Extractants of phosphorus and their correlation with soil properties and yield of maize


ABSTRACT

A pot experiment was conducted with 15 soils of Anand and Kheda varying widely in their P availability to find the suitable extractants for the determination of available P. It was found that the available P extracted with various extractants negatively associated with soil characteristics such as pH, EC, OC, CaCO₃, and clay. On the basis of correlation obtained between soil test values and P uptake, it was observed that Olsen’s and AB-DTPA extractable P were equally good indices of P availability for predicting P response to maize.

Key words: Different soil test methods, Soil properties, Yield and uptake

INTRODUCTION

Crop responses to phosphatic fertilizers vary with soil physico-chemical properties with the nature of crop, variety and climate. The variation in responses is due to the differences in their phosphorus requirement, utilization efficiency of soil and fertilizer phosphorus for same level of production. The crop responses have remained unpredictable because of poor recovery of phosphorus from applied fertilizers due to fixation in the soil and also for want of proper soil testing methodology.

The availability of soil phosphorus has been estimated by different reagents which include use of water, CO₂ saturated water, mild organic and inorganic acid solutions, alkalies buffered solutions or even chelating agents of the reagents proposed 0.5 M NaHCO₃ pH 8.5 (Olsen et al., 1954) has become more popular. In recent years, the methods Mehlich-3 (Mehlich, 1984) and AB-DTPA (Soltanpour and Schwab, 1977) are gaining importance. The information regarding appropriate extractant for determining phosphorus in Anand and Kheda soils is lacking for sound fertilizer recommendation.

MATERIALS AND METHODS

Fifteen surface soil samples varied from low to high in Olsen’s extractable P were collected in bulk quantity from different locations of Anand and Kheda districts. The soils under study have Ustochrepts as great group and inceptisols as order. But soils S₁, S₂, S₃, S₄, S₆, S₉, S₁₁, S₁₂, S₁₃, S₁₄ and S₁₅ have Typic Ustochrepts as sub-group, while soils S₅, S₇, S₈ and S₁₀ fall under vertic Ustochrepts. The soils S₁, S₂, S₃ and S₄ have loamy sand. So S₅, S₆ and S₁₀ have sandy loam and S₇, S₈, S₁₁, S₁₂, S₁₃, S₁₄ and S₁₅ have sandy clay loam texture. The values of water holding capacity ranged from 33.9 per cent in case of S₄ to 49.5 per cent in S₉ soil. The CaCO₃ content in these soils varied between 0.78 and 5.0 per cent. These soils are alkaline in reaction (7.40 - 8.77) but have no salt accumulation (0.08 - 0.52 dSm⁻¹). The values of CEC in these soils varied between 9.25 in S₁₀ and 18.52 Cmol kg⁻¹ in S₁₄. The organic carbon content ranged from 0.21 per cent in case of S₇ to 0.52 per cent in S₁₅, while the total nitrogen percentage ranged between (0.018 and 0.045 per cent). The soils S₁, S₂, S₃ and S₄ have high...
amount of available $P_2O_5$ (113.21-131.16 kg ha$^{-1}$) and potash content (373.10 - 501.63 kg ha$^{-1}$). Available $P_2O_5$ was medium (31.03 - 46.75 kg ha$^{-1}$) in $S_6$, $S_3$, $S_4$ and $S_{10}$ soils whereas soils $S_1$, $S_2$, $S_5$, $S_7$, $S_8$ and $S_9$ fall under low $P_2O_5$ content (10.51 - 18.97 kg ha$^{-1}$) except $S_5$ (68.32 kg ha$^{-1}$) soil. The soils had low status of sulphur (13.21 - 23.42 kg ha$^{-1}$) whereas they varied from low to marginal in case of zinc (0.43 - 1.14 ppm) and iron (3.64 - 8.87 ppm). The soils had high amount of CU (0.93-2.36 ppm) and Mn (9.00-15.23 ppm). The methods as given in Table 1 were employed for the determination of available $P_2O_5$.

**Correlation of available P with soil properties:**

Several factors affect the extraction of P from a soil and thereby the ‘availability of a nutrient in a soil. The factors such as soil reaction (pH), salt accumulation (EC), CaCO$_3$ per cent, organic matter and clay content are of greater significance.

**RESULTS AND DISCUSSION**

In the present study, the relationship between the quantity of P extracted from soil by different extractants and some of the physico-chemical characteristics was established by working out correlation coefficient “r” values in order to identify the soil factor or factors involved P extracted with various extractants correlated with soil characteristics are presented in Table 2.

