



## Distribution and indexation of plant available nutrients of rainfed calcareous soils of Pakistan

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### Abstract

Soil characteristics of Chakwal district were evaluated through physical and chemical analyses. Representative soil samples received/collected from farmers fields were analyzed for texture, electrical conductivity (EC), pH, organic matter (SOM), available phosphorus (P) and potassium (K) contents. Texture of the soils varied from sandy loam to loam. About 97% soils had EC values within the normal range ( $< 4 \text{ dS m}^{-1}$ ). The pH values of 64% soils ranged from 7.0 to 8.7 with an average of 7.9 and 6% soils had pH  $> 8.5$ . About 86% soils were poor in SOM and P, only 11% samples had satisfactory level of SOM ( $> 0.86\%$ ) and P ( $> 7.0 \text{ mg kg}^{-1}$ ) contents. The K status of most of soils (68%) was in satisfactory range. The frequency distribution indicated that most of the soils of Chakwal had SOM content in the range of 0.4-0.6%, P in the range of 2.1-4.0 and K in the range of 81-120  $\text{mg kg}^{-1}$ . The nutrient index values of Chakwal soils in respect of SOM and P were poor, whereas satisfactory for potassium.

**Key words:** Soil analysis, EC, pH, SOM, P, K, Chakwal, Nutrient index

### Introduction

A number of factors and their interaction impede sustainable growth in agriculture. Among these factors depletion of soil fertility through mining of soil nutrients from cropped area is real threat to food security and environmental degradation. Most of the soils in Pakistan have poor status of available plant nutrients and cannot support optimum levels of crop productivity (Rafiq, 1996; Ahmed and Rashid, 2003). Widespread nutritional deficiencies losses occur of relatively fertile soils layers by water erosion, coupled with continuous nutrient mining by crops in Pothwar area of Pakistan (Rashid *et al.*, 1997). The primary objective of soil testing is to help making soil test based fertilizer use recommendations. It helps in applying different nutrients in balanced ratio so as to get maximum efficiency of the applied fertilizers and profitable crop production (Motsara, 2002). Soil test measure some fraction of total supply of nutrients in the soil and indicate its available nutrient level. The higher soil test values mean higher level of nutrients and thus the lower will be the need for fertilization and *vice-versa*. There is a network of Soil and Water Testing Laboratories in the country to provide advisory service to farmers on soil and water management (Ahmed and Rashid, 2003).

Chakwal district is situated at 450 to 1050 m above mean sea level with average annual rainfall of 850 mm. It is

continuously divided into mountainous area of famous salt range, the unleveled areas of Pothwar Plateau and fertile belt of Soan river valley. Soils of this area have derived their parent material from underlying rocks like sandstone, limestone and shale. The soils are generally homogenized with weak structure and are calcareous. Chakwal District contains a large highly eroded area, either with rocks exposed to surface or lands with big gullies and cuts. Unbroken lands of thick material like gravels, stones and boulders also exist in the area. Dry farm agriculture is the main land use in the area (Soil Survey of Pakistan, 1975). The soils of Chakwal are sandy loam to loam in texture. The pH of soils is in alkaline range of 7.7-7.8. The fertility status is poor having SOM and P in the range of 0.36-0.61 and 5.9 to 7.1  $\text{mg kg}^{-1}$ , respectively, whereas K is in the satisfactory (80-180  $\text{mg kg}^{-1}$ ) range (Latif *et al.*, 2008; Mahmood *et al.*, 2008; Rashid *et al.*, 2008). The main objective of this study was to compile information on soil fertility and soil salinity/ sodicity status of Chakwal district on the basis of soil samples analyzed during the years 2006-2009.

