http://www.pjbs.org

PJBS

ISSN 1028-8880

# Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (12): 2082-2086, 2000


# Laboratory Study of Physical-chemical Characteristics and the Nutrient Status of Soils Collected from Rawalakot Azad Jammu and Kashmir

M. Shoaib Malik, M. Kaleem Abbasi[1] and Nasir Rahim
[1]Department of Soil Science, University College of Agriculture Rawalakot
Azad Jammu and Kashmir, Pakistan

**Abstract:** The study was carried out to evaluate the physical-chemical properties and the nutrient status of three soils collected around Rawalakot Azad Kashmir. For this purpose soil samples from 0 to 15 and 15 to 30 cm depth were taken and analysed for textural class, organic mater content, pH, $CaCO_3$, $EC_e$, $NO_3$-N, P, K, Ca, Mg, Zn, Cu, Fe and Mn. The texture analysis showed that the soils under study were silt dominant and the proportion of silt ranges from 60 to 92%. The pH values ranged from 5.77 to 6.69 indicated that soils are slightly acid to neutral. The organic matter content was 0.87 and 1.03%, which is in the range of low to medium. The soils were found to be non-calcarious as the calcium carbonate was in between 0.6 to 0.9%. The electrical conductivity of the saturation extract (ECe) was negligible. The concentration of $NO_3$-N and available P was extremely low ranging from 0.89 to 1.9 and 0.41 to 1.03 mg $kg^{-1}$, respectively indicated a substantial need of N and P through fertilization. Out of three soils studied, two were found low in available K. The concentration of calcium, magnesium, iron, manganese and copper were medium to high while Zn seemed to be low in one of the three soils tested. It was concluded that soils of Rawalakot are deficient in organic matter content, available N, phosphorus and potassium. The deficiency of these major elements is perhaps the main limiting factor in the agricultural production of this region. Application of N, P and K through chemical fertilizers is highly recommended. In addition, use of organic manures will be highly beneficial not only to enhance the fertility status of soils but also to improve the physical conditions of the soils.

**Key words:** Azad Jammu and Kashmir, physical properties, chemical properties, nutrient status, organic matter, macro nutrients, micro nutrients, soil pH

## Introduction

Azad Jammu and Kashmir lies between longitude 73 to 75° and latitude 33 to 36° in the North East of Pakistan under foothills of great Himalayas and comprises 13, 279 Sq km. The topography is mainly hilly and mountainous with valleys and stretches of plains. The area is full of natural beauty with thick forest, fast flowing rivers and winding streams. The climate is sub-tropical highland type with an average yearly rainfall of 1500 mm. The elevation ranges from 360 m in the south to 6325 m in the north. The snow line in winter is around 1200 m above sea level while in summer it rises to 3300 to (Anonymous, 1994).

Rawalakot is the district head quarter of Poonch. Its altitude is about 1800 m above the sea level. During summer temperature ranger from 10 to 25°C. Snow falls from December to March with intervals. Rawalakot has topography with slopes and planes. Agriculture mainly depends on rainfalls. The major crops are maize followed by wheat while almost all kind of vegetables especially potato garlic, karam, beans can easily be grown. A substantial part ni the area is under orchards mainly apple, pears, apricots, walnuts and plums. However much of land is under forest and grasses.

The soils of the area are clay to silt loam in texture. However, these soils are completely unexplored with regard to their classification, fertility status and physical and chemical characteristics. The study of physical and chemical characteristics is important because the physical properties depend largely on the size, shape, arrangement and mineral composition of the soil particles and include soil texture, structure, particle and bulk density, porosity, color and temperature. These soil properties influence the germination and emergence of young seedlings and root penetration and growth into the soil. In addition to their direct effect on plant growth, the physical properties of soil affect the movement of water with in the soil, the composition of soil air and the availability of plant nutrient, thus indirectly influence plant growth (Tagar and Bhatti, 1996). The degree and extent to which a chemical reaction can occur in soil solution and in solid phases is determined by chemical principles. The chemical properties of soil control solubility and bio-availability of essential plant nutrients and thus establish a strong relationship between soil constituents and plant productivity (Khattak, 1996). In the present study three soils from different places in and around the Rawalakot were collected to examine some physical-chemical properties and the nutrient status of these soils and to characterize them accordingly. It will provide useful information with regard to nutrient status and physical condition of soils, which will help Agriculture scientist and research workers in fertilizer recommendations and soil management practices of the area.

