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RESEARCH ARTICLE

CHARACTERIZATION OF SOILS OF COTTON GROWING AREAS OF ARBA MINCH ZURIA WOREDA, GAMO GOFA ZONE, SOUTHERN ETHIOPIA

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ABSTRACT

There is an enormous potential for the production of cotton in Ethiopia, given the suitable agro-ecological conditions in certain regions. However, with small area and low productivity, the country has insignificant gains from its cotton production. Soil-related constraints could be one of the factors for low cotton productivity. Presently, little information is available to farmers and extension workers on different aspects of soil management in the cotton growing areas of Ethiopia, in general, and Arba Minch Zuria Woreda in particular. To substantiate the information, 30 composite surface soil samples representing different sites in three kebeles (ZeyseElgo, Genta Kanchama, Shelle Mella) of woreda, were analysed for different physico-chemical properties. The texture of soils varied from silty loam to silty clay loam, the bulk density from 1.25 to 1.55 Mg m^{-3} and porosity from 39.2 to 47.9 %. While the soils of Genta Kanchama were moderately alkaline (pH 8.2), the soils of ZeyseElgo and Shelle Mella were strongly alkaline (pH 8.9 and 9.1). The soils of Genta Kanchama and Shelle Mellakebeles with EC of 4.5 and 9.0 dSm^{-1}, respectively were affected by soil salinity. All soils had very high concentrations of exchangeable Ca and Mg, contributing almost fully to the total base saturation. The CEC of soils varying from 38 to 55.10 $cmol_{(+)}$ kg^{-1} was high. The organic carbon content of 1.2 to 1.7 % was low to medium. The total N status of the soils was medium with its content varying from 0.13 – 0.19%. The available P of 12.7 to 47.0 mg kg^{-1} was medium to high. With high exchangeable K, all the kebele soils were adequately supplied with potassium. The contents of available micronutrients viz., Fe, Mn and Cu were sufficiently high in all the soils. The concentration of Zn was, however, at a critical level. For sustained cotton production in the area, the soil management would include control measures for the salinity-affected soils and addition of nitrogenous and zinc fertilizers and organic manure on all the soils.

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INTRODUCTION

Cotton is produced in over 70 countries to meet the domestic needs of fiber and textile industry and as an international trading commodity. The bulk of production takes place in countries like China, United States, India, Pakistan and Brazil. Nevertheless, many low income countries in Sub-Saharan Africa and elsewhere depend heavily on cotton for earning foreign exchange (Anderson and Valenzuela, 2006). Ethiopia is one of the African countries that produce and export cotton. The use of cotton in Ethiopia for making clothes is as old as history of country itself. Still about 85% of the rural population meets a significant part of its textile needs from cotton. Ethiopia has an estimated area of 2.6 million ha suitable for the cultivation of cotton, lying between 1000m and 1400m in lowlands, both under irrigated and rainfed situations (ESTC, 2006). Despite this potential, however, Ethiopia produced only 22,000 metric tons of lint cotton annually from a total area of 83,000ha (ICAC, 2006). Of this, 20,000 metric tons (about 90% of the total production) was for domestic consumption and only remaining 10 % was exported. The disparity between the existing potential and the actual practice is more obvious when we look at the share of Ethiopia in terms of international production and marketing of cotton with an average share of only 0.13% of the total cultivated land and 0.1% of the produced cotton for the year1998-2000 (MOARD, 2004). In terms of international tradeinlint cotton, the export share of Ethiopia was also a mere 0.1% with revenue of only 0.06%. This situation shows that the country is receiving insignificant benefits from its cotton and textile products export. Eventually, the cotton shortages in the country were debated by various stakeholders in the sector with a view to step up the production and exports (Anonymous, 2011). The situation, however, does not seem to be improving looking at the recent statistics supplied by the United States Department