### Materials and Methods

The soil samples were analyzed at Soil & Water Testing Laboratory, Chakwal during the year 2006-09. Samples were air dried, passed through 2mm sieve and analyzed for soil texture, by measuring saturation

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percentage of soils (Malik *et al.*, 1984), electrical conductivity (EC) by preparing 1:10 soil and water suspension (Soil Salinity Lab. Staff, 1954), pH (Schofield and Taylor, 1955), organic matter (Nelson and Sommers, 1982), available P (Olsen and Sommers, 1982) and K (Helmke and Sparks, 1996). The data were subjected to statistical analysis using MS Excel 2007 package. Nutrient Index (NI) was calculated by following formula (Parker, 1951).

$$\text{Nutrient Index (NI)} = ((N_i \times 1) + (N_m \times 2) + (N_h \times 3)) / N_t$$

Where

- $N_t$  = Total number of samples analyzed in a given area  
 $N_i$  = Number of samples falling in low category of given nutrient  
 $N_m$  = Number of samples falling in medium category of given nutrient  
 $N_h$  = Number of samples falling in high category of given nutrient

The criteria used to categorize the soil samples for various classes of texture, salinity/ sodicity and nutrients are given in table 1, 2 and 3 (Malik *et al.*, 1984).

**Table 1: The criteria used to categorize the soil samples for various classes of texture**

| Saturation % age | Textural Class |
|------------------|----------------|
| 0-20 %           | Sand           |
| 21-30 %          | Sandy Loam     |
| 31-45 %          | Loam           |
| 46-65 %          | Clay Loam      |
| 66-100 %         | Clay           |

(Malik *et al.*, 1984)

**Table 2: The criteria used to categorize the soil samples for various classes of salinity/sodicity**

| Status       | E.C (d Sm <sup>-1</sup> ) | Soil pH |
|--------------|---------------------------|---------|
| Normal       | < 4.0                     | < 8.5   |
| Saline       | > 4.0                     | < 8.5   |
| Saline Sodic | > 4.0                     | > 8.5   |
| Sodic        | < 4.0                     | > 8.5   |

(Malik *et al.*, 1984)

## Results and Discussion

### Soil texture

The saturation percentage ranged from 21 to 47 with a mean value of 27 (Table 4). The 60% soil samples were light and 30% were medium textured (Table 5) whereas, the proportion of heavy soil was only 10%. Rashid (1993) reported that the soils in Chakwal district were predominantly light textured as sandy loam and sandy clay loam were the dominant textured

classes. The dissected old loess and alluvial terraces in the area have predominantly silt and silt loam texture, formed from parent material loess, residual material, old river alluvium and sub recent out wash. About 31% soils are sandy to sandy loam in texture and the remaining are highly eroded (Tager and Bhatti, 2001). These medium textured (loam) soils are suitable for cultivation of all common crops while the light soil has less water holding capacity which needs to be enhanced through addition of farm yard manure to improve physical condition of these soils.

### Soil salinity/ sodicity

The EC of the soil samples varied from 0.15 to 4.78 dS m<sup>-1</sup> with an average value of 0.63 dS m<sup>-1</sup>. The soil pH values ranged from 7.0 to 8.9 with an average value of 7.9. The data (Table 5) indicated that 64% samples had pH < 7.5 while 30% samples had 7.5 to 8.5 and were classified as normal soil while 6% samples having pH value above 8.5 were considered as sodic. Similarly, 97% samples were found free from salinity hazard and 3% samples were either saline or saline sodic. Latif *et al.* (2008) also reported pH of Chakwal soils in alkaline range of 7.7-7.8. When the average values are taken in to consideration, the area looks free from salinity/ sodicity menace.

### Soil organic matter contents (SOM)

Nitrogen requirements are usually recommended by the Soil Testing Laboratories, based on the estimation of nitrogen released by the SOM contents (Cooke, 1982). The data revealed that 86% soils of Chakwal district were poor in SOM contents. The SOM contents ranged from 0.18 to 1.20% with mean value of 0.57% (Table 4). About 86% samples of Chakwal had poor SOM contents while 11% were in satisfactory range. Majority of samples (39%) were in the range of 0.41 to 0.60% whereas only 10% samples had SOM contents more than 1.0% (Table 6; Figure 1). Rashid (1994) reported and SOM contents ranged from 0.2-1.3% in surface soils of Chakwal. The soils of Pakistan are quite low in organic matter. Generally the soils in Punjab contained less than 1% organic carbon (Azam, 1988). The decline in SOM is due to crops grown without or very meager addition of plant and animal manures. When the SOM level declined to 40-60% of their original level, the soil productivity was affected, erosion losses of soil surface increased and net mineralization of soil fell below the level required for sustained grain crop production (Doran and Smith, 1987).

