

การศึกษาเบื้องต้นเพื่อเปรียบเทียบประสิทธิภาพของวิธีวิเคราะห์หา
ปริมาณฟอสฟอรัสในดินที่ใช้ได้โดยเทียบกับการทดสอบในเรือนกระจก

Preliminary Evaluation of Different Chemical Soil Test Methods for
Available Phosphorus through Correlation with Greenhouse Test¹

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Chemical methods for determination of the "easily soluble" or "available" fraction of soil phosphorus are numerous. Determinations of this kind are empirical since the fractions determined are in no way the estimates of any definite fraction of the soil phosphorus actually available to the plant. Consequently there is no general agreement on methods with regard to magnitude of the "available" P extracted as well as the degree of correlation with the actual P taken up by the crop. However, methods that show high degree of correlation with the results of field experiments can be used to interpret the actual phosphorus status of the soils studied. There are a

large number of phosphorus soil test methods proposed for the estimation of the phosphorus status of the soil, each of which may be suitable for particular soils at different locations. In order to correlate and calibrate P soil test methods with the field experiments, preliminary studies concerning the practical convenience of the methods, as well as their relation to phosphorus taken up by the crops, should be carried out in order to select those methods which show promise of being of practical value.

The present study involved the preliminary evaluation of some widely used P soil test methods by means of determining the correlation between "available"

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P of various soil test methods and amounts of P taken up by the crop in a greenhouse experiment. The comparison of the methods was based on the degree of correlation coefficient (r) obtained from the relationship between the soil test values and P taken up by an indicator crop grown in soils of different phosphorus status. The correlation coefficient is a simple index for expressing the linear relationship between two variables; in this case phosphorus soil test values versus phosphorus uptake values. The value of r varies between $+1$ and -1 . Positive values of r indicate a positive relationship where, on the average, an increase in one variable is accompanied by an increase in the other. On the other hand, negative values of r indicate a negative relationship where an increase in one variable is accompanied, on the average, by a decrease in the other variable. However, the nature of variables considered in this study are such that a positive r is expected. Therefore the closer the r value is to $+1$ the better is the relationship between the two variables. If r is equal to $+1$, then all points in the scatter diagram form a perfect straight line, with a positive slope.

It has been reported by many workers that the correlation coefficients obtained from soil test values compared with P taken up by plants grown in the greenhouse are much better than comparisons with the field values. This is due to the fact that many soil and climatic factors influencing the response of crops to fertilizer applications in the field are not reflected in the soil test values while these same factors do not enter into the

greenhouse values. For this reason, the comparison of soil test results with plant response in greenhouse studies give the better measurement of the ability of the soil test method to estimate the phosphorus supplying power of the soil. In this investigation, the phosphorus soil test methods which give the highest r values will be selected for further studies with field trials.

MATERIALS AND METHODS

Soil samples from four major corn producing areas—Veteran Farm at Muaklek, Prabuddhabat Agricultural Station, Agronomy Farm at Pakchong, and Banmai-Samrong Agricultural Experiment Station—were collected and brought to the greenhouse. Soil samples from each location were then treated with five different levels of phosphorus 0, 15.71, 31.42, 62.84 and 78.55 gm. of H_3PO_4 , these being designated as P_0 , P_1 , P_3 and P_4 respectively. A 5-kg. sample of each of the treated soils was placed in a one-gallon plastic pot and incubated under room conditions for 15 days. About 200 grams of sample was then taken from each pot, dried, ground to pass a 2mm. sieve, and stored in a plastic container. These samples were used for extraction by different P test methods.

Each treatment was replicated three times. Each level of phosphorus was also treated with two levels of nitrogen, N_1 and N_3 which amounted to 2.06 and 6.18 gm. of urea per plot respectively. Nitrogen was applied in the form of urea while potassium chloride at the rate of 3.2 gm. of KCL as a uniform application for all treatment. A treatment receiving

no fertilizers, for each soil, was also included in this experiment as control.

