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Soil Fertility Management for Sustainable Agriculture: A Case Studyof District Bahawalnagar, Pakistan

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Abstract
The study was conducted to classify soil of crop growing areas of District Bahawalnagar with respect to low, satisfactory and high soil fertility status for better management of the whole area. A total of 3624 soil samples collected from all tehsils of Bahawalnagar district (888 samples from Bahawalnagar, 743 samples from Chishtian, 528 samples from Fort Abbas, 573 samples from Haroon Abad and 892 soil samples from Minchin Abad) were tested in Soil and Water Testing Laboratory, Bahawalpur, Pakistan during 2011-2013.Soil characteristics of Bahawalnagar district were evaluated through physical and chemical analysis. Representative soil samples received/collected from farmers fields were analyzed for texture, electrical conductivity (EC), pH, organic matter (OM), available phosphorus (P) and potassium (K) contents. Texture of the soils varied from sandy loam to loam. About 66% soils had EC values within the normal range (< 4 dS m^{-1}). The pH values of 94% soils ranged from 7.5 to 8.5 with an average of 8.03 and 5% soils had pH > 8.5. About 99% soils were poor(< 0.86%) in organic matter and only 1% samples had satisfactory level of organic matter(0.86-1.29%).About 68% soils were poor(<7 ppm) in available phosphorus, 23 % samples had satisfactory level of available phosphorus(7-14 ppm) and only 9% samples had adequate level of available phosphorus (>14 ppm) contents. The K status of most of soils was in satisfactory (58%) and adequate range (30%).
The objective of present study is to assess the soil fertility and salinity status of Bahawalnagar district for formulation of optimum fertilizer recommendations for different crops grown in the area.
Key words: Soil Analysis, EC, pH, SOM, P, K, Bahawalnagar

Introduction
Soil fertility refers to the inherent capacity of a soil to supply nutrients to plants in adequate amounts and in suitable proportions. Based on the criteria proposed by Arnon and Stout (1939), the elements, C, H, O, N, P, K, S, Ca, Mg, Na, Cl, Si, Mo, Zn, B, Fe, Mn and Co are known to be essential. The plant nutrients are divided into macronutrients and micronutrients. The macronutrients are further classified: i) Major nutrient elements (carbon, hydrogen, oxygen), taken up by plants from air and water ii) Primary plant nutrient (Nitrogen, phosphorus and potassium) iii) Secondary plant nutrients (sulphur, calcium, magnesium).Nitrogen is taken up by plants as NO_3^- or NH_4, phosphorus as $H_2PO_4^-$ and potassium as K^+. Secondary nutrients such as sulfur, calcium, and magnesium are taken up by plants as SO_4^{2-}, Ca^{2+} and Mg^{2+}, respectively. Among the micronutrients, boron and chloride are taken up as $H_3BO_3^-$ and Cl^-, respectively. Rest of the micronutrients such as copper, iron, manganese, molybdenum and zinc are taken up as divalent cations.
In agricultural soils of Pakistan, organic matter level is quite low about 0.2% in dry hot climatic region. Inherent fertility status, especially of nitrogen, is quite low to low organic matter (Zia, 1990). Thus, almost all crops, except some leguminous, require the use of nitrogenous fertilizer for proper crop production. Majority of soils are low to satisfactory in P (Memon, 1986). Because most of the soils in Pakistan are alkaline and calcareous in nature and have bad affect on P availability to plants. Therefore, successful crop production demands judicious use of P fertilizers. Mica (K bearing mineral) is one of the dominant clay minerals in most of the agricultural soils of Pakistan. Its prevalence in soils clearly indicates abundance of K reserves in natives soils (Ranjha, 1988). Among the micronutrient, Zinc deficiency ranks at the top as about 70% soils in Pakistan are low in Zn content (Hussain & Rashid, 1979; Zia, 1990). Deficiencies of other nutrients such as boron and iron have also been reported because of increasing cropping intensity (Rashid & Rafique 1999).
Soil testing is a better method than deficiency symptom and plant and tissue analysis, because it helps in determining the nutrient need of the plant before the crop is planted. It is simpler and less time consuming than other methods. The main objectives of soil analysis are to assess the nutrient status of soil and diagnostic problems of salinity/sodicity and to quantify the gypsum requirement if needed.
Bahawalnagar District is a district of Punjab province in Pakistan. It is on the border. Before the independence of Pakistan, Bahawalnagar was a part of Bahawalpur state governed by the Nawab of Bahawalpur. The city of Bahawalnagar is the capital of the district. The district of Bahawalnagar is spread over an area of 8,878 square kilometres comprising five tehsils and 118 Union Councils. The boundaries of Bahawalnagar in the East and