### Available phosphorus (P)

The P contents ranged from 1.8 to 17.2 with a mean value of 4.35 mg kg<sup>-1</sup> and standard deviation of 1.02 (Table

4). The 86% soils were poor, 11% had satisfactory level while only 3% had adequate P. The frequency distribution analysis (Table 7) indicated that majority of soils (45%) in Chakwal district had P in the range of 2.1-4.0 mg kg<sup>-1</sup>, followed by 21% in 4.1-6.0 mg kg<sup>-1</sup> range whereas only 2.5% samples had >14 mg kg<sup>-1</sup>. Malik *et al.* (1984) and Rashid (1994) reported that 75-95% soils in Punjab are deficient in P. They also indicated that 61% soils contained

up to 3 mg kg<sup>-1</sup> and 34% soils had 3-12 mg kg<sup>-1</sup> P contents.

### Available potassium (K)

The K contents ranged from 43-278 with a mean value of 105 mg kg<sup>-1</sup>. The classification (Table 5) showed that 68% samples contained satisfactory while 10% had adequate K contents. The frequency distribution data (Table 8) indicated that 48% soils had 81-120 mg K kg<sup>-1</sup>,

**Table 3: The criteria used to categorize the soil samples for various classes of essential soil nutrients**

| Status       | Organic Matter<br>% | Available Phosphorus<br>mg kg <sup>-1</sup> | Available Potassium | Nutrient Index value (NI) |
|--------------|---------------------|---------------------------------------------|---------------------|---------------------------|
| Poor         | <0.86               | > 7                                         | > 90                | < 1.5                     |
| Satisfactory | 0.86-1.29           | 7-14                                        | 90-180              | 1.5 - 2.5                 |
| Adequate     | >1.29               | > 14                                        | >180                | > 2.5                     |

(Malik *et al.*, 1984; Motsara, 2002)

**Table 4: Minimum, maximum and mean values of different soil parameters of Chakwal District**

| Estimation             | Total No. of Samples | Range       | Mean | SD   |
|------------------------|----------------------|-------------|------|------|
| Saturation %age        | 10314                | 21- 47      | 27   | 2.3  |
| Soil pH                | 10314                | 7.0 - 8.9   | 7.9  | 0.26 |
| EC                     | 10314                | 0.15 - 4.78 | 0.63 | 0.07 |
| Organic Matter         | 10314                | 0.18 - 1.20 | 0.57 | 0.24 |
| Available Phosphorus   | 10314                | 1.8 -17.2   | 4.35 | 1.02 |
| Exchangeable Potassium | 230                  | 43 - 278    | 105  | 15.8 |