Sorghum almum was grown as the indicator crop. Seeds were sown directly on the pot, and after the plants germinated and grew to a height of about 3 inches, they were thinned to two plants per pot. Forty-five days later, when most of the plants had flowered, the plants were cut at the base and the stumps allowed to ratoon. The second growth was cut again when it reached the same stage as the first cutting.

The harvested plants were placed in a hot air oven at 60°C. to drive off moisture for 24 hours. The oven-dried top growth obtained from each treatment was weighed and recorded. All of the plant parts were then ground in a Wiley Mill and collected in a plastic cup for determination of phosphorus uptake.

Three groups of chemical soil test methods, for the analysis of "available" P, were selected for the evaluation study. They are methods which are presently well known and widely used in numerous laboratories. There three groups are:

(1) Methods employing HCl and NH_4F .

This group includes two related methods established by Bray and Kurtz (1). One is frequently referred to as Bray No. 1 and involves extraction of the soil with a solution of 0.025 N HCl and 0.03 N NH_4F . In the other, extraction is with a solution of 0.10 N HCl and 0.03 N NH_4F . This method is often referred to as Bray No. 2 and utilizes a stronger acid extractant, and consequently removes more of the phosphorus from the less forms. In both

solutions, the fluoride ion is included for replacement of the so-called "sorbed phosphate".

(2) Methods involving strong acid extractants.

Two methods of this group were studied. One is the extractant consisting of a combination of .05 N HCl and .025 N H_2SO_4 . This method was developed by A. Mehlich⁽⁸⁾ for determination of P, Ca, Mg, K, Na and NH_4 for the North Carolina Soil Testing Laboratory. For the sake of convenience the method will be designated as Mehlich's method. The other method is Truog's method (2) in which phosphorus is extracted by 0.002 N H_2SO_4 containing 3 gm. of $(\text{NH}_4)_2\text{SO}_4$ per liter.

(3) Methods involving bases or alkaline extractants.

Many basic or alkaline solutions have been proposed by many workers for determining "available" P for soils high in phosphorus fixing capacity and sesquioxides. The theoretical basis of these methods utilizes the fact that the form of phosphate in tropical red soils are present mostly as the iron and aluminum phosphates, and these forms seem to reflect the phosphorus status of soils better than dilute acid soluble forms which occur mostly as calcium phosphates. Since iron and aluminum phosphates are easily soluble in alkaline solution especially in sodium hydroxide solution, Jones (3) recommended 0.5 N NaOH solution for use in the acid red soils of Kenya. Williams (4) suggested the use of 0.1 N NaOH solution for South Australian soils. More recently,

Olsen et al (5) proposed a 0.5 M NaHCO_3 for the extraction of alkaline soils. The mechanism of the bicarbonate method is based on the increased solubility of calcium phosphate while decreasing the activity of Ca^{++} in solution. They also claimed that the method could be applied to acid and neutral soils as well as alkaline soils. Thomson and Pratt (6) and Datta and Kamath (7) also provided positive evidences of the satisfactory use of the NaHCO_3 method for both the acid

and alkaline soils.

The sodium bicarbonate extractant, usually known as Olson's method, which consists of 0.5 M NaHCO_3 solution pH 8.5, is the method from this group used in this evaluation study.

Details concerning the constituents and concentrations of the various extractants, the time of shaking, and the soil to solution ratios required by the different methods are shown in Table 1.

Table 1

Characteristics of five chemical soils tests for "available" phosphorus

Method	Extracting solution	Soil: Solution ratio	Time of shaking
Bray No. 1	0.025 N HCl + 0.03 N NH_4F	1 : 10	60 seconds
Bray No. 1	0.1 N HCl + 0.03 N NH_4F	1 : 10	40 seconds
Olson's	0.5 M NaHCO_3 , pH 8.5	1 : 10	30 minutes
Truog's	0.002 N H_2SO_4 + $(\text{NH}_4)_2\text{SO}_4$, pH 3.0	1 : 10	30 minutes
Mehlich's	0.05 N HCl + 0.025 N H_2SO_4	1 : 4	5 minutes