## Materials and Methods

**Soil sampling:** The study was carried out in arable soils of Rawalakot Azad Jammu and Kashmir. Soil was collected from three different locations namely Merall Gala (Farmer's Farm), Agricultural Nursery Farm Chare and University Farm, Shamsabad. Soil samples were taken with the help of soil auger at two depths i.e. 0 to 15 and 15 to 30 cm. For this purpose 6 to 8 spot were selected in each location. Samples from two depths were taken into a separate, dry and clean plastic bucket and mixed thoroughly by hands.

For composite sample, one kg soil from each bucket was taken into separate plastic bags and labeled. These samples were brought into the laboratory of Soil Science University College of Agriculture, Rawalakot for further processing.

**Laboratory analysis:** During Laboratory analysis, following soil characteristics were studied: mechanical analysis, soil pH, organic matter, $CaCO_3$ content, ECe, TSS. $NO_3$-N, P, K, Na, Zn, Fe, Cu and Mn. Laboratory analysis was done in two stages. In the first stage soil properties including mechanical analysis, soil pH, organic matter, $CaCO_3$ content: ECe; and TSS were determined in the laboratory of Soil Science University College of Agriculture, Rawalakot following the methods described by Hussain and Jabbar (1985). In the next stage, $NO_3$-N, P, K, Na, Zn, Fe, Cu and Mn were determined in the Laboratory of Land Resources National Agriculture Research Centre (NARC) Islamabad Pakistan. These nutrients were determined using the ammonium bicarbonate di-ethylene tri-amine penta acetic acid (AB-DTPA) method as described by Winkleman *et al*. (1990).

## Results and Discussion

**Soil texture:** Soil texture is used as an indicator of soil structure, consistence, aeration, water-holding capacity and nutrient-holding capacity. It is also used to determine the suitability of a particular soil for different crops. Fine-textured soils are most suitable for rice, while coarse-textured soils are preferable for leguminous crops (Tagar and Bhatti, 1996). The percent distribution of sand, silt and clay of three selected soils is presented in Table 1. The average values (two depths) showed that the proportion of sand, silt and clay for University farm was 36.5, 60 and 3.5%, for Nursery farm 9.2, 85.9 and 5% and for Merall Gala 4.3, 91.7 and 4%, respectively. Results indicated that among three soils, University farm contained 36.5% sand as compared to 9.4 and 4.3% sand in the Nursery farm and Merall Galla site, respectively. The proportion of silt between Nursery farm and Merall Galla was almost the same 86 and 92%, while University farm had 60% silt. All the three soils had small proportion of clay ranging from 3 to 5%.

Results indicated that within two depths, there was an increase in clay and decrease in sand with depth. The classes of selected soils were presented in Table 1, which indicated that selected soils were silt loam to silt in texture. The silt dominant soils have the property to become cloddy when dry and readily runs together and become puddles when wet (Tagar and Bhatti, 1996). They have the tendency to become compact when grazed or through human activity on their surface.

**Soil Reaction (pH):** The pH of three selected soils is presented in Table 2. Mean pH values were 6.64, 5.88 and 6.55 for University farm, Nursery farm and Merall Gala soils, respectively. The University farm had relatively more pH probably due to presence of more $CaCO_3$ and T.S.S as shown in Table 2. The data indicated that there was a small increase in pH as depth increases. This might be due to presence of more $CaCO_3$ and cations like Na and Mg at lower depth which formed $Ca(OH)_2$ and NaOH resulted an increased in soil pH. The data indicated that pH values of Rawalakot soils were slightly acidic to neutral ranging from 5.9 to 6.6. Because of heavy rainfall during monsoon the bases may leached down from the upper part of the soil profile resulted in low pH. Moreover, the selected soils were low in $CaCO_3$, which might be a reason for low pH in these soils. In addition, the area around Rawalakot is enriched with coniferous forest and Populous vegetation, that is why pH values less than 7 have been observed. The pH values observed are ideal for the growth of most of the crops, maximum nutrient availability and microbial activity and function. Foth (1984) reported that rice, maize, tobacco, wheat, peas, peanuts, clovers can grow successfully in the pH range of 5.5 to 7.0 white most of the forest plants grow well in pH range of 4 to 7. It is concluded that the soils under investigation are suitable for most of the crops, fruits, vegetables and forest vegetation.

