



Chapter – V

Summary and Conclusion

5. SUMMARY AND CONCLUSION

An investigation was undertaken with the soils of *terai* region of West Bengal, India and its various land use patterns to i) study the nature and distribution of forms of soil P as well as to identify the active forms of inorganic P which contribute significantly towards the plant available P, ii) screen out the most effective one among the various prevalent soil test methods for available P, iii) study the P adsorption-desorption behaviour of soils.

Soils of tea garden and orchard were strongly to moderately acidic while soils of cultivated land and forest were strongly acidic to neutral in reaction. Average organic carbon content of these soils was high which probably strongly influenced the cation exchange capacity. Soils of tea garden and orchard were loamy sand to loam while soils of cultivated land and forest were sandy loam to loam in texture. The soils under tea garden exhibited maximum total potential acidity, pH dependent acidity, hydrolytic acidity, extractable Al^{3+} and non-exchangeable Al^{3+} followed by orchard, forest and cultivated land whereas exchange acidity and total acidity followed the order: orchard > tea garden > forest > cultivated land soils. The electrostatically bound H^+ constituted 17.2 to 20.5% of exchange acidity while pH dependent acidity contributed 86.4 to 93.4% of total potential acidity. Exchangeable Al^{3+} alone could explain about 99% variability in exchange acidity of the soils of *terai* region. Exchangeable Al^{3+} and cation exchange capacity collectively could explain 91% and 76% variation in total acidity and total potential acidity, respectively, while 76% variability in pH dependent acidity could be explained by cation exchange capacity and extractable Al^{3+} .

1. Soils of tea garden contained the highest amount of total P and the magnitudes in different land use patterns were in the following order: tea garden > forest > cultivated land > orchard while the sequence with respect to organic P content was: tea garden > forest > orchard > cultivated land. Inorganic P (53%) and organic P (47%) in these soils were more or less in equal proportion to total P. Dominance of Ca-P (35.3%) over other inorganic P forms indicated that these soils were of the recently developed with the alluvium of north eastern rivers. Different

inorganic P forms did not follow a regular sequence in soils of various land use patterns. In orchard and tea garden soils reductant soluble P (RS-P) was found to be the most dominant. However, Al-P and Fe-P always held the second highest position in the sequence. Al-P ($r = -0.501^{**}$) and RS-P ($r = -0.573^{**}$) had a significant negative relationship while Ca-P ($r = 0.620^{**}$) had a positive relation with pH of soil. Ca-P ($r = -0.412^{**}$) and RS-P ($r = -0.342^{**}$) content in these soils decreased with increase in organic carbon content probably through complexation of Ca and Fe by organic anions produced during mineralisation of organic residues.

Stepwise regression analysis between P availability indices and soil P forms indicated that organic P alone could explain 64.5 per cent variability in total P, while Fe-P accounted for 61.1% variation in Bray-1-P and Fe-P, Al-P and Ca-P jointly contributed 90.6% variation in Olsen-P. Thus, the regression equations showed that Fe-P was the most active inorganic forms of P, which controlled the amount of P, extracted by Bray-1 and Olsen methods. Though, the above observation apparently indicated that Olsen-P could be a better index for assessing available P status of these soils, but Bray-1 ($r = 0.879^{**}$) had a higher correlation with P uptake by wheat than Olsen-P ($r = 0.739^{**}$).

Barring few exceptions, dry matter yield and P uptake by wheat had a significant relation with Al-P and Fe-P in all land use patterns indicated that those were active inorganic forms, which controlled the P nutrition of crops in these soils. The significant increase of dry matter yield ($r = 0.603^{**}$) and P uptake ($r = 0.700^{**}$) by wheat in forest soils with increase in RS-P indicated that this form also acted as a potential source of available P.

Stepwise multiple regression analysis showed that 86% of the variation in P uptake by wheat under forest land use was explained by Al-P and RS-P while 57.8% variation in the said parameter was explained by Al-P and Occl-P jointly in tea garden soils. However, Al-P and Fe-P single could explain 84.2% and 38.2% variation in P uptake in cultivated land and orchard soils, respectively. Thus, the result revealed that with an exception of orchard soils, Al-P was the major source of plant available P as it alone could explain 81.7%, 36.2% and 84.2% variation in

P-uptake of forest, tea garden and cultivated land soils respectively, while in orchard soils Fe-P controlled the P nutrition to wheat. In conclusion, it might be inferred that to assess available P status of soils, the contribution of different inorganic P fractions towards available phosphorus in different land use patterns should be taken into consideration.