Determination of phosphorus in plant tissue

The plant samples were wet digested and analyzed for phosphorus as follows: The samples were first predigested with concentrated nitric acid until the brown nitric oxide fumes disappeared. This mixture was then further digested with perchloric acid on the hot plate until the solution was clear, and fumes of perchloric acid persisted. About 20 ml. of distilled water was added and the mixture

heated to boiling for a few minutes. The solution was cooled, filtered and diluted with water to 50 ml. Phosphorus in the solution was determined by ammonium molybdate -1,2,4 aminonaphthol sulfonic acid. Perchloric acid was employed to acidify the system. The transmittancy of the developed blue colored solution was measured on a Cenco Photometer using a red filter (645 micron).

RESULTS AND DISCUSSION

Soil samples collected from each pot were analysed for "available" P with five different extracting solutions. Soil samples of the same treatment but collected from different replications were analysed separately. The amounts of extractable P obtained by different methods of soils from Pakchong, Muaklek, Prabuddhabat and Banmai-Samrong are shown in Tables 2 to 5 respectively. Yield dry matter and amounts of phosphorus taken up by *Sorghum almum* grown in the respective soils are also shown with the soil test results. It was obtained that, in general, as the level of nitrogen and phosphorus increased, the yield and P uptake of the crop increased, (Tables 6 and 7), whereas the P test values increased only with increasing levels of phosphate (Tables 2 to 5).

In order to see, however, whether treatments of nitrogen and phosphorus applied to soils influenced the yield and P uptake, analyses of variance were performed. The analyses are shown in Tables 6 and 7 respectively. The analyses of variance indicate that the treatments (including 2 levels of N and 5 levels of P_2O_5) significantly increase yield and phosphorus uptake in all four soils. When the individual effects of N and P upon the yield and P uptake were determined, data indicated that increasing levels of N and P significantly increased yield and P uptake of *Sorghum almum*. It was noted that the differences in yield between P_0 and the other four levels of P are highly significant whereas the differences among P_1 , P_2 , P_3 , and P_4 are not significant in

all soils. This can be explained from the fact that the amounts of phosphoric acid applied to the soils were at the sufficient levels for normal growth at P_1 . Therefore the significance of the crop, in terms of an increasing yield, at higher levels of P were not obtained.

Phosphorus taken up by the crop at P_0 was significantly lower than at the other levels of P. Eventhough yield did not significantly increase when phosphorus levels increased, the phosphorus taken up by the crop tended to increase as phosphorus level increased from P_1 to P_4 .

Data (Tables 6 and 7) also indicated that the higher level of nitrogen significantly increased both yield and phosphorus taken up by the plant. However, interaction between N and P upon yield was not obtained in all soils, while only slight interactions of $N \times P$ upon P uptake were obtained in soils, from two locations namely: Prabuddhabat and Banmai-Samrong.

Soil Test Correlation

In order to determine the adaptability of the soil test methods to different soils, linear regression analyses were performed between soil test values versus yield and total P uptake for each soil. Correlation coefficients obtained for each methods as applied to the different soils are shown in Table 8. From the table, it is clear that the correlation coefficients for the relationship between soil test values and phosphorus uptake for all methods in all soils are much higher than the corresponding relationship

obtained between soil test values and yield of the crop. Apparently the O soil test values are more closely related to the amounts of P taken up by the plant than the actual amount of growth of the crop. It is shown that one of the soil test methods gave approximately the same degree of correlation in the same soil but differed significantly among different soils. Correlation coefficients of all soil test methods seemed to be higher for the soils from Pakchong and Prabuddhabat and lower for soils from Muaklek and Banmai-Samrong. The data indicate that, for any one soil, there is no single method superior to the others, and any method may be used successfully. However, so far as practical usefulness is concerned, it is impractical to test each of different soil with the separate method best suited for it. Therefore, it is necessary to choose one method which is best adapted to as many soils as possible. The basis for selecting this method is a correlation of the soil test values of each method with yield and phosphorus uptake from all soils. The method that gives the highest r will then be the method that is best related to the phosphorus status of all soils and, therefore, should be the one selected. Correlation coefficients between the soil test values versus yield and phosphorus uptake of all four soils are shown in Table 9. Again from this data correlation coefficients of soil test values of all methods with yield are much lower than those related to phosphorus uptakes. The correlation coefficients of soil tests with yield vary from 0.243 for Mehlich's method to 0.477 for Olson's method, whereas the