**Organic matter:** Data regarding the organic matter content of three sites is presented in Table 2. Mean organic matter content of three soils ranging from 0.87 to 1.03%. The Nursery farm had relatively more organic matter probably because of continuous addition of leaves and other plant material from adjoining plants present in the area. The organic matter with respect to depth showed that maximum amount was present in the top 0 to 15 cm depth. The presence of grass, stubble, roots and their decomposition, more microbial biomass and more favorable condition for decomposition increases the organic matter of surface layer. According to the data presented and soils are classified as follows: Low $<$0.86% 0.M., medium 0.86 to 1.29 and high $>$1.29%. According to this classification University farms and Merall Gala soils were medium in organic matter content while the Nursery farm soil was high in organic matter. On an overall the soils contained relatively low organic matter content. Soil erosion and small annual additions of organic matter from plant sources are the major causes of low organic matter content in our soils.

**Calcium Carbonate ($CaCO_3$):** The data pertaining to calcium carbonate of three selected soils is presented in Table 2. The mean % ages of $CaCO_3$ of three selected soils ranging from 0.74 to 0.85%. Within two depths $CaCO_3$ content increased as soil depth increased due to the downward movement of $CaCO_3$ through surface runoff. According to the classification presented in Table 6 soils with $CaCO_3$ in between 1 to 20%, were known as calcareous. The selected soils contain less than 1% $CaCO_3$, so these soils were non-calcareous.

**Macro nutrients**

**Nitrate-nitrogen ($No_3$-N):** The mean values of available $NO_3$- N were in the range of 0.89-1.9 mg $kg^{-1}$ (Table 3). The Nursery farm contained relatively more $NO_3$-N, which might be attributed to the presence of high amount of organic matter in this soil, The data indicated that $NO_3$-N was increased to some extent as the depth increased. This might be due to the diffusion and movement of available $NO_3$-N from upper layer to lower one. Rashid and Ahmad (1994) reported that soils contained $NO_3$-N less than 10 mg $kg^{-1}$ were low in available $NO_3$-N. The soils under study had $NO_3$-N even less than 2 mg $kg^{-1}$ are extremely deficient in available N.

**Phosphorus (P):** The mean P content of three soils was in the range of 0.41 to 1.30 mg $kg^{-1}$ soil. The maximum P

Table 1: Textural analysis of three soils collected from 0 to 15 cm and 15 to 30 cm depth

| Lotation | Depth (cm) | % Sand | Mean | % Silt | Mean | % Clay | Mean | Textural Class |
|---|---|---|---|---|---|---|---|---|
| University Farm | 0-15 | 41.3 | | 56.7 | | 2.0 | | Silt Loam |
| | | | 36.5 | | 60.0 | | 3.5 | |
| | 15-30 | 31.7 | | 63.3 | | 5.0 | | |
| Nursery Farm | 0-15 | 9.7 | | 88.3 | | 2.0 | | Silt |
| | | | 9.2 | | 85.9 | | 5.0 | |
| | 15-30 | 8.6 | | 83.4 | | 8.0 | | |
| Merall Gala | 0-15 | 6.8 | | 91,2 | | 2.0 | | Silt |
| | | | 4.3 | | 91.7 | | 4.0 | |
| | 15-30 | 1.8 | | 92.2 | | 6.0 | | |

Table 2: Some Chemical Characteristics of three soils sampled from 0 to 15 cm and 15 to 30 cm depth

| Location | Depth (cm) | pH | Mean | O.M. (%) | Mean (%) | $CaCO_3$ (%) | Na (mg $kg^{-1}$) | TSS (mg $kg^{-1}$) | ECe (mS $cm^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| University farm | 0-15 | 6.59 | | 0.90 | | 0.68 | 02 | 213 | 0.36 |
| | 15-30 | 6.69 | 6.64 | 0.85 | 0.87 | 0.80 | 03 | 226 | 0.37 |
| Nursery farm | 0-15 | 5.77 | | 2.70 | | 0.60 | 11 | 194 | 0.28 |
| | 15-30 | 6.00 | 5.88 | 2.40 | 2.50 | 0.90 | 14 | 156 | 0.24 |
| Merall Gala | 0-15 | 6.49 | | 1.20 | | 0.80 | 10 | 134 | 0.21 |
| | 15-30 | 6.62 | 6.55 | 0.87 | 1.03 | 0.90 | 17 | 137 | 0.21 |

