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# Phosphorus Recommendations for Various Soil Series of Pakistan in Relation to P Fixation Tendencies

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**Abstract:** This study was conducted with the objective to improve the P fertilizer recommendation system by selecting procedure take care of initial P status of soil and P fixation tendencies. For this purpose, phosphorus fixation tendencies of six soils were ascertained by using P recovery after two hours and its P application. Initial recommendation was estimated based on fixation tendency and it was correlated with P fertilizer recommendation on eight weeks soil equilibration pot study. Regression equations relating fixation tendencies and eight weeks equilibration results were used to predict P requirement associated with maximum maize yield. The degree of association was high enough ($r^2$ =0.98) between two sets of data obtained independently. The procedure is competent to be followed in routine fertilizer recommendations, as it is rapid, takes care of fixation tendency, initial soil status and permits values analogous to actual values achieved by eight weeks equilibration period.

**Key words:** P fixation, soil series, maize crop, P requirement

## INTRODUCTION

In Pakistan, we have already surpassed the stage of phosphorus fertilizer introduction. However, the rate of phosphorus application varies from farmers to farmers. The reason might be that blanket fertilizer recommendations are developed for the province or region, irrespective of soil variability and consequent differential response of various soils to P fertilizer application[1-3]. An effective and rapid procedure can help to formulate the fertilizer recommendation. However the current methods for estimating optimum amount of phosphorus to be applied to a crop based on response curve studies, percent efficiency, net return and GNR with cost benefit ratio 1:3.These procedures are less competent to be followed for site specific research as it is time consuming, do not take into account the original phosphorus status of soil and phosphorus supplying power of the soil to crop[4]. This seems especially important when soils vary in phosphorus and nutrient P fixation tendency. The need for improved fertilizer recommendation based on soil test has been suggested[4,5].

To convert soil test values for phosphorus in fertilizer recommendations needs (I) Existing level of available P in soils (ii) The quantity of fertilizer required to reach the soil test level (iii) The quantity of fertilizer P which is sufficient for maximum or optimum yield[6]. The 1st and 2nd of the values can be ascertained by soil test with suitable method in soil testing laboratory[5]. The third value may be obtained from crop response studies in the farmer's fields.

Early workers[5,7] introduced a method through which the P fertilizer recommendation (Pf) to attain sufficiency level (Psl) from the initial soil P level (Pel) can be formulated from an equation;

$$Pf= Fp\ (Psl-Pel)$$

where Fp = reciprocal of fixation of added P recovered (fixation factor).

This procedure included both fixation tendency and initial soil P level. Therefore, it may provide reliable information. Recommendations are based on two hours quick test procedure to rapidly provide information regarding P fixation as described by Mclean *et al.*[5] and adopted by Akram *et al.*[8].

The purpose of the present study was to evaluate suitability of P fertilizer recommendations based on P fixation tendency of soil for maize crop.

## MATERIALS AND METHODS

Six soil series of Pakistan were sampled namely Missa, Rojar, Faisalabad, Kotli, Shahdara and Hafizabad

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from the surface to 30 cm depth. These soils were air dried, ground and passed through a 2 mm sieve and were analyzed for their pH by U.S. Salinity Lab Staff[9] texture and lime[10] $NaHCO_3$ extractable P[11] and organic matter by Walkley and Black[12]. Classification and physico-chemical properties of these soils are given in (Table 1).

Fixation tendencies of these soils were determined by taking 1g of each soil adding 0.5 ml of $KH_2PO_4$ solution of 60 mg P $l^{-1}$ and equilibrated for 2 h. The reciprocal of P fraction recovered of that added was designated as P fixation factor (Fp).

Eight weeks equilibration P recoveries for actual (P Fixation estimations) were determined by applying P @ 0,20,40,60 and 80 mg P $kg^{-1}$ as finely ground TSP (Triple Super Phosphate) to each soil duly repeated thrice in pots. The TSP was mixed uniformly in 1 kg soil and moistened with distilled water. Aliquot of each soil was removed after 8 weeks equilibration and analyzed for available-P. Linear functions of added P vs. available-P in soil were determined. The amount of fertilizer P actually required to bring the available-P in the various soils is to be 21 mg P $kg^{-1}$ of soil[8].

