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SOME PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL IN SUGARCANE CULTIVATED AREAS OF NAWABSHAH, SINDH, PAKISTAN

MUHAMMAD ANWAR ARAIN, MUBARIK AHMED AND MUZAFFAR A. KHAN*

Tropical Agricultural Research Centre, Pakistan Agricultural Research Council, Karachi University Campus, Karachi, Pakistan.

Abstract

A declining trend in per hectare yield of sugarcane in Nawabshah is being observed since 1992. Soil samples collected from Nawabshah, Padedan and Sakrand when analysed for soil properties and some macro and micro nutrients showed that the soil is highly deficient in organic matter (X=0.35%) and phosphorus (X=6.2 ppm). Soil pH was found to be 8.35 indicating its alkalinity. Sodium was found to be the dominant cation (X=950 ppm) affecting electrical conductivity (7.71 millimohs/cm). Mean exchangeable sodium percentage and sodium absorption ratio were 5.4% and 9.5 millimol/l respectively. The soils were found to have sufficient potassium (X=500 ppm), calcium (X=10500 ppm) and magnesium (X=3500).

Introduction

During the last decade a declining trend in per hectare yield of sugarcane and sugar recovery was observed in Nawabshah, Sindh which may be the consequence of torrential rains that flooded the area in 1992 for about two months. The flood resulted into migration of deleterious salts from the saline regions and caused depletion of organic matter and subsequently soil microflora and fauna. Sugarcane is high nutrient demanding crop and requires adequate quantities of nitrogen, phosphorus, potassium besides several micronutrients viz., zinc, silica, manganese, magnesium, calcium etc. The soil should also be free from toxic salts and ions that are likely to retard the productivity (Yadava, 1991).

The Nawabshah region is characterized by large variations in temperature. During summer the night and day temperature ranges between 25 and 45°C. Since the sugarcane crop is at grand vegetative growth stage it is likely to be suppressed by extreme heat induced water stress. In saline soil, high temperature causes salinity induced drought injury to plants (Levitt, 1980).

In Pakistan, 90% soils are deficient in nitrogen and phosphorus, 50% have insufficient potash in addition to micro nutrient deficiencies (Bajwa, 1990). The salt affected soil becomes saturated with Na^+, Ca^{++} and Mg^{++} cations and their respective anions form chloride, sulphate and carbonate salts that may likely depress the potash and nitrate uptake by the plants (Muhammad *et al.*, 1990). The soil profile survey conducted by Muhammad (1983) showed that as a result of increase in salt concentration and soil pH due to evapotranspiration, a part of calcium and magnesium from soil solution

*Engro Chemical Pakistan Ltd., Karachi, Pakistan.

precipitates as calcium carbonate, magnesium sulphate and magnesium silicate. Precipitation of these sparingly soluble salts increases their free concentration in soil solution and thus disbalances the Na/K, Na/Ca and Na/Mg cationic ratio at soil exchange complex. Presence of such salts serves as the parent material for saline and saline sodic soil formation (Muhammad, 1986). The fertility status of soils in the irrigated area was found to be 68-88% P deficient, 5-52% K deficient, 48-75% Zn deficient whereas boron was quite high i.e., 25-50% (Zia *et al.*, 1998).

Presence of excessive salts seriously affect the growth and morphology of sugarcane crop. The cane displays an irregular, short, thin, ill and stunted growth with short internode and bushy habits. Root hairs and membrane becomes seriously damaged resulting into dead root. Such plants can easily be uprooted. They are poor in sugar recovery and contains high molasses contents (Barnes, 1974). To understand the magnitude of the problem, some sugar mills in Nawabshah area have initiated their research and developmental programmes. Complimenting to their efforts, the present studies were carried out to determine the physico-chemical characteristic of soil in sugarcane growing areas of Nawabshah and to identify the soil factors affecting the sugarcane productivity.