r of soil tests versus phosphorus uptake vary from 0.620 for Mehlich's method to 0.746 for Bray No.2 and 0.701 for Olson's method. The data indicate that Bray No.2 and Olson's method are best suited for future studies of soil test correlation with field experiments. It should be noted that even though the two methods yielded the highest r of the group, the magnitude of the r values were still quite low. The coefficients of the determination ($r^2 \times 100$) of Bray No.2 and Olson's method were only 55.6 and 49.1 percent respectively. The coefficients of determinations indicated that only about 55.6 and 49.1 percent of the variation of the "available" P determined by Bray No.2 and Olson's methods could be predicted or accounted for by variation in the amount of phosphorus actually utilized by the plant. The reason for low values of r may possibly be explained from the fact that the soils employed in this study vary in their characteristics. Details of the procedure, namely the time of shaking and the ratio of soil to solution, as described by the methods may not be suitable for the soils studies. Correlation coefficient could be improved if they are modified to suit the soils and laboratory condition. Another possible explanation is that too high levels of phosphate were applied to the soil. The P_1 level was already too high that there were no intermediate level of P that would give an intermediate yield and P uptake. At too high levels of P, yields and P uptake tend to level off whereas soil test values were still increasing with the soil phosphorus levels.

สรุป

เป็นการทดลองเพื่อศึกษาเปรียบเทียบการวิเคราะห์หา "available" P วิธีต่าง ๆ โดยการหาความสัมพันธ์กับผลของการทดลองในกระถาง การทดลองใช้ดินจาก 4 แห่ง แต่ละแห่งได้รับไนโตรเจน 2 ระดับ และฟอสฟอรัส 5 ระดับ รวมเป็น 10 treatment การทดลองเป็นแบบ randomized complete block นำดินที่ใส่ปุ๋ยฟอสฟอรัสในอัตราต่าง ๆ นี้มาวิเคราะห์ทางเคมีเพื่อหา available P ด้วยวิธีวิเคราะห์ที่ต่างกัน 5 วิธี ปลูกหญ้า *Sorghum almum* ลงไปในดินที่ได้รับปุ๋ยต่าง ๆ เหล่านี้ เพื่อศึกษาปริมาณการเจริญเติบโตและปริมาณ ฟอสฟอรัสที่พืชดูดขึ้นมา (phosphorus uptake)

จากการวิเคราะห์ analysis of variance ปรากฏว่าดินที่ได้รับปุ๋ยฟอสฟอรัสในระดับสูงขึ้นไปจะทำให้ yield dry weight และ P uptake ของ *Sorghum almum* สูงขึ้นในระดับฟอสฟอรัสที่เท่ากัน พืชที่ได้รับไนโตรเจน อัตราสูงจะเจริญเติบโตได้ดีกว่า และสามารถดึงฟอสฟอรัสจากดินขึ้นมาใช้ได้มากกว่าพืชซึ่งได้รับไนโตรเจนอัตราต่ำ

จากการหาความสัมพันธ์ระหว่างวิธีวิเคราะห์ "available" P ทั้ง 5 วิธีกับ yield dry weight และ phosphorus uptake ของ

Sorghum almum ปรากฏว่าค่า correlation coefficient (r) ของทุก ๆ วิธีมีความสัมพันธ์กันทางตรงกับปริมาณของฟอสฟอรัส (P uptake) และน้ำหนักแห้งของพืช (yield dry weight) อย่างมีนัยสำคัญยิ่ง นั่นคือเมื่อค่าของ "available" P ซึ่งวิเคราะห์ได้โดยวิธีใดวิธีหนึ่งก็ตามสูงขึ้นเท่าใด ปริมาณของฟอสฟอรัสในพืชและปริมาณน้ำหนักแห้งของพืชก็จะสูงตามไปด้วยเช่นเดียวกัน