Phosphorus recommendations for all six selected soils were computed from both fixation tendency and actual eight weeks equilibration in pot study. The stepwise computation is given below:

1. The actual values (y) were obtained from linear equations relating $NaHCO_3$ P at the end of eight weeks equilibration to the added P.
2. The computed values $y_1$ realized form constant recovery (fixation factor) Table 2 were confessed by solving Pf = Fp (Psl-Pel).
3. The regressed value ($y_2$) were acknowledged by substituting $y_1$ value for "x" into the regression equation (Y = bx-a).

## RESULTS AND DISCUSSION

The phosphorus fixation factors of the six soil series are given in Table 1. The data revealed that phosphorus fixation factors were higher for all soil series except the Hafizabad series. Mean value i.e. 3.12 was 32% recovery of added phosphorus. It was 23% higher than average recovery of some western soils that are being used as a basis for recommending fertilizer P[14]. The order of soils according to their P fixation factors was:

The soil D> the soil A> the soil C> the soil B> the soil E > the soil F

**Eight weeks equilibration:** The available phosphorus levels after eight weeks equilibration in various soils according to the rate of P added with their regression equations and the degree of association of the two variables ($r^2$) are given in Table 2. The data revealed that to get actual values of P required producing near maximum maize yield. The pot study indicated that $NaHCO_3$ P was increased significantly in all the soils by addition of P. The highest amount of P added was recovered from the Hafizabad soil. The higher recovery of added P from Hafizabad soil might be due to its low fixation factor (Table 1) and low maximum adsorption (b) and the affinity coefficient (k) as these parameters have been reported elsewhere. Ahmad[13] published that the maximum adsorption soil parameter can be used successfully to estimate the percentage of phosphate to be used to an unfertilized soil. The affinity coefficient indicates comparatively how easily the added phosphate be adsorbed on or released from the adsorbing surfaces. Coefficients of determination ($r^2$) were higher in all soils (Table 2). The actual P levels built up after eight weeks equilibration by five P applications are plotted in Fig. 1 against corresponding values computed from fixation factor. The degree of association was high enough ($r^2$>0.98) between these two set of data obtained independently. It was noted that circled and crossed points marked for the Hafizabad and the Kotli soil series respectively fall slightly away from the trend line on opposite side. These points are manifested when P application rates were higher. This tendency might be due to relatively low fixation capacity in case of hafizabad soil and higher fixation capacity in case of Kotli soil during longer period (8 weeks) equilibration in pot study compared to short period (2 h).

The actual (y) amounts of fertilizer P (PF) from the available P vs added P function are depicted in Table 3 and 4. In addition, these tables contain computed. PF values on constant recovery of P from all the soils ($y_1$), regression adjusted ($y_2$) values and the equations correlation coefficients ($r^2$) values relating to the computed Vs the actual fertilizer P levels. The Phosphorus recommendations as determined by the fixation factor ($y_2$) are an improvement over those computed by the constant recovery procedure $y_1$ (Table 3 and 4).

These regression equations that relate fixation factor values ($y_1$) against eight weeks equilibration values (y) were determined i.e. y= 0.920x-5.104 and y = 1.0058x-0.231) for 99% (Psl=21) and 95% (Psl =14) relative yield goal, respectively. Regression brought "y" intercept essentially at the origin (Fig. 2 and 3) and reduced the average deviation from actual values (from 1.22 to-25%).

Table 1: Classification and selected physico-chemical properties of the soils

| Soil series | Soil order | P Fixation factor | $NaHCO_3$ extractable P mg $kg^{-1}$ | pH | $CaCO_3$ (%) | Clay (%) | Organic matter (%) |
|---|---|---|---|---|---|---|---|
| Missa | Inceptisols | 3.46 | 2.60 | 8.15 | 13.47 | 19.2 | 0.72 |
| Rojar | Entisols | 2.55 | 3.70 | 7.57 | 10.50 | 18.2 | 0.32 |
| Faisalabad | Aridisols | 3.84 | 3.90 | 7.43 | 2.34 | 17.3 | 0.63 |
| Kotli | Vertisols | 4.67 | 10.50 | 7.48 | 2.90 | 47.4 | 1.35 |
| Shahdara | Entisols | 2.37 | 1.70 | 7.87 | 4.60 | 9.3 | 0.21 |
| Hafizabad | Aridisols | 1.83 | 4.50 | 7.95 | 2.10 | 14.2 | 0.54 |