Materials and Methods

Soil samples were randomly collected from sugarcane growing areas of Nawabshah, Sakrand and Padedan with soil samples. The samples were collected by field staff of Habib Sugar Mills in March and April, 1998 from the field possessing appropriate moisture for sample collection. The samples were collected and preserved by using the method as described by Rowell (1994). During sampling, necessary care was taken to avoid sampling errors including any abnormal occurrence in the field or road side sampling etc. About 1 kg soil sample was collected from each field. Each sample was divided into two equal halves and each half was separately packed in air tight polyethylene bags and labelled for its location and history. The samples were sent to the laboratories i.e., M/S Engro Field Services Laboratory, Ghotki and M/S. Fauji Fertilizer Field Services Laboratory, Sadiqabad. Phosphorus was determined by spectrophotometric method as described by Rowell (1994), potassium and sodium were analysed by using flame photometer as recommended by US Salinity Laboratory (Anon., 1954), calcium and magnesium were determined by atomic absorption spectrophotometer as described by US Salinity Laboratory (Anon., 1954), pH was measured by using Orion pH meter (model 201), the electric conductivity was measured by digital EC meter (model LF 5500) and the organic matter analysed by the method of Walkley & Black (1934). Each set of samples were separately analysed for soil composition. The results obtained were statistically analysed using Costat computer programme.

Table 1. Some properties of soil in the sugarcane cultivated area in Nawabshah, Sindh, 1998.

Factors	Measuring unit	Range (%)	Mean (%)	Frequency distribution	
				class interval	percentage
Organic matter	percentage	0.2-0.5	0.35+0.12	0.2-0.3	15
				0.3-0.4	60
				0.4-0.5	25
pH	Numbers	6.68-8.66	8.35+1.06	6.1-7.0	01
				7.1-8.0	07
				8.1-9.0	92
Electrical conductivity	Millimohs/ cm	0.5-16.3	7.71+2.1	0.0-2.0	20
				2.1-4.0	27
				4.1-6.0	29
				6.1-8.0	11
				>8.0	13
Exchangeable sodium percentage	Percentage	1-20	5.4+1.43	1.0-5.0	75
				5.1-10.0	13
				>10.0	12
Sodium absorption ratio	mmol/litre	5-18	9.5+1.36	5-10	25
				10-15	50
				15-20	25

Results and Discussion

i. Soil properties

Among the major soil properties, organic matter content, pH, electrical conductivity(EC), exchangeable sodium percentage (ESP) and sodium absorption ratio (SAR) were studied which are presented in Table 1.

a. Organic matter: The organic matter (OM) content in the plough layer of sugarcane cultivated area of Nawabshah ranged between 0.3 to 0.5 percent (X=0.35% Table 1). The OM content in the Australian soil, ranges between 15-30% (Kirkby & Mengel, 1987). The OM contents found in Nawabshah are far below than the minimum quantities required (2-3%) for sugarcane cultivation. Such low organic matter content in the Nawabshah soil is presumably due to the hot climate and intensive cultivation without using the farm yard manure and the lack of other manuring practices. Such practices seems to have exhausted the soil nitrogen reservoir and the organic matter content. Under such conditions the supply of nutrients using chemical fertilizer may have further aggravated the problem and created nutritional imbalance (Yadava, 1991). Organic matter content in soil not only effects the yield but also determines the juice quality and

quantity by increasing the sucrose content and decreasing the level of reducing sugars (Singh & Solomon, 1995). Pakistan's soils are extremely low in organic matter (Zia *et al.*, 1998; Bhatti, 1999).