None of the P extraction method correlated positively with any of the soil properties. The soil pH and organic carbon showed a negative correlation with different P extractants. The results suggested that an irreversible fixation of extractable-P by organic matter occurs when the pH is high. Rahman *et al.* (1995) observed similar results. Different extractants due to variation in their constitutional composition will alter pH of the soil medium differently and thereby the nutrient in a soil. These findings confirm the results of Kanwar and Grewal (1960), Mehta and Patel (1963) and Sharma and Kalia (1985).

The negative associationships were observed between available content of P as determined by various extractants and CaCO$_3$ and clay contents of soils. In cases of the methods $P_7$, $PS_5$ and $P_8$ the decrease in P with increase in CaCO$_3$ content of these soils was perhaps due to the fact that ability of HCO$_3$ ions to extract Ca-bound P by reducing calcium activity in soil was suppressed with increase in calcium carbonate content of soil. The suppression effect may be due to decreased dissolution of Ca-P and or reprecipitation of dissolved phosphate due to increased calcium activity in soil solution (Mehta and Patel, 1963). Vig *et al.* (2000) also observed
and CaCO$_3$ contents of soil. A negative association between $P_6$ extractant and pH further substantiates the view that calcium bound phosphorus is released in appreciable amount with low pH extractants (Fried and Broeshart, 1967).

A negative correlation of $P$ extracted by different extractants with clay content is an indication of more retention of $P$ in finer fraction by anion exchange (Raychaudhuri and Lindsay, 1960) resulting in low P availability. Rahman et al. (1995) and Vig et al. (2000) have also found the decrease in P availability with increase in clay content of soils.

**Correlation between different P extractants and biological indicates:**

Values of available P as determined by different methods (Table 1) were correlated with dry matter yield, content and uptake of P by maize. The “r” values for these parameters for P are given in Table 3.

In case of yield, the results (Table 2) showed that $P_4$ of Soltanpour and Schwab (1977) was significantly correlated with dry matter yield ($r = 0.936^{**}$) followed by $P_2$ ($r = 0.922^{**}$) of Olsen et al. (1954) and $P_6$ ($r = 0.898^{**}$) of Mehlich (1984). The correlation values were identical in case of $P_5$ ($r = 0.885^{**}$) of Dalal (1973) and $P_5$ ($r = 0.883^{**}$) of Dabin (1967). Water soluble P ($P_1$) showed least correlation value ($r = 0.765^{**}$) with dry matter yield of maize.

A perusal of the results for concentration of P has shown that soil status determined by various extractants established highly significant associations ranging from the maximum of “$r$” = 0.942** recorded for $P_2$ of Olsen et al. (1954) and to the minimum of “$r$” = 0.806** for water soluble P ($P_1$). A narrow range of variation was observed between the methods $P_4$ ($r = 0.923^{**}$) and $P_5$ ($r = 0.934^{**}$). Method $P_5$ also showed a close relationship with P content ($r = 0.941^{**}$) of the plants.

The quantity of P depleted from the soils showed a highly significant correlation with P status as determined by various tests (Table 3). The maximum correlation coefficient “$r$” for P uptake against available content was 0.958** for $P_5$ of Olsen et al. (1954) followed by method $P_4$ ($r = 0.957^{**}$) of Soltanpour and Schwab (1977) and $P_5$ ($r = 0.953^{**}$) of Mehlich (1984), whereas the minimum of “$r$” = 0.787** was observed under $P_1$ of Saxena (1987). The percentage of prediction ($r^2$ x 100) between P uptake and different soil tests (Table 3) for available P could be arranged in following descending order as: $P_4$ (91.77 %) > $P_5$ (91.58 %) > $P_5$ (90.82 %) > $P_4$ (79.03 %) > $P_5$ (76.61 %) > $P_6$ (61.93 %). It is interesting to note that relatively higher prediction for available P in these soils through uptake of P by maize crop were found with extractants, which contained HCO$_3$ ions as one of the compositional ingredient, viz., $P_2$, $P_3$, $P_4$ and $P_5$ extractants.

After establishing the relationship, the question arises for the selection of the method for determination of P. Since, the uptake is the product of dry matter yield and concentration of plants, the evaluation of extractants for the suitability to measure P availability in soil could be more valid on the basis of its relationship with nutrient uptake by maize plant rather than individual factor like dry matter yield or nutrient concentration.