South touches the Indian territory while Bahawalpur district lies on its West and river Sutlej flows on its Northern side. District Bahawalnagar has a very hot and dry climate in summer. The maximum temperature touches 52 $C^{0.}$ Wind and storms are quite common during the summer. The average annual rainfall in the district is 119 mm. Major crops of district Bahawalnagar are wheat, sugarcane, cotton, rice and rape/mustard seeds. At present, the major industrial units operating in district Bahawalnagar are sugar mills and textile spinning mills. There is also potential for milk processing unit, dairy farms, cattle/sheep/goat fattening farm, tannery, leather products, and machine made wool carpet units.

The human interference in the form of irrigation network has greatly damaged the natural environment. Increases in cultivation, waterlogged areas, and salinity have badly hurt plant life. Because of the increase of salinity at the surface, only salt resistant plants can survive in most of the area.

Keeping the above all points in view, this study was designed to assess the fertility status of soil with the objectives, to classify the areas into low, satisfactory and high fertility status for the better nutrient management.

Materials and Methods

This study was conducted in Soil and Water Testing Laboratory, Bahawalpur, Pakistan during 2011-13. Composite soil samples from all tehsils of district Bahawalnagar (888 samples from Bahawalnagar, 743 samples from Chishtian, 528 samples from Fort Abbas,573 samples from Haroon Abad and 892 soil samples from Minchin Abad) were collected from 0-15 cm depths for crops and vegetables. Samples were air dried, passed through 2 mm sieve and analyzed for soil texture, by measuring saturation 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.

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 (dSm^{-1})	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)

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

Status	Organic Matter	Available phosphorus	Available Potassium	Nutrient Index Value
	%	$mg\ kg^{-1}$	$mg\ kg^{-1}$	
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 Bahawalnagar District

Estimation	Range	Mean	Standard Deviation
Saturation % age	26-46	33.47	3.38
Soil pH	2-9.8	8.03	0.45
EC	0.6-97.8	5.14	8.06
Organic Matter	0-2.12	0.44	0.16
Avail. Phosphorus	0.9-21.2	6.20	4.72
Exchangeable Potassium	10-800	165.82	106.42

Table 5: Categorization of soil samples into different classes based on criteria described in Table 1, 2 & 3.

Particular		No. of Samples	Percentage (%)
Soil Texture			
1.	Light	859	24
2.	Medium	2765	76
3.	Heavy	0	0
Salinity/Sodicity			
1.	Normal (EC< 4.0)	2387	66
2.	Saline (EC ≥4.0)	1237	34
Soil pH			
1.	>7.5	37	1
2.	7.5-8.5	3414	94
3.	>8.5	173	5
Soil Organic Matter			
1.	Poor (< 0.86 %)	3620	99
2.	Satisfactory (0.86-1.29 %)	4	1
3.	Adequate (>1.29 %)	0	0
Available Phosphorus			
1.	Poor (<7.0 mg kg^{-1})	2469	68
2.	Satisfactory(7-14 mg kg^{-1})	822	23
3	Adequate (> 14 mg kg^{-1})	333	9
Available Potassium			
1.	Poor (< 80 mg kg^{-1})	432	12
2.	Satisfactory(80-180mg kg^{-1})	2114	58
3	Adequate (> 180 mg kg^{-1})	1078	30

Results and Discussion

Soil Texture

Soil texture is basic to many other soil properties and serves as an indicator of water holding capacity, cation exchange capacity, aeration and organic matter content. Soil texture also controls the retention and losses of nutrients in soil-plant environment.

The saturation percentage ranged from 26-46 with a mean value of 33.47 (Table 4). The 24 % soil samples were light and 76% were satisfactory textured (Table 5).These satisfactory textured (loam) soils are suitable for cultivation of all common crops while the light soils has less water holding capacity which needs to be enhanced through addition of farmyard manure to improve physical condition of these soils.