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of Agriculture on cotton production (USDA, 2016). The production in 2012, 2013, 2014 and 2015 years was only 94, 59, 84 and 79 thousand metric tons, respectively. A host of factors may be responsible for the low yields of cotton in Ethiopia. The low soil productivity (yield per unit area) could be one of the factors for low yields. The low productivity of 265 Kg/ha of lint cotton has been reported by ICAC (2006) for whole of Ethiopia. Likewise, low productivity of 812 kg/ha of seed cotton has been reported for the Metema District of Ethiopia (Bosena et al., 2011). The interventions to increase productivity of cotton per unit area of land through proper utilization of land resource have been emphasized by them. The soil productivity, in turn, is a function of various soil-related factors influencing soil physical, chemical and biological environment for plant growth. According to information contained in a report of Agriculture Development Office (Anonymous, 2012), about 70% of the study area was under cultivation including cotton. However, little information is, presently, available to farmers and extension workers on different aspects of soil management in the study area. Therefore, this study was initiated with the objective of characterizing the soils of the area for chalking out appropriate management strategy aimed at higher cotton productivity in Arba Minch Zuria Woreda.

MATERIALS AND METHODS

Location and description of the study area

Arba Minch Zuria is one of the woredas in Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia (Figure 1). Arba Minch is located 505 km south of Addis Ababa and 278 km from the regional center, Hawasa. The area is low land in southern part of Ethiopian main rift. Its elevation ranges from 1200 masl at the northern end to 1320 masl at the southern end. It has two rift valley lakes lying closeby named Abaya and Chamo.

Asariftvalley area, it is at the foot of the western escarpment. The Gamo highland starts from the top of the escarpment. As per long-term weather information at Arba Minch Meteorological Station, the are are receives bimodal rainfall of 830.7 mm per annum, with maximum fall in the months of June, July and August. The mean minimum, mean maximum and average temperatures are 15.1,29.9 and 22.5°C, respectively. The area falls in the semi-arid moisture regime where evapotranspiration exceeds precipitation. In general, the length of growing period (LGP) of Arba Minch area is 61 days (Lemma Gonfa, 1996), implying there by that evapotranspiration is by far greater than rainfall and there is need for irrigation to grow different crops. The geology and geomorphology of the area falling in Rift Valley comprised Miocene to Pleistocene deposits (King and Brachall, 1975).

Site selection and soil sampling

The surface soil samples (0-20 cm) were collected from 30 sites in Arba Minch ZuriaWoreda representing three important cotton producing kebeles, namely Zeyse Elgo, Genta Kanchama and Shelle Mella. For each site, the composite soil sample was made from 15 sub samples taken from the representative farms. Each sub sample was further prepared by compositing soil samples taken from different points in the farm field. The site and farm selections were made in discussion with development agents and the District Agricultural Office. The disturbed soil samples were collected using auger while undisturbed soil samples were collected employing core sampler.

Analyses for physical and chemical properties

Soil particle size distribution was determined by the hydrometer method (Bouyoucos, 1962) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with