b. pH: The pH is an important property of soil that determines the acidity or alkalinity and affects the chemical reaction between water and soil minerals. In sugarcane cultivated area Nawabshah, the soil pH ranged between 6.68 to 8.66 (X=8.35). Above 92% fields under investigation have a soil pH of 8.3 and higher (Table 1) whereas the optimum pH required for sugarcane cultivation should be between 6.5-7.0 (Barnes, 1974). There is a strong relationship between soil pH and nutrient availability. Alkaline soils with pH ranging between 7 and 8 are generally deficient in Zn, Fe and P (Marschner, 1986). The uptake of various plant nutrients is also pH dependent. Most of the primary nutrients like nitrogen, phosphorous and potassium and secondary nutrients like calcium, magnesium and sulphur are best utilized by the plants when the soil pH ranges between 5.5 to 7.9. The uptake of most of the micro-nutrient also takes place in acidic medium (Lucas & Davis, 1961). Our soils generally have a pH of above 8 (Bhatti, 1999). Soil pH also influences the activity of micro-organisms. At pH 5.5, fungi generally dominate the soil whereas at higher pH levels the bacteria are predominant (Trolldenier, 1973).

c. Electrical conductivity (EC): Electrical conductivity is the quantity of ionic salts in the soil which determines the concentration of ionic charges in soil solution. Sugarcane crop is best suited at EC level below 4 mmhos/cm (Muhammad, 1990). In Nawabshah, the EC ranges between 0.15-16.0 millimohs (X=7.71) and about 50% farmer fields have EC beyond the tolerance limit which may be the result of heavy accumulation of salts in the region.

d. Exchangeable sodium percentage (ESP): The mean ESP of Nawabshah soil is 5.4% (Table 1). Most of the soils analysed were found to have ESP below 10% and only 4% soils were found to record ESP between 15 and 20%. The results suggested that the soil in sugarcane cultivation area of Nawabshah are saline but not saline sodic. The exchangeable sodium percentage is an important parameter of soil that differentiates the saline and saline sodic soils. Higher ESP values are a result of leaching down of cations (Ca^{++}, Mg^{++}, K^{+}) from soil exchange complex mainly due to excessive sodium. The ESP of more than 15% makes the soil saline sodic (Muhammad *et al.*, 1990).

e. Sodium Absorption Ratio (SAR) mmol/l: The mean SAR in the Nawabshah soil is 9.5 mmol/l and ranges between 5 to 18 mmol/l (Table 1). This is due to high sodium concentration in the soil. The SAR higher than 13 mmol/l is considered to be dangerous and above this limit the soil is categorized as saline sodic (Muhammad *et al.*, 1990). Sodium absorption ratio (SAR) is the indication of relative sodium concentrations in the soil. It determines hazards of irrigation water because of high sodium, calcium and magnesium salt contents.

Table 2. Chemical composition of soil in sugarcane cultivated area in Nawabshah, Sindh.

Factors	Range (ppm)	Mean+SE (ppm)	Frequency distribution	
			Class interval (ppm)	Percentage
Phosphorus	1-20	6.2+0.12	1.0-4.0	23
			4.1-8.0	35
			8.1-12.0	17
			12.1-16.0	11
			16.1-20.0	10
Potassium	80-1440	500.0+8.7	80-160	13
			161-240	20
			240-320	13
			320-400	17
			> 400	37
Calcium	7500-18833	10500+10.0	7001-8000	09
			8001-9000	08
			9001-10,000	22
			10001-11,000	21
			11001-12,000	13
			> 12000	17
Magnesium	1000-8500	3500+6.0	1001-2000	15
			2001-3000	10
			3001-4000	65
			> 4000	10
Sodium	160-3500	950+9.1	1-200	04
			200-400	24
			401-600	15
			601-800	17
			801-100	20
			> 1000	25

ii. MINERAL NUTRIENTS

a. Phosphorous (P): Most of the Nawabshah soil were P deficient. Data of soil P analysis of 100 farmers' fields showed a variation in phosphorus content which ranges between 1-20 ppm (Table 2). The average P contents was found to be 6.2 ppm. The optimum P contents for crop growth should range between 20 and 40 ppm and below 6 ppm it may cause deficiency symptoms in plants. Generally most of the soils in Pakistan are P deficient (Muhammad *et al.*, 1990). High salinity and alkalinity may depress the availability of P and Zn in soil. However, excess of P applications may aggravate Zn deficiency due to its bonding reaction (Muhammad *et al.*, 1990). Physiologically

