 per cent for corn, 61 per cent for small grain, and 69.8 per cent for all crops was found using this method when a critical soil potassium level of 125 pounds per acre was used. By using a critical soil potassium level of 100 pounds per acre, the prediction accuracy was 75 per cent. However, when a critical nutrient level of 100 pounds per acre was used, there were 7 responses to potash fertilization on soils testing more than 100 pounds per acre, as compared to only 4 responses when the 125 pound per acre level was used.

The ammonium sulfate method using a 1-8 soil-solution ratio gave approximately the same prediction accuracy for all crops as did the ammonium sulfate method using a 1-4 soil-solution ratio. The critical soil potassium level of 150 pounds per acre was selected for this method.

TABLE VIII

PREDICTION ACCURACY (RESPONSE TO PHOSPHATE) FOR FIVE SOIL TEST METHODS*

Soil Test Method	Critical Nutrient Level (pounds per acre)	Prediction Accuracy (per cent)
Sodium perchlorate-perchloric acid	10	56
Ammonium sulfate	15	89
Bray No. 1	3	56
Bray No. 2	35	84
Hydrochloric-sulfuric acid	25	84

* Calculated from data in Table I.

TABLE IX

PREDICTION ACCURACY (RESPONSE TO PHOSPHATE) FOR THREE SOIL TEST METHODS FOR FIVE CROPS*

Crop	Number of Field Experiments	Soil Test Methods: Sodium Perchlorate-Perchloric Acid (per cent)	Ammonium Sulfate 1-4 (per cent)	Ammonium Sulfate 1-8 (per cent)
Corn	21	53	81	76
Small grain	20	75	90	90
Cotton	6	100	100	100
Alfalfa	6	83	83	83
Permanent pasture	3	100	100	100
Total	56			
Weighted Average		70.0	87.5	85.7

* Calculated from data in Tables II, III and IV.

TABLE X

PREDICTION ACCURACY (RESPONSE TO POTASH) FOR THREE SOIL TEST METHODS FOR FIVE CROPS*

Crop	Number of Field Experiments	Soil Test Methods: Sodium Perchlorate-Perchloric Acid (per cent)	Ammonium Sulfate 1-4 (per cent)	Ammonium Sulfate 1-8 (per cent)
Corn	20	60	70	65
Small grain	18	56	61	61
Cotton	6	50	83	67
Alfalfa	6	83	83	83
Permanent pasture	3	67	67	67
Total	53			
Weighted Average		60.4	69.8	66.0

* Calculated from data in Tables V, VI and VII.

CHAPTER VI

SUMMARY

Soil samples from the four unfertilized check plots of 56 field experiments were tested for available phosphorus and potassium by several methods. Yield data used to calculate crop response to fertilization were obtained from O. H. Long. A preliminary study evaluating five methods resulted in dropping three methods from further consideration. All 56 field experiments were used in evaluation of the remaining three methods. The ammonium sulfate methods (both the 1-4 soil-solution ratio and the 1-8 soil-solution ratio) gave higher prediction accuracies for crop response to phosphate fertilization than did the sodium perchlorate-perchloric acid method, especially for corn on the West Tennessee soils.

There was relatively little difference among the three methods in predicting crop response to potash fertilization. However, the ammonium sulfate methods gave higher prediction accuracies than the sodium perchlorate-perchloric acid method.

The ammonium sulfate method using 5 grams of soil to 20 ml. of extracting solution (1-4 soil-solution ratio) was adopted at the state soil testing laboratory on the basis of this study.

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