ค่า correlation coefficient ของ "available" P vs P uptake ของทุก ๆ วิธีจะสูงกว่าค่า r ที่ได้จาก "available" P vs yield dry weight แสดงให้เห็นว่าปริมาณของฟอสฟอรัสในพืชเป็นตัวบ่งชี้ระดับของฟอสฟอรัสที่แตกต่างกันในดินได้ดีกว่าปริมาณการเจริญเติบโตของพืช

จากการเปรียบเทียบค่า correlation coefficient ของวิธีต่าง ๆ ปรากฏว่าค่า r ของวิธี Bray No.2 และของ Olson สูงกว่าวิธีอื่น ๆ ซึ่งแสดงว่าวิธีทั้งสองนี้เป็นวิธีที่มีแนวโน้มที่จะเป็นวิธีที่ดีกว่าอีก 3 วิธี และควรจะเป็นวิธีที่น่าจะนำมาศึกษาและปรับปรุงเพื่อทดสอบกับการทดลองในไร่นาต่อไป

SUMMARY

Preliminary evaluation of different phosphorus soil tests was determined by means of correlation with a greenhouse experiment. Soil from four locations

were employed. They were treated with two levels of nitrogen and five levels of phosphorus, a total of ten treatment combinations. The treated soils were analyzed for "available" P by five different chemical methods. *Sorghum alnum* was used as an indicator crop for greenhouse experiment, where total yield (dry weight) and phosphorus taken up by the crop were measured.

Analysis of variance indicated that increasing rate of phosphorus increased total yield and total phosphorus taken up by crop. Both nitrogen and phosphorus significantly increase yield, and phosphorus significantly increase yield and phosphorus uptake. At the same rate of phosphorus, the plant grew better and obtained more phosphorus from the soil where the higher rate of nitrogen was applied than at the lower rate.

Relationship between soil test values of all the methods with total yield and phosphorus uptake are positive and linear. This indicates that as the soil test values of the soils increase the corresponding total yield and P uptake also increases.

The correlation coefficients (r) obtained from "available" P vs P uptake of all methods were much higher than those obtained from "available" P vs total yield, this indicates that phosphorus content of the plant is a better indicator of phosphorus status of soil than the yield of the plant.

The magnitude of the correlation coefficients of all methods were relative-

ly low, however the Olson's and Bray No.2 methods yielded the highest r values which indicates that further correlation studies with these methods should be made with field experiments.

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Table 2
 "Available" P determined by chemical soil test methods
 of soil at Pakchong location

Treatment	Soil analysis of different methods (ppm P)				
	Bray No.I ppm P	Bray No. II ppm P	Olson's ppm P	Truog's ppm P	Mehlich's ppm P
Control	13.36	24.70	5.06	32.33	37.60
N ₁ P ₀	12.70	23.16	4.80	27.33	27.73
N ₁ P ₁	189.58	178.33	68.66	10.36	160.98
N ₁ P ₂	322.50	348.30	148.00	200.66	389.33
N ₁ P ₃	451.66	632.50	213.00	318.00	640.33
N ₁ P ₄	656.66	735.80	314.00	439.00	797.33
N ₃ P ₀	12.46	21.00	4.86	48.33	33.60
N ₃ P ₁	209.16	240.33	69.66	147.66	183.20
N ₃ P ₂	342.50	410.00	163.66	280.60	421.66
N ₃ P ₃	492.08	570.83	222.00	345.60	766.13
N ₃ P ₄	713.16	790.00	335.66	476.00	953.46

Table 3
 "Available" P determined by different chemical soil test methods
 of soil at Muaklek location