**Table 5: Categorization of soil samples into different classes based on criteria described in Table-1 during 2006-09**

| Particular           |                                                | Year    |         |         |       |    |
|----------------------|------------------------------------------------|---------|---------|---------|-------|----|
|                      |                                                | 2006-07 | 2007-08 | 2008-09 | Total | %  |
| Soil texture         |                                                |         |         |         |       |    |
| 1.                   | Light                                          | 1844    | 2043    | 2316    | 6203  | 60 |
| 2.                   | Medium                                         | 795     | 1236    | 1024    | 3055  | 30 |
| 3.                   | Heavy                                          | 187     | 659     | 210     | 1056  | 10 |
| Salinity/sodicity    |                                                |         |         |         |       |    |
| 1.                   | Normal (EC<4.0)                                | 2801    | 3647    | 3550    | 9998  | 97 |
| 2.                   | Saline (EC>4.0)                                | 25      | 291     | 0       | 316   | 03 |
| Soil pH              |                                                |         |         |         |       |    |
| 1.                   | >7.5                                           | 2397    | 2533    | 1707    | 6637  | 64 |
| 2.                   | 7.5-8.5                                        | 381     | 909     | 1768    | 3058  | 30 |
| 3.                   | >8.5                                           | 48      | 496     | 75      | 619   | 06 |
| Organic matter       |                                                |         |         |         | 0     |    |
| 1.                   | Poor (< 0.86 %)                                | 2595    | 3401    | 2829    | 8825  | 86 |
| 2.                   | Satisfactory (0.86-1.29 %)                     | 172     | 456     | 525     | 1153  | 01 |
| 3.                   | Adequate (>1.29 %)                             | 61      | 81      | 196     | 338   | 03 |
| Available phosphorus |                                                |         |         |         |       |    |
| 1.                   | Poor (< 7.0 mg kg <sup>-1</sup> )              | 2593    | 3402    | 2827    | 8822  | 86 |
| 2.                   | Satisfactory ( 7.0 -14.0 mg kg <sup>-1</sup> ) | 169     | 461     | 542     | 1172  | 11 |
| 3                    | Adequate (> 14 mg kg <sup>-1</sup> )           | 64      | 76      | 181     | 321   | 03 |
| Available potassium  |                                                |         |         |         |       |    |
| 1.                   | Poor (< 80 mg kg <sup>-1</sup> )               | 0       | 0       | 51      | 52    | 22 |
| 2.                   | Satisfactory ( 80 -180 mg kg <sup>-1</sup> )   | 0       | 0       | 156     | 156   | 68 |
| 3                    | Adequate (> 180 mg kg <sup>-1</sup> )          | 0       | 0       | 23      | 23    | 10 |

**Table 6: Frequency distribution of soil organic matter contents of Chakwal District for three years**

| Organic Matter Range (%) | 2006-07 | 2007-08 | 2008-09 | Total | %age |
|--------------------------|---------|---------|---------|-------|------|
| 0.0 – 0.20               | 204     | 615     | 216     | 1035  | 10   |
| 0.21 – 0.40              | 670     | 680     | 410     | 1760  | 17   |
| 0.41 – 0.60              | 1210    | 1640    | 1129    | 3979  | 39   |
| 0.61 – 0.80              | 326     | 395     | 1050    | 1771  | 17   |
| 0.81 – 1.00              | 210     | 71      | 360     | 641   | 06   |
| 1.01– 1.20               | 76      | 350     | 110     | 536   | 05   |
| 1.21 – 1.40              | 70      | 81      | 196     | 347   | 03   |
| > 1.40                   | 60      | 106     | 79      | 245   | 02   |

**Table 7: Frequency distribution of soil available phosphorus contents of Chakwal District for three years**

| Available P Range (mg kg <sup>-1</sup> ) | 2006-07 | 2007-08 | 2008-09 | Total | %age |
|------------------------------------------|---------|---------|---------|-------|------|
| 0-2.0                                    | 256     | 790     | 50      | 1096  | 11   |
| 2.1-4.0                                  | 1733    | 2230    | 700     | 4663  | 45   |
| 4.0-6.0                                  | 505     | 297     | 1400    | 2202  | 21   |
| 6.1-8.0                                  | 156     | 300     | 610     | 1066  | 10   |
| 8.1-10.0                                 | 148     | 110     | 275     | 533   | 5    |
| 10.1-12.0                                | 10      | 82      | 252     | 344   | 3    |
| 12.1-14.0                                | 0       | 10      | 122     | 132   | 1    |
| >14.0                                    | 18      | 119     | 141     | 278   | 3    |

**Table 8: Frequency distribution of available potassium contents of Chakwal District for three years**

| Available K Range (mg kg <sup>-1</sup> ) | 2006-07 | 2007-08 | 2008-09 | Total | % age |
|------------------------------------------|---------|---------|---------|-------|-------|
| 0-40                                     | 0       | 0       | 5       | 5     | 2     |
| 41-80                                    | 0       | 0       | 45      | 45    | 20    |
| 81-120                                   | 0       | 0       | 109     | 109   | 48    |
| 121-160                                  | 0       | 0       | 40      | 40    | 18    |
| 161-220                                  | 0       | 0       | 12      | 12    | 5     |
| 221-260                                  | 0       | 0       | 11      | 11    | 5     |
| 260-300                                  | 0       | 0       | 2       | 2     | 1     |
| >300                                     | 0       | 0       | 1       | 1     | 0     |