Table 2: Sodium bicarbonate phosphate (average of 3 repeats) found after eight weeks equilibrium at various rates of P added to six soils and linear regression equations

| | | | P added (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|---|---|
| Soils | Equations | $r^2$ | 0 | 20 | 40 | 60 | 80 |
| Missa | Y= 2.147+0.355x | 0.992 | 3.25c | 7.98c | 15.6b | 24.4a | 28.60a |
| Rojar | Y=4.176+0.468x | 0.992 | 4.78c | 11.76c | 24.6b | 31.67b | 41.82a |
| Faisalabad | Y=4.02+0.310x | 0.995 | 4.45e | 9.90d | 15.78c | 23.13b | 31.73a |
| Kotli | Y=9.040+0.293x | 0.993 | 9.70e | 13.58d | 21.38c | 26.60b | 32.71a |
| Shahdara | Y=6.635+0.429x | 0.987 | 5.87d | 16.15c | 26.24b | 30.79b | 32.55a |
| Hafizabad | Y=6.199+0.731x | 0.999 | 5.60e | 21.75d | 35.29c | 49.80b | 62.37a |

Mean with same letters in each horizontal column are not significantly different at 0.05 level of probability, Correlation coefficient is significant at 0.01 level of probability

Table 3: Fertilizer phosphorus required mg P $kg^{-1}$ soil) for near maximum maize yield (99% potential)

| Soil | Actual (Y) | Computed constant recovery (Y1) | Regression (Y2) |
|---|---|---|---|
| Missa | 53 | 64 | 54 |
| Rojar | 36 | 44 | 35 |
| Faisalabad | 55 | 66 | 56 |
| Kotli | 41 | 49 | 40 |
| Shahdara | 33 | 39 | 31 |
| Hafizabad | 20 | 30 | 22 |
| Mean | 39.67 | 48.67 | 39.67 |
| $R^2$ | 0.99 | 0.99 | |
| Regression | | Y= 0.920X-5.104 | Y=1.0058X-0.231 |
| Mean deviation from actual (%) | | -25 | 1.22 |

Y = Actual requirement based on eight week equilibration obtained by setting 21 and solving for x in respective equation
Y1 = Fixation factor (21-Pel) Y2 = Regression adjusted

Table 4: Fertilizer phosphorus required (mg P $kg^{-1}$ soil) for near maximum maize yield (95% potential)

| Soil | Actual (Y) | Computed constant recovery (Y1) | Regression (Y2) |
|---|---|---|---|
| Missa | 33 | 39 | 32 |
| Rojar | 21 | 26 | 21 |
| Faisalabad | 32 | 39 | 32 |
| Kotli | 17 | 16 | 13 |
| Shahdara | 17 | 22 | 18 |
| Hafizabad | 11 | 17 | 14 |
| Mean | 22 | 26 | 22 |
| $R^2$ | | 0.96 | 0.96 |
| Regression | | Y= 0.836X-0.375 | Y=0.915X-1.62 |

Y = Actual requirement based on eight week equilibration obtained by setting 14 and solving for x in respective equation
Y1 = Fixation factor (14-Pel)
Y2 = Regression adjusted

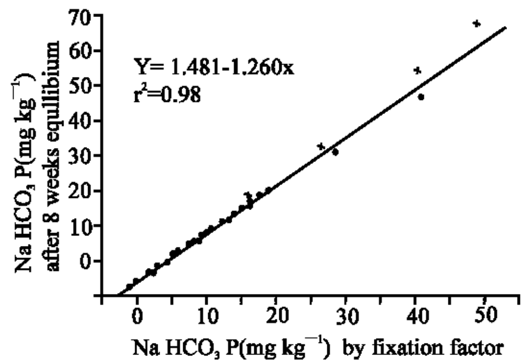


Fig. 1: Amount of sodium bicarbonate P computed from fixation factor (quick test) vs. 8 weeks soil equillibrium