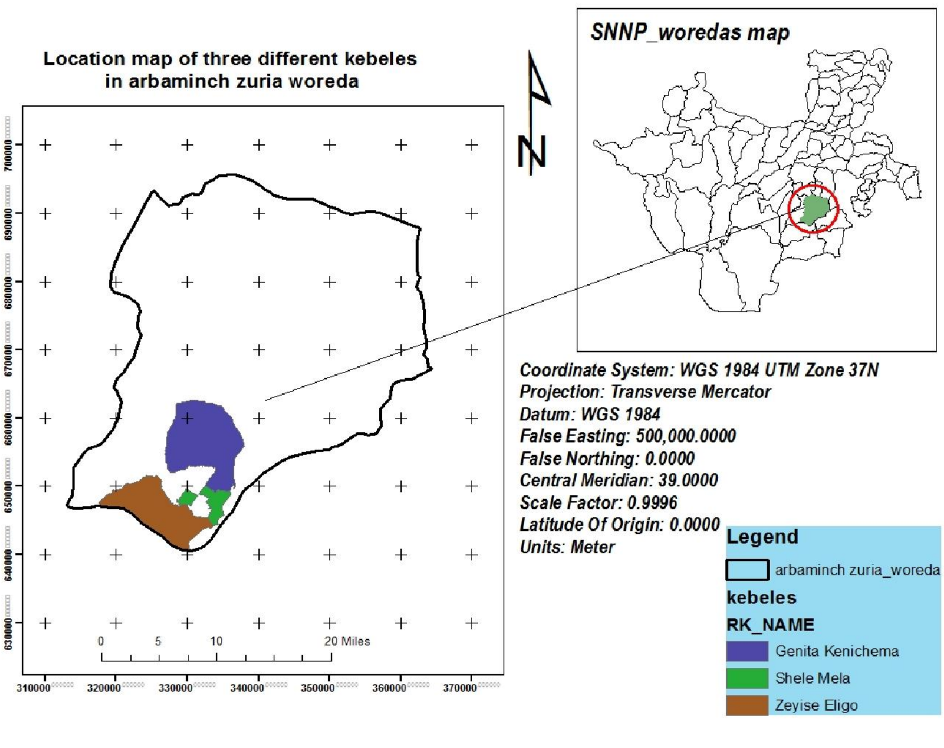

Fig.1. Location map of the study area

sodium hexametaphosphate. Soil bulk density (BD) was measured from undisturbed soil samples which were weighed at field moisture and after oven drying the pre-weighed soil core samples to constant weight (105 ^{0}C) as per the procedure described by Black (1965). Particle density (PD) was determined by the pycnometer method (Devis and Freitans, 1984). Total porosity was estimated from the bulk and particle densities as follows:

Total porosity (%) = (1- BD/PD) x 100

Soil pH was determined in a 1:2.5 soil to water suspension using pH meter (Van Reeuwijk, 1992). Electrical conductivity (EC) was determined by using 1:2.5 soils to solution ratio using EC meter as outlined by Havlin *et al.* (1999). Organic carbon (OC) was determined following the wet digestion method as described by Walkley and Black (1934). Soil organic matter (SOM) was calculated by using the expression as follows:

SOM = (% OC x 1.724)

Total N of the soil was determined through digestion, distillation and titration procedure of the Kjeldahl method as described by Jackson (1970). Available P was determined using the Olsen extraction method (Olsen and Dean, 1965). The exchangeable bases (Na, K, Mg and Ca) in the soil were determined from the leachate of a 1 M ammonium acetate (NH_4OAc) solution (pH 7) used as an extractant. Exchangeable K and Na were read using flame photometer (Rowell, 1994), whereas Ca and Mg were measured by atomic absorption spectrometry. Cation exchange capacity (CEC) was measured after leaching the ammonium acetate extracted soil samples with 10% sodium chloride solution. The amount of ammonium ion in the percolate was determined by the Kjeldahl procedure and reported as CEC (Chapman, 1965). Exchangeable sodium percentage (ESP) is calculated as the ratio of exchangeable Na to the CEC of the soil.

$$ESP = \frac{\text{Exchangeable Na}}{\text{CEC}} \times 100$$

Available Fe, Mn, Zn and Cu were extracted from the soil samples with diethylenetriaminepenta acetic acid (DTPA) as described by Lindsay and Norvell (1978). The micronutrients extracted were measured by atomic absorption spectrometry.

RESULTS AND DISCUSSION

Soil physical properties

Soil texture

Soil texture determines a number of physical and chemical properties of soils. The texture of Zeyse Elgo was silty loam and that of Genta Kanchama and Shelle Mella as silty clay loam (Table 1). The finer texture of the latter two soils was due to less proportion of sand and more of clay compared to former soil.

Bulk density, particle density and porosity

The soils of Zeyse Elgokebele had higher bulk density value (1.55Mg m^{-3}) followed by soils of Genta Kanchama (1.35Mg m^{-3}) and Shelle Mella (1.25Mg m^{-3}) kebeles (Table 1). The particle density values also followed the same trend. While soils with lower values of bulk density exhibited favourable soil conditions, the one with higher value reflected otherwise. Lower bulk density implies greater pore space which is evident by higher values of porosity for Shelle Mella (47.9 %) and Genta Kanchama (44.9%) compared to Zeyse Elgo soils (39.2%). More porosity would improve aeration, creating a better environment for biological activity. An inverse relationship between soil bulk density and porosity has been reported by Murphy (1968).

Soil chemical properties

Soil reaction (pH)

The pH of the soils varied from 8.25 to 9.10 (Table 2). The ratings of soils based on soil pH suggested by Murphy (1968) for Ethiopian soils are < 5 as very strongly acidic, 5.1 to 5.5 as strongly acidic, 5.6 to 6.0 as moderately acidic, 6.1 to 6.5 as slightly acidic, 6.6 to 7.3 as neutral, 7.4 to 7.8 as slightly alkaline, 7.9 to 8.4 as moderately alkaline, 8.5 to 9.0 as strongly alkaline and > 9 as very strongly alkaline soils. Accordingly, the Genta Kanchamakebele soils (pH 8.25) were moderately alkaline, the Zeyese Elgo soils (pH 8.90) as strongly alkaline and Shelle Mella soils (pH 9.10) as very strongly alkaline. The latter two soils with pH >8.5 could suffer due to high pH-induced deficiencies as well as toxicities of micronutrients.