**Table 9: Soil Fertility Index of soils in Chakwal district**

| Available Nutrient        | % soil samples |              |          | Nutrient Index (NI) |
|---------------------------|----------------|--------------|----------|---------------------|
|                           | Poor           | Satisfactory | Adequate |                     |
| Organic Matter / nitrogen | 86             | 11           | 3        | 1.18                |
| Available Phosphorus      | 86             | 11           | 3        | 1.17                |
| Exchangeable Potassium    | 22             | 68           | 10       | 1.87                |

while 22% soils had K in poor range (< 80 mg kg<sup>-1</sup>). The K content had invariably been reported as adequate in Punjab soils except eroded or light textured soils (Bajwa, 1990). Rashid *et al.* (2008) reported K in the satisfactory range (80-180 mg kg<sup>-1</sup>) in Chakwal soils. However, Rashid (1994) reported low K contents in 30% surface soils of groundnut growing areas of Chakwal.

### Soil nutrient index (NI)

Soil fertility level was measured in terms of NI values. The NI values (Table 9) in present study indicated that SOM and P levels were low and K level (1.87) was found in medium range. Nutrient index value of <1.5 is taken as low, values between 1.5 -2.5 indicates medium and >2.5 as higher fertility status of the given area (Motsara, 2002).

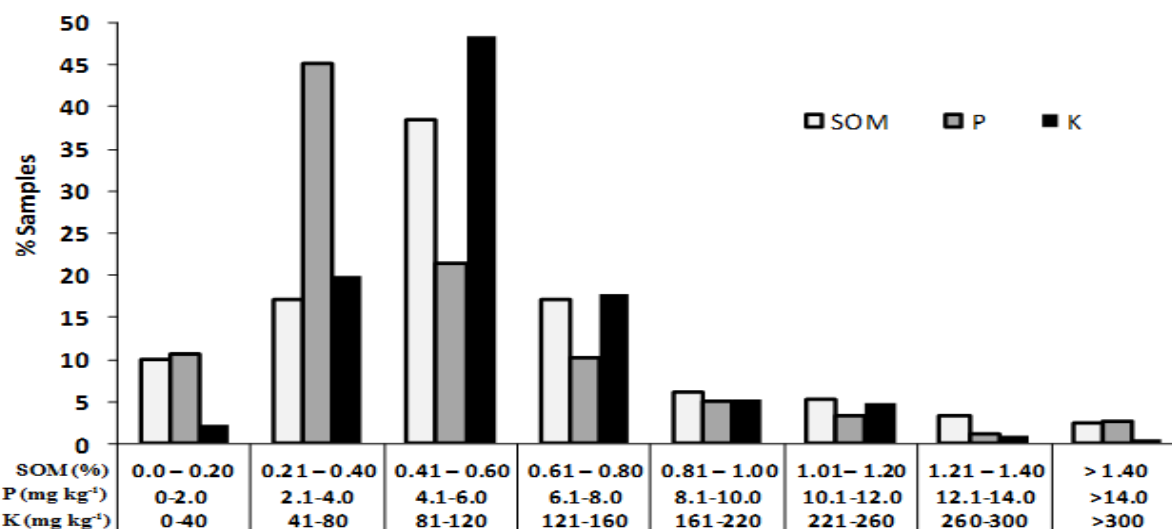


Figure1: Frequency distribution of soils for SOM, P and K in Chakwal district

## References

- Ahmed, N. and M. Rashid. 2003. Fertilizer Use in Pakistan. NFDC. Planning and Development division, Islamabad. 141p.
- Azam, F. 1988. Studies on organic matter fractions of some agricultural soils of Pakistan. *Sarhad Journal of Agricultural Research* 4(3):355-365
- Bajwa, M.I. 1990. Soil fertility management for sustainable agriculture. p. 7-23. In: Proceeding 3<sup>rd</sup> National Congress of Soil Science, March 20-22, 1990, Lahore.
- Cooke, G.W. 1982. An introduction to soil analysis. *World Crops* 1: 8-9.
- Doran, J.W. and M.S. Smith. 1987. Organic matter management and utilization of soil and fertilizer nutrients. p. 53-71. In: Soil Fertility and Organic Matter as Critical Components of Production System. J.J. Mortvedt and D.R. Buxton (eds). Soil Science Society of America, WI, USA.
- Helmke, P.A. and D.L. Sparks. 1996. Lithium, sodium and potassium. p. 551-575. In: Methods of Soil Analysis. part 2. Chemical and Microbial Properties. A.L. Page, O.A. Helmke, P.N. Sultanpure, M.A. Tabatabai and M.E. Summer (eds.). Soil Science Society of America, WI, USA.
- Latif, R., S. Ali and R. Hayat. 2008. Nitrogen fixation and yield of peanut affected by inorganic fertilizers, variety and inoculums interaction in rainfed areas of Punjab. *Soil and Environment* 27(1): 77-83.