Table 3: Macro nutrient Status of selected soils collected in and around Rawalakot Azad Kashmir

| Location | Depth (cm) | Macro nutrients (mg $kg^{-1}$ soil) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N0-N | Mean | P | Mean | K | Mean | Ca | Mean | Mg | Mean |
| University Farm | 0-15 | 1.88 | | 1.15 | | 52 | 58.7 | | 15.5 | | |
| | 15-30 | 1.92 | 1.90 | 0.90 | 1.03 | 47 | 49.5 | 49.8 | 54.3 | 15.8 | 15.6 |
| Nursery Farm | 0-15 | 1.02 | | 0.49 | | 89 | 34.6 | | 19.6 | | |
| | 15-30 | 1.63 | 1.32 | 0.33 | 0.41 | 67 | 78.0 | 35.7 | 35.2 | 19.7 | 19.6 |
| Merall Gala | 0-15 | 0.47 | | 1.31 | | 57 | 44.3 | | 19.3 | | |
| | 15-30 | 1.31 | 0.89 | 0.65 | 0.98 | 54 | 55.5 | 39.1 | 41.7 | 19.6 | 19.5 |

Table 4: Ca:K and Mg:K ratio of three selected soils (average of two depths)

| Location | K (mg $kg^{-1}$) | Ca (mg $kg^{-1}$) | Mg (mg $kg^{-1}$) | Ca:K | Mg:K |
|---|---|---|---|---|---|
| University Farm | 49.5 | 54.3 | 15.6 | 1.09 | 0.32 |
| Nursery Farm | 78.0 | 35.2 | 19.6 | 0.45 | 0.25 |
| Merall Gala | 55.5 | 41.7 | 19.5 | 0.75 | 0.35 |
| Recommended (Liebhardt, 1981) | | | | 5.0 | 0.60 |

Table 5: Macro nutrient Status of selected soils collected in and around Rawalakot Azad Kashmir

| Location | Depth (cm) | Micro nutrients (mg $kg^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Zn | Mean | Cu | Mean | Mn | Mean | Fe | Mean |
| University Farm | 0-15 | 3.38 | | 0.28 | 6.7 | | 28.82 | | |
| | 15-30 | 2.11 | 2.75 | 0.66 | 0.47 | 3.92 | 5.31 | 20.86 | 24.84 |
| Nursery Farm | 0-15 | 2.04 | | 0.74 | 12.24 | | 58.68 | | |
| | 15-30 | 0.84 | 1.44 | 0.92 | 0.83 | 13.66 | 12.95 | 50.61 | 54.64 |
| Merall Gala | 0-15 | 0.55 | | 0.42 | 3.12 | 2.59 | 23.94 | | |
| | 15-30 | 0.51 | 0.53 | 0.46 | 0.44 | 2.08 | 2.59 | 23.37 | 23.85 |

content was found in the University farm (1.03 mg $kg^{-1}$) followed by Merall Gala (0.98 mg) and then Nursery farm (0.41 mg $kg^{-1}$). The pH of a soil is an important factor for P availability and the maximum availability was reported in the range of pH 6 to 7 (Tisdale *et al*., 1997). The pH of the soils tested is ideal for P availability but the concentration of P found to be very low in all cases. Presence of organic matter in soils has been shown to increase P availability. The selected soils were low m organic matter resulted the low concentration of P in these soils. It was observed that in almost all cases there was slight decrease in available P with increase in soil depth. This decrease might be due to decrease in organic matter content with depth. According to the classification presented, the soils under study were deficient in available phosphorus.

**Potassium (K):** The mean concentration of available K for three soils studied were 49.5, 78.0 and 55.5 mg $kg^{-1}$ soil for University farm, Nursery farm and Merall Gala soil, respectively. Within three soils studied, Nursery farm contained higher concentration of K compared with other two soils. It might be due to the presence of higher amount of clay and organic matter in the soil. The clay and organic fraction because of their negativity hold the K ions more

rigidly and tightly and chances of leaching losses may be less (Roy *et al*., 1981; Bajawa and Rehman, 1996). The K content of -upper 0 to 16 cm was slightly higher than the K content of 15 to 30 cm depth. This might be due to presence of relatively more organic matter in upper surface of soil which is not only an important source of K in soil but also holds 10 more rigidly and tightly on the surface. Rashid and Ahmad (1994) classified K level in soils with respect to AB-DTPA extractable as follows: Low $<60$ mg kg$^{-1}$, medium 60 to 120 high $>120$ mg kg$^{-1}$. According to this classification the soils of University farm and Merall Gala were deficient in available K while that of Nursery farm has medium level of potassium.