The overall results indicate that $P_2$ ($r = 0.958^{**}$) method of Olsen et al. (1954) had shown the highest relationship with P uptake followed by $P_4$ ($r = 0.957^{**}$) of Soltanpour and Schwab (1977) and $P_6$ ($r = 0.953^{**}$) of Mehlich (1984). Amongst, different methods of P determination, the method of Olsen et al. (1954) has been quite popular due to its capacity to show excellent

Table 2: Correlation coefficient “r” amongst P extractants and soil properties

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Extractants</th>
<th>pH</th>
<th>OC</th>
<th>CaCO$_3$</th>
<th>EC</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$P_1$</td>
<td>-0.177</td>
<td>-0.312</td>
<td>-0.278</td>
<td>-0.626</td>
<td>-0.585</td>
</tr>
<tr>
<td>2.</td>
<td>$P_2$</td>
<td>-0.167</td>
<td>-0.359</td>
<td>-0.345</td>
<td>-0.699</td>
<td>-0.684</td>
</tr>
<tr>
<td>3.</td>
<td>$P_2$</td>
<td>-0.183</td>
<td>-0.369</td>
<td>-0.335</td>
<td>-0.714</td>
<td>-0.661</td>
</tr>
<tr>
<td>4.</td>
<td>$P_4$</td>
<td>-0.146</td>
<td>-0.322</td>
<td>-0.288</td>
<td>-0.687</td>
<td>-0.608</td>
</tr>
<tr>
<td>5.</td>
<td>$P_5$</td>
<td>-0.193</td>
<td>-0.297</td>
<td>-0.265</td>
<td>-0.597</td>
<td>-0.660</td>
</tr>
<tr>
<td>6.</td>
<td>$P_6$</td>
<td>-0.152</td>
<td>-0.372</td>
<td>-0.328</td>
<td>-0.683</td>
<td>-0.685</td>
</tr>
</tbody>
</table>

Table 3: Correlation of phosphorus status of the soils with biological indices

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Methods</th>
<th>Yield</th>
<th>Plant’s parameter</th>
<th>P uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>$P_1$</td>
<td>0.765**</td>
<td>0.806**</td>
<td>0.787**</td>
</tr>
<tr>
<td>2.</td>
<td>$P_2$</td>
<td>0.922**</td>
<td>0.942**</td>
<td>0.958**</td>
</tr>
<tr>
<td>3.</td>
<td>$P_3$</td>
<td>0.936**</td>
<td>0.923**</td>
<td>0.957**</td>
</tr>
<tr>
<td>4.</td>
<td>$P_4$</td>
<td>0.885**</td>
<td>0.879**</td>
<td>0.898**</td>
</tr>
<tr>
<td>5.</td>
<td>$P_5$</td>
<td>0.883**</td>
<td>0.934**</td>
<td>0.907**</td>
</tr>
<tr>
<td>6.</td>
<td>$P_6$</td>
<td>0.898**</td>
<td>0.941**</td>
<td>0.953**</td>
</tr>
</tbody>
</table>
pearlmillet (Dhillon et al., 1987), wheat (Jaggi et al., 1990), greengram (Thind et al., 1991), rice (Khadtar et al., 1991), sugar cane (Murugappan et al., 1989) and maize (Vig et al., 2000) grown in diversified type of soils. Similarly, the method $P_3$ of Soltanpour and Schwab (1977) has been found to give significant relationship with yield and uptake of $P_2O_5$ by wheat (Palwe and Sonar, 1989), maize (Singh and Bishnoi, 1993), sunflower (Singh et al., 1997) and barley (Singh and Bishnoi, 1998). In the present study also, the 0.5 M NaHCO$_3$, pH 8.5 extractable P (method $P_2$ of Olsen et al., 1954) and ammonium bicarbonate-DTPA extractable P (method $P_3$ of Soltanpour and Schwab, 1977) showed a significant positive relationship with yield as well as uptake. Between the methods $P_3$ and $P_6$, the relative values of available P are quite high in case of method $P_6$. But in fact, the occurrence of low and high values have nothing to do with the relationship but the occurrence of low and very high values would need excellent care in determination of P, which is very difficult to manage when large samples are handled. Again method $P_3$ of Olsen’s et al. (1954) has given excellent relationship in many countries with different types of crops. These results showed that Olsen’s and ammonium bicarbonated DTPA extractable P were equally good indices of P availability for predicting P response to maize. Therefore, any one of these extractants could be recommended.

REFERENCES