- Mahmood, S., M.A. Qazi and I. Ali. 2010. Annual Report 2008-09. Soil & Water Advisory Service in Punjab. Soil Fertility Research Institute, Department of Agriculture, Lahore.
- Malik, D.M., B. Ahmed and M. Ahmed. 1984. Survey of soil fertility status and quality of ground waters. Punjab Digest 1981-84. Department of Agriculture, Punjab, Lahore.
- Malik, D.M., M.A. Khan and T.A. Choudhry. 1984. Analysis Manual for Soil, Water and Plants. Directorate of Soil Fertility and Soil Testing, Lahore.
- Motsara, M.R. 2002. Available nitrogen, phosphorus and potassium status of Indian soils as depicted by soil fertility maps. *Fertilizer News* 47(8):15-21.
- Nelson, S.W. and I.E. Sommers. 1982. Total carbon, organic carbon and organic matter. P. 539-80. In: Methods of Soil Analysis. Chemical and Microbial Properties. Agron. No. 9. Part 2, 2<sup>nd</sup> Ed. A.L. Page (ed.). American Society of Agronomy, Madison, Wisconsin, USA.
- Olsen, S.O. and I.E. Sommers. 1982. Phosphorus. p. 403-430. In: Methods of Soil Analysis. A.L. Page (ed.). Chemical and Microbial Properties. Part 2, 2<sup>nd</sup> Ed. American Society of Agronomy, Madison, Wisconsin, USA.
- Parker, F.W., W.L. Nelson, E. Winters and I.E. Miles. 1951. The broad interpretation and application of soil test information. *Agronomy Journal* 43:105-112.
- Rafiq, M. 1996. Soil resources of Pakistan. p. 439-469. In: Soil Science. E. Bashir and R. Bantel (eds.). National Book Foundation. Islamabad, Pakistan.
- Rashid, A. 1993. Nutrient disorders of rapeseed-mustard and wheat grown in Potohar area. Micronutrient Project. Annual Report 1991-92. NARC, Islamabad.

- Rashid, A. 1994. Nutrient Indexing Surveys and Micronutrient Requirement of Crops. NARC, Islamabad.
- Rashid, A., E. Rafique and N. Bughio. 1997. Micronutrient deficiencies in rainfed calcareous soils of Pakistan. I. Iron chlorosis in peanut. *Communication in Soil Science and Plant Analysis* 28: 135-148.
- Rashid, M., M.N. Iqbal, M. Akram, M. Ansar and R. Hussain. 2008. Role of gypsum in wheat production in rainfed areas. *Soil and Environment* 27(2): 166-177.
- Schofield, R.K. and A.W. Taylor. 1955. The measurement of soil pH. *Soil Science Society of America Proceeding* 19: 164-167.
- Soil Survey of Pakistan. 1975. Reconnaissance Soil Survey of Salt Range. Directorate of Soil Survey (Reconnaissance), Lahore.
- Soil Salinity Lab. Staff. 1954. Diagnosis and Improvement of Saline and Alkali Soils. *USDA Hand book 60*, Washington, D.C., USA.
- Tager, S. and A. Bhatti. 2001. Physical properties of soil. p. 113-144. *In: Soil Science*. E. Bashir and R. Bantel (eds.). National Book Foundation, Islamabad, Pakistan.