Treatment	Soil analysis of different methods (ppm P)				
	Bray No.I ppm P	Bray No. II ppm P	Olson's ppm P	Truog's ppm P	Mehlich's ppm P
Control	17.91	27.20	9.53	28.60	2.98
N ₁ P ₀	17.80	25.33	6.23	32.33	2.66
N ₁ P ₁	35.40	118.30	85.33	55.20	8.58
N ₁ P ₂	44.16	250.16	147.00	156.33	15.76
N ₁ P ₃	49.08	320.83	252.33	244.33	33.71
N ₁ P ₄	73.33	425.00	355.33	346.00	47.46
N ₃ P ₀	19.06	25.46	6.76	33.35	2.37
N ₃ P ₁	40.00	126.66	78.00	59.00	14.02
N ₃ P ₂	49.00	221.66	146.66	134.33	24.96
N ₃ P ₃	56.25	287.50	260.00	227.66	42.09
N ₃ P ₄	72.50	408.16	406.66	297.33	46.00

Table 4
 "Available" P determined by different chemical soil test methods
 of soil at Saraburi location

Treatment	Soil analysis of different methods (ppm P)				
	Bray No. I ppm P	Bray No. II ppm P	Olson's ppm P	Truog's ppm P	Mehlich's ppm P
Control	18.50	23.73	7.60	48.60	21.46
N ₁ P ₀	12.48	23.76	10.33	51.00	24.80
N ₁ P ₁	267.50	244.58	109.00	179.33	246.06
N ₁ P ₂	472.50	471.25	176.00	265.66	548.26
N ₁ P ₃	708.30	650.83	336.00	340.00	801.60
N ₁ P ₄	844.16	860.41	378.00	533.33	993.60
N ₃ P ₀	16.70	21.56	6.23	50.33	20.26
N ₃ P ₁	272.50	290.00	174.00	226.66	281.80
N ₃ P ₂	481.16	515.41	240.30	344.33	593.84
N ₃ P ₃	727.50	619.16	296.00	422.60	776.00
N ₃ P ₄	810.66	856.25	366.60	562.66	100.96

Table 5
 "Available" P determined by different chemical soil test methods
 of soil at Banmai-Samrong location

Treatment	Soil analysis of different methods (ppm P)				
	Bray No. I ppm P	Bray No. II ppm P	Olson's ppm P	Truog's ppm P	Mehlich's ppm P
Control	95.80	79.33	25.63	103.33	66.66
N ₁ P ₀	98.33	95.83	32.46	151.33	94.06
N ₁ P ₁	306.60	361.66	245.00	315.00	482.66
N ₁ P ₂	561.25	568.75	296.33	437.33	762.60
N ₁ P ₃	708.30	799.75	375.66	517.66	1157.33
N ₁ P ₄	1103.33	1051.66	488.00	752.00	1477.30
N ₃ P ₀	97.08	75.00	29.66	134.00	89.06
N ₃ P ₁	327.08	358.33	175.33	442.66	409.06
N ₃ P ₂	418.33	393.33	254.66	559.66	677.33
N ₃ P ₃	729.58	787.91	342.00	650.33	1092.00
N ₃ P ₄	1121.66	1101.66	422.00	767.63	1668.00

Table 6
Total yield dry weight of *Sorghum alnum* growing in
soils treated with different levels of N and P₂O₅

Treatment	Total yield dry weight* (gm.)			
	Pakehong location	Muaklek location	Saraburi location	Banmai-Somron location
N ₁ P ₀	51.02	51.13	35.22	93.79
N ₃ P ₀	45.63	34.17	36.25	81.03
N ₁ P ₁	146.45	156.34	123.79	76.26
N ₃ P ₁	196.95	198.64	157.28	101.03
N ₁ P ₂	131.30	175.59	133.35	90.84
N ₃ P ₂	204.84	221.97	149.24	117.45
N ₁ P ₃	188.42	163.34	139.17	89.27
N ₃ P ₃	234.93	221.19	165.76	104.78
N ₁ P ₄	185.38	142.16	132.25	114.11
N ₃ P ₄	194.38	186.45	160.45	148.30
LSD. 5%	51.85	40.34	28.20	37.29
LSD. 1%	71.03	55.26	38.62	51.69

* Average of three replications.