Dissolved Salts (Electrical Conductivity)

Dissolved salts in soils create hindrance in normal nutrient uptake process by imbalance of ions, antagonistic and osmotic effects. Normally for research purpose, electrical conductivity of soil extract (ECe) is used for total dissolved salts but for assessing soil salinity and sodicity for advisory purpose, a soil-water suspension of EC1:10 is normally used as described in the manual of Malik *et al.*, 1984 The data (Table 5) showed that 66 percent of soil samples analysed in district Bahawalnagar were free from salinity/sodicity and 34 percent soil were saline/sodic. Regarding ranges of EC (Table 4), minimum value was 0.6 dS/m while maximum value 97.8 dS/m was noticed in district Bahawalnagar, with an average value of 5.14 dS/m during the year 2011-13.

Soil Reaction (pH)

The pH has significant influence on solubility and bioavailability of nutrients. NO_3 and NH_4 -N are available in a

relatively wider range of pH (6.0-8.5). In calcareous soils with high pH the availability of P to plants is decreased. The solubility of P is optimum over a narrow pH range (6.5-7.5). The micronutrients, Fe, Cu, Zn and Mn are more soluble in the pH range 5.0 to 6.0, and their availability in soils varies considerably with the seasonal changes in temperature, moisture and microbial activity (Hodgson, 1963).

The results (Table 5) further revealed that 1 percent soils at district level had pH < 7.5, which are considered as the best for agricultural use especially for growing high value crops, fruits and vegetables. Similarly 94 percent soils had pH 7.5-8.5. The soil pH values ranged from 2.0 to 9.8 with an average value of 8.03. The data (Table 5) indicated that 5% samples were either saline or saline sodic. These soils are also good for agriculture but pH towards higher side (i.e. > 8.5) has some limitations for high value crops. Soils having pH > 8.5 need special attention and some suitable amendment (acid or gypsum) is to be applied for their reclamation according to the soil gypsum requirement. When the average values are taken in to consideration, the area looks free from salinity/ sodicity menace. As the pH of soils is alkaline due to the indigenous parent material, calcareousness and low organic matter, this situation is similar in almost all soils. These results are supported by the findings of earlier workers.

Soil Organic Matter (SOM)

Nitrogen requirements are usually recommended by the Soil Testing Laboratories, based on the estimation of nitrogen released by the SOM contents (Cooke, 1982).

Higher organic matter reflects the higher crops yield. The data (Table 5) showed that 99 percent soils in Bahawalnagar district were poor and only 1 percent were satisfactory with respect to organic matter. The reason for low organic matter in these tehsils is that temperature in summer exceeds 45 °C due to which its decomposition rate is increased. Also farmers generally do not use farmyard manure and remove crops totally (grain plus straw) from soils leaving it fallow. The trend of green manuring is also not observed. These results are in line with those of earlier scientists who found that soils in these areas are deficient in organic matter.

Plant Available Phosphorus

The data (Table 5) showed that 68 percent soils in Bahawalnagar district were poor, 23 percent satisfactory and only 9 percent were adequate with respect to phosphorus availability to plants. The reasons for poor plant available phosphorus is that the farmers do not apply phosphatic fertilizers to crops according to recommendations and only nitrogenous fertilizers are applied due to price hike of phosphatic fertilizers. These results coincide with the findings of previous scientists according to which soils in this tract are poor in available phosphorus.

Available Potassium (K)

The available K varies with the soil texture depending upon the parent material and its degree of weathering. Generally, clayey soils have more available K than loamy and sandy soils (Saleem and Bertilsson, 1978).

The data (Table 4) showed that the K contents ranged from 10-800 with a mean value of 165.82 mg kg^{-1}. The classification (Table 5) showed that 12% soil samples were poor, 58% samples contained satisfactory while 30% had adequate K contents. The K content had invariably been reported as adequate in Punjab soils except eroded or light textured soils (Bajwa, 1990).

Recommendations

Experiments have shown that crops on saline soils also respond well to fertilizers, especially phosphorus. However, if a serious yield reduction because of salinity is expected, reduce the nitrogen dose but keep to the phosphorus and potassium recommendations. In connection with gypsum application, the nitrogen dose should be kept in the higher range. The key point to decide the dose in these soils should be plant population. These soils are also good for agriculture but pH towards higher side (i.e. > 8.5) has some limitations for high value crops. Soils having pH > 8.5 need special attention and some suitable amendment (acid or gypsum) is to be applied for their reclamation according to the soil gypsum requirement. Soil organic matter level and soil fertility status may be increased by green manuring (sesbania, guar, etc.) once in three years. With this practice, the sufficient moisture can be preserved for rabi crops. Inorganic fertilizers (NPK) should be applied in balanced form according to soil test value and their use efficiency can be increased by band placement for row-sown crops.