**Calcium (Ca):** Results showed that average content of extractable Ca for University farm, Nursery farm and Merall Gala soils were 54.3, 35.2 and 41.7 mg kg$^{-1}$ of soil, respectively. The soil collected from the University farm has the maximum Ca content of 54 mg kg$^{-1}$ probably due to more pH relative to other two soils. Roy *et al*. (1981) explained that soil pH is one factor, which affect the availability of Ca. Results indicated a decrease trend in Ca with depth because Ca is capable to held very strongly on clay lattice and chances to leached down are unlikely. Cochrane *et al*. (1984) classified the soils with respect to Ca content as follow: Low $<8$ mg kg$^{-1}$, medium 8-80 mg kg$^{-1}$ and high $>80$ mg kg$^{-1}$. The average Ca content of selected soils were ranging from 35.2 to 54.3 mg kg$^{-1}$, so all the soils under investigation were medium in Ca concentration and do not need additional Ca. The Ca/K ratio of the soil tested were 1.09, 0.4 and 0.75 for University farm, Nursery farm and Merall Gala soils, respectively. Liebhardt (1981) reported that Ca/K ratio of 5 is considered to be adequate. According to this range the Ca/K ratio of tested soils was below than recommended value.

Table 6: Generalized test interpretive guide for nutrients

| S. No | Ranges | | | |
|---|---|---|---|---|
| | Parameters | Low | Medium | Adequate |
| 1 | O.M. (%) | | | |
| **Mineral Nutrients (mg kg$^{-1}$)** | | | | |
| | | <0.86 | 0.86 | 1.29 | >1.29 |
| 2 | $NO_3$-N | <10 | 10.0-20 | >20 |
| 3 | | <3 | 3.0-7.0 | >7 |
| 4 | K | <60 | 60.0-120.0 | >120 |
| 5 | Ca | <8 | 8.0-80 | >80 |
| 6 | Mg | <2.4 | 2.4-9.6 | >9.6 |
| 7 | Zn | <0.9 | 0.9-1.5 | >1.5 |
| 8 | Cu | <0.2 | 0.2-0.5 | >0.5 |
| 9 | Fe | <3.0 | 3.0-5.0 | >5.0 |
| 10 | Mn | <0.5 | 0.5-1.0 | >1.0 |

Sources: Rashid and Ahmad (1994) and Cochrane *et al*. (1984)

**Magnesium (Mg):** The average content of available Mg for three soils were in the range of 15.6-19.6 mg kg$^{-1}$. The soil from Nursery farm had slightly higher Mg content than other two soils. It might be due to presence of relatively high content of clay and organic matter in this soil. Cochrane *et al*. (1984) had classified the soils according to available Mg as following: Low $<2.4$ mg kg$^{-1}$, medium 2,4-9.6 mg kg$^{-1}$ and high $>9.6$ mg kg$^{-1}$. According to this classification, the soil under investigation exhibited very high concentration of Mg. However, The Mg/K values of selected soils were 0.32, 0.25 and 0.35 for University farm, Nursery farm and Merall Gala soils, respectively. Mg/K ratio were found below recommended ratio of 0.6 presented in Table 4.

**Micronutrient status**

**Zinc (Zn):** The data pertaining to micro nutrients status of the soils tested during the study is presented in Table 5. On an average the Zn content of three soils studied ranging from 0.53 to 2.75 mg kg$^{-1}$. The maximum Zn concentration (2.75 mg kg$^{-1}$) was observed in the soil collected from the University farm followed by Nursery farm (1.44 mg kg$^{-1}$) while soils from Merall Gala site had the minimum concentration of Zn (0.53 mg kg$^{-1}$). According to the classification presented in Table 6 the Zn status of soils from University farm was high, medium in Nursery farm and low in Merall Gala soils.