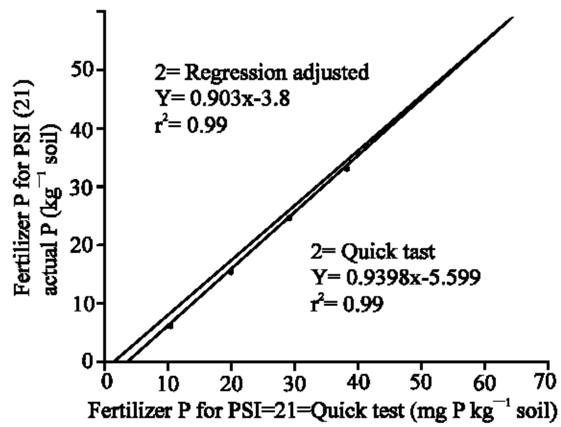


Fig. 2: Relationship of recommended P fertilizer for 99% relative corn yield (quick test vs actual)

Therefore, these equations calculate P requirement using P fixation factor that are similar to actual values. Regression of data obtained from fixation factor from each soil verses actual values resulted in a strong correlation ($r^2$ =0.99) for 99% near maximum yield. The fixation factor procedure estimated higher P requirement compared to the actual value. A mean values (48 mg P $kg^{-1}$) was obtained by fixation factor method which was higher than actual values (40 mg $kg^{-1}$) (Table 3). But predictive ability was

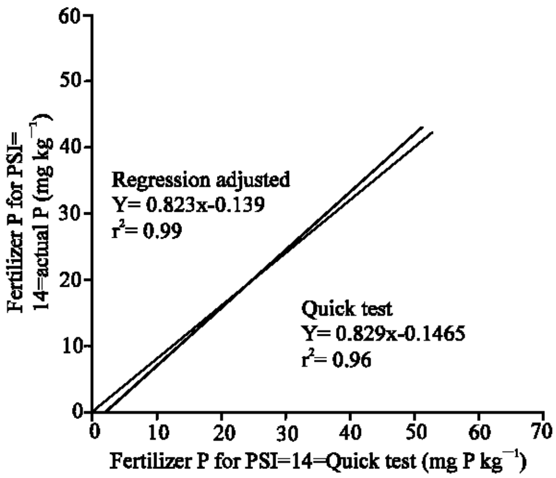


Fig. 3: Relationship of recommended P fertilizer for 95% relative maize yield, quick test vs actual

improved by using regression adjustment that improved $r^2$ values and resulted similar mean values. These regression equations and the $r^2$ values for fertilizer P requirement based on fixation factor for all the soils vs actual values indicate considerable room for improvement. Akram *et al.*[8] obtained the regression equation between the P requirement from actual P values (y) and fixation factor values ($y_1$) was 1.432x-23.742 with $r^2$ value of 0.94. The curve slop was very near to curve slop of six soils. The degree of association was also highly significant. It confirms the efficiency of fixation factor procedure. The procedure is competent to be followed in routine fertilizer recommendation as it is rapid, take care of fixation tendency, initial soil status and permit the various analogous to actual values achieved by eight weeks equilibration period. However, it might be a subject to use a large population of soils for estimating the P requirement through fixation factor. Based on the concept following two procedures can be suggested for P fertilizer recommendations.

1. Divulge P fertilizer requirements ($P_F$) by solving equation.

A. PF=[FP (21-Pel) X 4.58 for 99% relative maize yield]

B. PF=[FP (14-Pel) X 4.58 for 95% relative maize yield]

Where FP = fixation factor and Pel = Existing soil P in mg $kg^{-1}$ soil

The average fixation factor 3.12 confessed from average recovery of added P to six soils can be used instead of fixation factor for individual soils.

II. A Substituting PF value (21) for x into the equation y=0.920x-5.104.

Y= recommended P fertilizer in P kg per ha for 99% relative maize yield.

B. Substituting PF values (14) for x in to the equation Y= 829x-0.1465 (Y= recommended P fertilizer in P kg per ha for 95% relative maize yield.

The data support the suggestions that the proposed procedure is a very satisfactory technique for maximizing the accuracy of recommendation as to know how much fertilizer P is required by a given soil to reach a sufficient level for maximum yield of a crop.

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