RANGES OF DIFFERENT SOIL PARAMETERS (TEHSIL -WISE)

Fig.1. Categorization of District Bahawalnagar Soils with regard to EC

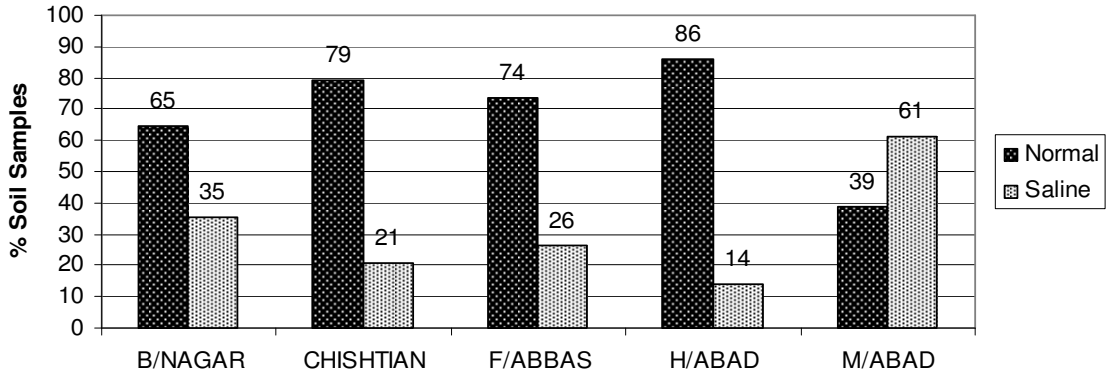
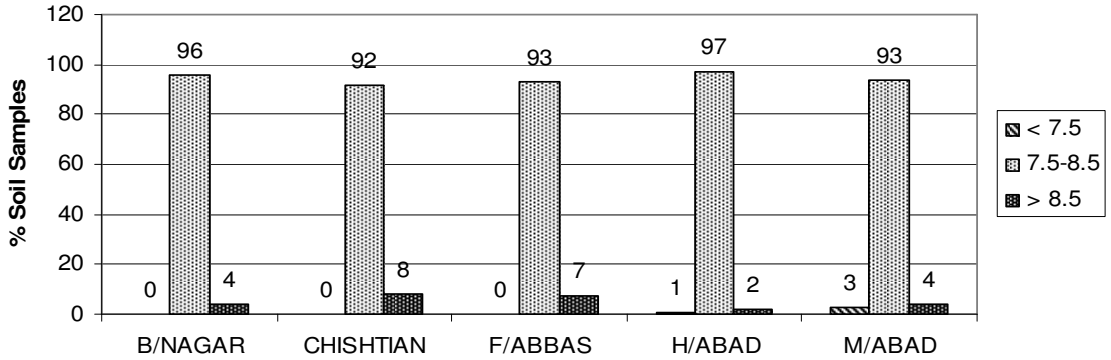
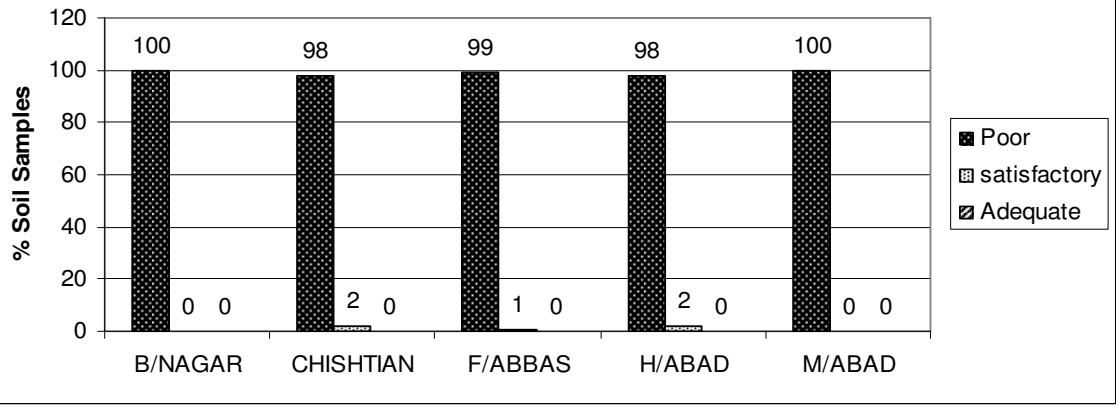