**Copper (Cu):** The mean content of available Cu in three sites was 0.47, 0,83 and 0.44 mg kg$^{-1}$ for soils collected from University farm, Nursery farm and Merall Gala soil, respectively. The maximum Cu content was observed in the Nursery farm, which might be due to the low pH of this soil as compared to other two. The availability of most of the micro nutrients in soil is high at low pH (Tisdale *et al.*, 1997; Lindsay, 1979). Rashid and Ahmad (1994) classified the soil with reference to available Cu content as follows: Low $<0.2$ mg kg$^{-1}$, medium 0.2 to 0.5 mg kg$^{-1}$ and high $>0.5$ mg kg$^{-1}$. According to this classification the Cu status of the soil under study was medium to high.

**Manganese (Mn):** The mean content of available Mn in three soils was 5.31 mg kg$^{-1}$, 12.95 mg kg$^{-1}$ and 2.59 mg kg$^{-1}$ for University farm, Nursery farm and Merall Gala soils, respectively. On an average basis the maximum Mn Content (12.95 mg kg$^{-1}$) was observed in Nursery farm. The pH of the soil was low compared to other two soils, which may be a factor for high Mn concentration. Lindsay (1979) reported that the availability of Mn decreases as hundred folds for each unit increase in pH, Organic matter also play an important role in micro nutrients availability as certain type of organic matter form insoluble complex with divalent Mn, thus rendering it unavailable to plants (Tisdale *et al*., 1997). According to the classification presented in Table 6 the selected sites were found high in Mn content.

**Iron (Fe):** The mean content of available Fe in three sites were 24.84 mg kg$^{-1}$, 54.65 mg kg$^{-1}$ and 23.65 mg kg$^{-1}$ for University farm, Nursery farm and Merall Gala soils, respectively. The maximum mean content of Fe was observed in Nursery farm. It might be due to lower pH (Table 2) than other two sites. The solubility of Fe in soil is highly pH dependent and decreases by factor of 1000 per unit pH increase as described by Lindsay (1979). Rashid and Ahmad (1994) classified the soils with reference to available Fe content as follows: Low $<3.0$ mg kg$^{-1}$, medium 3.0 to 5.0 mg kg$^{-1}$ and high $>5.0$ mg kg$^{-1}$, According to this classification all selected sites were extremely high in Fe.

## References

Anonymous, 1994. Azad Kashmir at a glance (statistics section). Department of Planning and Development, Azad Jammu and Kashmir.

Bajawa, M.I. and F. Rehman, 1996. Soil and Fertilizer Potassium. In: Soil Science, Bashir, E. and R. Bantle (Eds.)., National Book Foundation, Islamabad, Pakistan, pp: 317-340.

Cochrane, T.T., L.G. Sanckez, L.G. deAzevedo, J.A. Porras and C.L. Graver, 1984. Land in Tropical America. CIAT/EMBRAPA-CPAC., Colombia.

Foth, H.D., 1984. Fundamentals of Soil Science. 7th Edn., John Wiley and Son, New York.

Hussain, T. and A. Jabbar, 1985. Soil and plant analysis. Department of Soil Science, University of Agriculture, Faisalabad, Pakistan.

Khattak, A.A., 1996. Chemical Properties of Soil. In: Soil Science, Bashir, E. and R. Bantle (Eds.)., National Book Foundation, Islamabad, Pakistan, pp: 167-200.

Liebhardt, W.C., 1981. The basic cation saturation ratio concept and lime and potassium recommendations on Delaware's coastal plain soils. Soil Sci. Soc. Am. J., 45: 544-549.

Lindsay, W.L., 1979. Chemical Equilibrium in Soils. John Wiley and Sons, New York.

Rashid, A. and N. Ahmad, 1994. Soil testing in Pakistan: Country Report. Proceedings of the FADINAP Regional workshop on co-operation in soil Testing for Asia and the Pacific, August 16-18, 1993, Bangkok, Thiland, United Nations, New York, pp: 39-53.

Roy, H.F., S.M. Larry and H.D. Roy, 1981. Fertilizers and Soil Amendments. Prentice Halt, Inc., Englewood Cliffs, New Jersey.

Tagar, S. and A. Bhatti, 1996. Physical Properties of Soil. In: Soil Science, Bashir, E. and R. Bantle (Eds.)., National Book Foundation, Islamabad, Pakistan, pp: 116-143.

Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L. Havlin, 1997. Soil Fertility and Fertilizers. 5th Edn., Prentice Hall of India Pvt. Ltd., New Delhi.

Winkleman, E.R., W.A. Amin and M.B. Tahir, 1990. Methods Manual Soils Laboratory. BARD, PARC, Islamabad, Pakistan.