Electrical conductivity (EC)

The electrical conductivity of soils, a measure of soluble salts concentration in soils, varied from 3.40 to 9.01dS m^{-1} in soils (Table 2). According to Landon (1991), EC of 4 dSm^{-1} was a critical level for most of crops. The soils having EC more than the critical level are categorized as saline soils. Accordingly, the soils of two kebeles, namely Genta Kanchama and Shelle Mella, are affected by soil salinity. Such soils are commonly found in arid and semi-arid regions of rift valley, where rainfall is insufficient to leach soluble salts below the root zone (MoA, 1995). Also the presence of salinity in the area was evidenced by the presence of white crusts of salts called as white alkali (Denise Mc-W, 2003) on the soil surface. This condition was mainly observed onsoils of Shelle Mella Kebele.

Soil organic carbon

In general, as organic matter is the main supplier of soil N, S and P in low input farming systems, a continuous decline in the soil organic matter content of the soils is likely to affect the soil productivity and sustainability**.** The organic carbon (OC) content of soils varied from 1.2 to 1.7 % (Table 2). It was highest (1.7%) in Shelle Mella followed by Genta Kanchama (1.45%) and Zeyse Elgo (1.2%). The soil OC ratings suggested by Tekalign (1991) for Ethiopian soils are OC < 0.5% as very low, 0.5 to 1.5% as low, 1.5 to 3% as medium and > 3% as high. Accodingly, the OC status of the studied soils was from low to medium. The higher SOC content in Shelle Mella soils is apparent due to higher amounts of clay, as clay particles having substantial exchange surface areas adsorb and stabilize organic matter in soils (Saggar et al., 1994, 1996). This is also in agreement with study by Ladd *et al.* (1990) who reported that soils relatively higher in clay contents tend to stabilize and retain more organic matter than those low in clay contents.

Table 1. Mean values of soil Physical properties of the surface soils (0-20cm) of kebeles of Arba Minch ZuriaWoreda

Soil property	Zeyse Elgo	Genta Kanchama	Shelle Mella
Sand fraction (%)	31	12	18
Silt fraction (%)	50	60	50
Clay fraction (%)	19	28	32
Textural Class	Silty Loam	Silty Clay Loam	Silty Clay Loam
Particle Density			
(Mg m^{-3})	2.55	2.45	2.40
Bulk Density			
(Mg m^{-3})	1.55	1.35	1.25
Total porosity			
(%)	39.20	44.90	47.90

Table 2. Mean values of chemical properties of the surface soil (0-20cm) in kebeles of Arba Minch ZuriaWoreda

Soil properties	Zeyse Elgo	Genta Kanchama	Shelle Mella
pH (H_2O)	8.90	8.25	9.10
EC(µs/cm)	340	454	901
Total N (%)	0.13	0.16	0.19
OC (%)	1.20	1.45	1.70
OM (%)	2.07	2.50	2.93
AvP (mg kg^{-1})	47.00	12.70	40.75
Na ($cmol_{(+)}$ kg^{-1})	0.25	0.36	1.00
K ($cmol_{(+)}$ kg^{-1})	2.45	1.70	2.80
Mg ($cmol_{(+)}$ kg^{-1})	15.00	18.9	15.00
Ca ($cmol_{(+)}$ kg^{-1})	34.30	34.90	27.00
ESP	0.5	0.65	2.6
CEC ($cmol_{(+)}$ kg^{-1})	45.75	55.10	38.00
PBS (%)	113	101	120
Fe (mg kg^{-1})	14.00	13.70	13.90
Mn (mg kg^{-1})	17.90	13.90	20.70
Zn (mg kg^{-1})	0.90	0.60	0.95
Cu (mg kg^{-1})	1.35	1.85	1.30

*OC = Organic carbon; AvP = Available phosphorous; EC = Electrical Conductivity; CEC = Cation exchange capacity; PBS = Percentage base

The low to medium SOC contents in the studied soils would suggest application of fertilizers to maintain sustained supplies of nutrients to the crops.