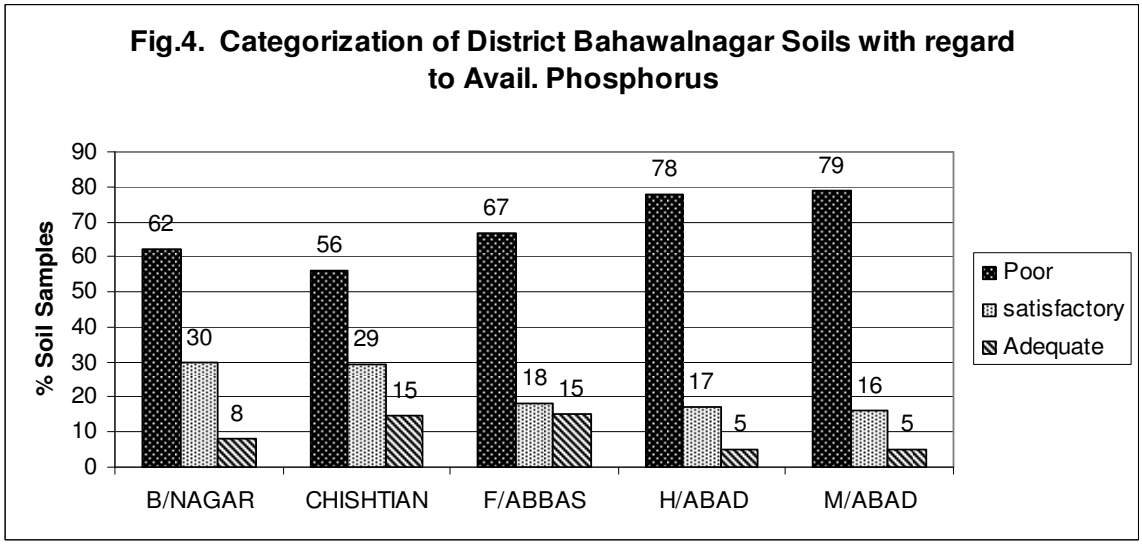
Fig.2. Categorization of District Bahawalnagar Soils with regard to pH

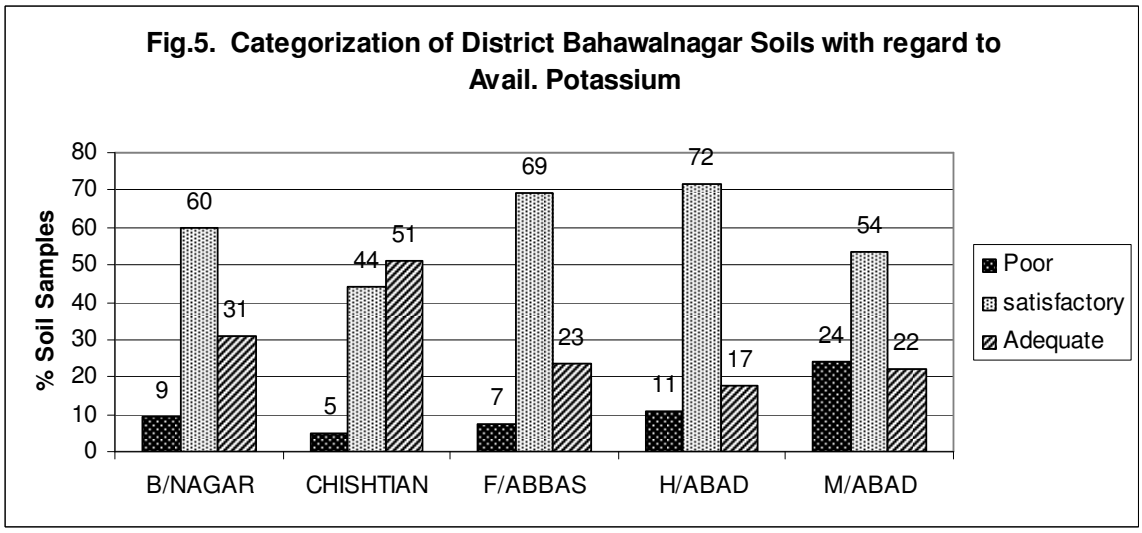


*B/Nagar (Bahawalnagar),*F/Abbas (Fort Abbas),*H/Abad (Haroon Abad), *M/Abad (Minchin Abad)

Fig.3. Categorization of District Bahawalnagar Soils with regard to Organic Matter







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