2. With a view to identify the most suitable P extractant for soils of *terai* agroclimatic zone and its various land uses five extractants namely, Bray-1, Bray-2, Olsen, Mehlich-1 and AB-DTPA were tested.

From the performance of these extractants it was recorded that the highest amount of P in *terai* soils as well as its land uses were extracted by Bray-2 method. However, the amount of P extracted by different extractants did not follow any definite order in the land uses. The differential behaviour of various extractants was attributed to the relative contribution of different inorganic P fractions to total inorganic P in the soil as well as the efficiency of different extractants in extracting these fractions. A significant positive correlation existed between clay content and available P extracted by various methods. Bray-2 and Mehlich-1 soil tests had significant negative correlation with organic carbon content ($r = -0.353^{**}$ and -0.343^{**}) and cation exchange capacity ($r = -0.513^{**}$ and $r = -0.286^{*}$).

Olsen's extractable P and Bray-1 P showed significant positive correlation with Fe-P ($r = 0.947^{**}$ and $r = 0.513^{**}$) and Al-P ($r = 0.784^{**}$ and 0.564^{**}) fractions. AB-DTPA-P had significant positive relationship with Fe-P ($r = 0.664^{**}$), Al-P ($r = 0.435^{**}$), Ca-P ($r = 0.385^{**}$) and Occl ($r = 0.318^{*}$). Mehlich-1-P also being a strong reagent correlated significantly with Fe-P ($r = 0.623^{**}$), Al-P ($r = 0.453^{**}$), Occl-P ($r = 0.385^{*}$) and Ca-P ($r = 0.259^{*}$) while Bray-2-P showed significant correlation only with Fe-P ($r = 0.761^{**}$) and Ca-P ($r = 0.548^{**}$). Fe-P contributed the maximum amount of available P followed by Al-P, while Ca-P contributed the least. Thus, it could be inferred that Fe-P and Al-P were the major inorganic P fractions contributed towards available P in these soils.

In tea garden and forest soils Bray-2 extractant was found to be the most efficient while Bray-1 was found to be the most suitable for orchard and cultivated

land soil in assessing available P of soils as evidenced by the highest correlation co-efficient with P uptake data.

A significant correlation was observed between Bray-1-P ($r= 0.879^{**}$), Bray-2-P ($r= 0.760^{**}$), Olsen-P ($r= 0.739^{**}$), Al -P ($r=0.515^{**}$) and Fe-P ($r=0.482^{**}$) with dry matter yield of wheat grown in Neubauer technique. Bray-1-P and reductant soluble P (RS-P) and occluded (Occl-P) jointly contributed 82% variation in P-uptake, while Bray-2 P alongwith Ca-P \times clay and Ca-P collectively explained 74% variation in P-uptake. Thus, it might be concluded that soil P fractions in the form of Fe-P and Al-P contributed more towards P nutrition of wheat crop in these soils. Accordingly, an extractant dissolving these fractions from these soils would be considered to be the best in determining available P. Bray-1 extractable P seemed to be the most suitable method as it extracted P from both Fe-P and Al-P fractions and inclusion of RS-P and Occl-P alongwith Bray-1-P jointly could explain about 82% variability in P-uptake of wheat in these soils.