Analysis of variance

Source of variation	F-ratios			
	Pakchong	Muaklek	Saraburi	Banmai Samrong
Replication	3.7762**	0.4523	0.748	0.6279
Treatment combination	13.6924**	22.7885**	25.545**	2.8279*
N	9.9239**	17.3558**	12.206**	4.9412*
P	26.6101**	44.5255**	53.523**	4.0299*
N × P	1.7169	2.4094	0.902	1.0562

* significant at 5% probability level.

** significant at 1% probability level.

Table 7
Phosphorus taken up by *Sorghum almum* in soils treated
with different levels of N and P₂O₅

Treatment	Average total P uptake (mg.P.)			
	Pakchong	Muak Lek	Saraburi	Banmai-Samrong
N ₁ P ₀	58.89	35.05	31.05	99.74
N ₃ P ₀	53.97	50.87	25.36	882.31
N ₁ P ₁	188.60	266.84	252.86	143.99
N ₃ P ₁	295.11	353.40	185.78	167.04
N ₁ P ₂	258.91	215.67	313.97	160.09
N ₃ P ₂	312.27	266.29	352.88	231.54
N ₁ P ₃	401.19	255.57	364.08	199.77
N ₃ P ₃	494.79	278.39	500.85	314.98
N ₁ P ₄	501.81	236.75	377.83	322.67
N ₃ P ₄	649.86	422.74	590.53	575.79
LSD. 5%	150.20	67.38	132.08	108.18
LSD.1%	205.75	92.30	181.20	148.19

Analysis of variance

Source of variation	F-ratios			
	Pakchong	Muak Lek	Saraburi	Banmai-Samrong
Replication	1.0194	1.334	0.0519	0.235
Treatment combination	13.2968**	16.744**	16.868**	16.037**
N	6.1552**	15.445	4.997**	14.966**
P	31.0287**	30.975	33.541**	28.230**
P×P	0.6573	2.837	3.163	4.112

* significant at 5% probability level.

** significant at 1% probability level.

Table 8

Comparison of the correlation coefficient (r) of different phosphorus soil test methods when correlated with yield dry weight and P uptake for different soils

Method	Correlation coefficient (r)							
	Pakchong		Muaklek		Saraburi		Banmai – Samrong	
	yield dry weight	P uptake	yield dry weight	P uptake	yield dry weight	P uptake	yield dry weight	P uptake
Bray No. 1	0.736	0.921	0.698	0.753	0.794	0.899	0.608	0.839
Bray No. 2	0.742	0.904	0.633	0.665	0.778	0.875	0.579	0.820
Olson's method	0.694	0.895	0.585	0.674	0.803	0.877	0.572	0.732
Truog's method	0.757	0.928	0.516	0.564	0.765	0.854	0.673	0.825
Mehlich's method	0.720	0.917	0.624	0.583	0.740	0.848	0.595	0.833

Table 9

Comparison of the correlation coefficient (r) of different phosphorus soil test methods when correlated with yield (dry weight) and P uptake in all soils

Method	P soil test vs total yield dry weight		P soil test vs total P uptake	
	r	Linear regression equation	r	Linear regression equation
Bray No. 1	0.285	$\bar{y}_x=105.518+0.059x$	0.669	$\bar{y}_x=128.31+0.375x$
Bray No. 2	0.432	$y_x=88.8+0.093x$	0.746	$\bar{y}_x=84.937+0.438x$
Olson's method	0.477	$y_x=83.292+0.219x$	0.701	$\bar{y}_x=87.57+0.876x$
Truog's method	0.332	$\bar{y}_x=83.292+0.106x$	0.633	$\bar{y}_x=100.072+0.548x$
Mehlich's method	0.243	$\bar{y}_x=108.861+0.036x$	0.620	$\bar{y}_x=147.755+0.247x$