phosphorous is important for sugarcane nutrition as it regulates the photosynthesis, photo-phosphorylation, energy transfer, interaction with several other plant nutrients like N, K and Zn. It controls the carbohydrate metabolism, starch synthesis and chlorophyll formation (Marschner, 1986). About 68-88% soils of irrigated area are P deficient (Zia *et al.*, 1998).

b. **Potassium (K):** Nawabshah soils were not deficient in K contents (Table 2). The mean K was found to be 500 ppm and ranged between 80 to 1440 ppm. The optimum levels required for sugarcane cultivation are known to be 180-300 ppm and below 60 ppm deficiency symptoms may appear. About 25% farmer's fields exhibited K contents below the optimum level. Most of the cultivated soils in Pakistan have sufficient availability of K for optimum plant growth (Malik *et al.*, 1989). Potassium is the major nutrient after N and P which is considered essential for plant growth. It is an enzyme activator, increases photosynthesis and sugar translocation and reduces the crop lodging (Rashid *et al.*, 1990). Potassium leaching and availability has become a limiting factor for crop production in many soils of Pakistan (Saleem, 1986). The release and fixation of K is controlled by several factors such as properties of 2:1 soil type clay/mineral, structural configuration and interlayer charge density (White *et al.*, 1988). The problem of potash deficiency was of lesser extent in irrigated area where it ranges between 5 - 52% (Zia *et al.*, 1998).

c. Calcium (Ca): The soil in sugarcane cultivated area of Nawabshah, being calcareous, the calcium appeared to be the dominant cation (Table 2). The soil Ca content was found to range between 7500 to 18833 ppm (X=10500 ppm). Calcium deficiency symptoms generally occurs below 500 ppm (Donahue *et al.*, 1977). Increasing sodium salt may lead to precipitation of calcium with carbonates and bicarbonates (Muhammad, 1990). Physiologically calcium is important in plant nutrition. It regulates the growth, IAA hormone, calmodulin barrier across the cell membrane to regulate the intercellular cation and anion balance (Marschner, 1986).

d. **Magnesium** (Mg): Nawabshah soils were not found deficient in magnesium (Table 2). The soil magnesium contents were found to range between 1000 to 8500 ppm with an average of 3500 ppm. Magnesium deficiency generally occurs below 60 ppm (Donahue *et al.*, 1977). Magnesium plays an active role in plant growth and metabolism. It regulates the ATPase enzymes, carbon dioxide fixation, cellular pH control, chlorophyll content, chloroplast pigmentation and many other functions of crop development (Marschner, 1986). Magnesium present in dark coloured mineral soil in dolomitic lime stone consists of calcium, magnesium and carbonates. The amount of exchangeable Mg is less than the exchangeable calcium in most soil complexes (Donahue *et al.*, 1977).

e. Sodium (Na): The average Na content in soil of Nawabshah area was found to be 960 ppm and ranged between 160-3500 ppm (Table 2). The Na concentration from 50 to 100 millimol/l in soil solution is known to cause detrimental effect on the growth of most crop plants (Marschner, 1986). Physiologically sodium helps in osmo-regulation,

heat expansion and may act as a potassium substitute. However, high sodium causes ionic toxicity and imbalances the Na/K, Na/Ca, Na/Mg ratio and may cause salt injury to sugarcane (Marschner, 1986).

Results show that Nawabshah soils are highly alkaline and saline but not saline sodic. Good drainage in the present practices may prevent the soil from deleterious salts. It is therefore suggested that green manuring, farmyard manuring and recycling of sugarcane industrial wastes will be helpful to maintain the nutritional balance and pH, for the existence of soil microflora and fauna.

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