3. In the study of the phosphate adsorption-desorption behaviour it was observed that the amount of P adsorbed by the soils of *terai* agroclimatic zone and its different land use patterns increased steadily with increase in the level of P in solution whereas the proportion of the added P sorbed followed a decreasing trend. The amount of P adsorbed at 0.2 mgPL^{-1} equilibrium solution P concentration i.e. standard P requirement (SPR), an index of adsorption capacity of soil, was significantly and positively correlated with organic carbon ($r= 0.520^{**}$), CEC ($r= 0.414^{**}$), Free Fe_2O_3 ($r= 0.385^{**}$) and AEC ($r= 0.255^*$) indicated that organic matter and free Fe_2O_3 provided the major sites for P adsorption. Free Fe_2O_3 and exchangeable Al^{3+} together accounted 67.1% variation in sorbed P in tea garden soils and CEC, AEC and pH collectively explained about 68.5% variation in sorbed P in forest soils at the highest solution P concentration (100 mgPL^{-1}). Freundlich equation explained the adsorption pattern better for the soils of orchard, cultivated land and forest, while modified Freundlich for the soils of tea garden. However, a good fit of all the equations for all land use patterns indicated a similarity in their adsorption behaviour despite their variation in physico-chemical properties.

The adsorption data fitted in the Langmuir adsorption isotherm could be resolved into two straight lines, suggesting existence of two types of adsorption reactions in operation. Upto 2 mgPL⁻¹ equilibrium solution P concentration (3 mgPL⁻¹ for tea garden) reaction followed the monolayer adsorption and beyond this concentration reactions were of precipitation type. SPR was the least in cultivated land soil (40.2 mgkg⁻¹) indicating a chance of substantial cut in P fertilizer requirement for optimum crop yield in cultivated soils over the others. A significant negative relationship ($r = -0.280^*$) between SPR and P uptake by wheat suggesting the acceptability of the former to explain the plant availability of P in these soils.

Correlation analysis between various sorption parameters and soil properties indicated that P adsorption behaviour in the soils under four different land use patterns was governed by organic matter, free ferric oxide contents and cation exchange capacity. Highest bonding energy in forest soils led to least dry matter production and P uptake by wheat while lower bonding in cultivated land soils resulted the highest P uptake. At any given level of added P the supply parameter (SP) values in tea garden, cultivated land and orchard soils were at close proximity to each other whereas the said parameter was somewhat lesser in forest soil. SP could explain the availability characteristics of these land use soils at lower solution P concentration (~ 10 mgPL⁻¹) it had significant relation with dry matter yield ($r = 0.325^*$) and P uptake ($r = 0.438^{**}$) by wheat.

The constant relating to the bonding energy was higher in forest and tea garden soils indicated that phosphorus was held more tenaciously possibly by higher amount of organic matter through polyvalent cations like Fe³⁺ and Al³⁺. Cultivated land soils with higher buffering capacity attributed to higher amount of organic matter would lead to less amount of P concentration in soil solution for exploitation by plant roots. The maximum buffering capacity (K_b) was more closely associated with organic carbon ($r = 0.440^{**}$) and Fe₂O₃ ($r = 0.418^{**}$) than CEC ($r = 0.386^{**}$) suggesting the significant role of organic matter and free Fe₂O₃ in P sorption behaviour of these soils. The Freundlich constant, K', was also significantly related with organic carbon ($r = 0.514^{**}$), CEC ($r = 0.438^{**}$) and Fe₂O₃ ($r = 0.408^{**}$). In conclusion, it might be inferred that soils under forest having higher

bonding energy resulting higher P adsorption and P buffering capacity than the other land use patterns might need higher levels of P application for better crop growth. Highest P uptake in cultivated land soils was justified by lower bonding energy, buffering capacity and SPR values.

The highest amount of desorption of added P was recorded in cultivated land (52.2%), while tea garden recorded the least (32.2%). A substantial amount of extraction of sorbed P (11.2 to 17.8%) during second desorption run indicated that a good amount of P might be available to plant even after exhaustion of Olsen-P. During desorption runs first desorption released the major portion (around 65%) of cumulative release of P (CRP). Degree of P saturation was fundamentally important to govern the intensity and rate of P removal by plants. Desorption of sorbed P was maximum in cultivated land (mean 171.7 mgkg^{-1}) and was minimum (mean 105.7 mgkg^{-1}) in tea garden soils. The maximum attainable recovery followed the sequence: cultivated land (mean 67.3%) > orchard (57.7%) > forest (57.1%) > tea garden (42.8%).

At any level of equilibrium solution P concentration the amount of P sorbed during sorption was always higher than that during desorption run. The extent of hysteresis was dependent on the sorption parameters like bonding energy, buffering capacity etc.