Total nitrogen

Nitrogen is one of the most deficient elements in the tropics for crop production (Mesfin, 1998). The nitrogen content of the soils was 0.13% in Zeyse Elgokebele, 0.16 % in Genta Kanchama and 0.19% in Shelle Mella (Table 2). The ratings of total N in soils given by Landon (1991) are: total N< 0.05% as very low, 0.05 to 0.12% as low, 0.12 to 0.25% as medium, and >0.25% as high. The higher content of total N in Shelle Mella soils was related with the higher OC contents in them. The total N content of a soil is directly associated with its OC content, since organic matteris the main supplier of soil N.

Available phosphorus

Phosphorus is the most limiting nutrient in tropical soils after nitrogen (Asgelil, 2000).The available P was highest (47.0 mg kg^{-1}) in Zeyse Elgokebele followed by Shelle Mella (40.7mg kg^{-1}) and Genta Kanchama (12.7mg kg^{-1}). According to Landon (1991), available soil P of < 5 mg kg^{-1} is rated as low, 5-15 mg kg^{-1} as medium and > 15 mg kg^{-1} as high. As per the ratings, the Zeyse Elgo and Shelle Mellasoils were high in available soil P, while Genta Kanchama soils were medium in available soil P. This is in contrast to the findings of Eyilachew (1987) who concluded that the majority of Ethiopian soils were low in available P due to continuous mining by crop harvest under low or no input farming practices and high P fixation capacities of the soils.

Exchangeable bases

Concentrations of exchangeable cations were generally in the order of Ca>Mg>K>Na (Table 2). This might have resulted from the strong energy of adsorption of Ca and Mg, making them more abundant as exchangeable cations than K or Na. Thus, as expected, exchangeable Ca and Mg cations dominated the exchange sites in the studied soils. Similarly, Mesfin

(1998) and Eyelachew (2001) reported that Ca and Mg cations dominated the exchange sites of most of Ethiopian soils and contributed higher to the total percent base saturation particularly in Vertisols. In the present study also while taking cognizance of the CEC values (Table 2), the exchangeable Ca and Mg contributed almost 100 percent to the total base saturation of the soils. Following the ratings of exchangeable Mg and Ca given by FAO (2006), (Mg and Ca, respectively < 0.3 and 2 $cmol_{(+)}$ kg^{-1} as very low, 0.3 to 1 and 2 to 5$cmol_{(+)}$ kg^{-1} as low, 1 to 3 and 5 to 10 $cmol_{(+)}$ kg^{-1} as medium, 3 to 8 and 10 to 20 $cmol_{(+)}$ kg^{-1} as high and > 8 and 20 $cmol_{(+)}$ kg^{-1} as very high), the soils of studied kebeles were having very high concentrations of exchangeable Mg and Ca. While the concentrations of exchangeable Ca and Mg were higher in Zeyse Elgo and Genta Kanchamakebeles compared to Shelle Mella, the reverse was the case for the exchangeable Na. However, the amounts of exchangeable Na were insignificant in all the soils, varying from 0.25 - 1.0$cmol_{(+)}$ kg^{-1}.The low values of exchangeable sodium percentage of 0.5-2.6 (Table 2) further indicated that sodicity was not a problem in the studied soils. With high exchangeable K (Table 2), all the kebele soils are adequately supplied with potassium.

Cation exchange capacity

Cation exchange capacity represents the primary soil reservoir of available K, Ca, Mg and several micronutrients. It also helps to prevent nutrients from leaching. The larger the CEC, the more nutrients the soil can supply to crops.The ratings of CEC suggested by Landon (1991) are:CEC of < 5 $cmol_{(+)}$ kg^{-1} is very low, 5 to 15 $cmol_{(+)}$ kg^{-1} is low, 15 to 25 $cmol_{(+)}$ kg^{-1} is medium, 25 to 40 $cmol_{(+)}$ kg^{-1} is high and > 40 $cmol_{(+)}$ kg^{-1} is very high. Accordingly, the CEC values ranging from 38 to 55.10 $cmol_{(+)}$ $kg^{-1}$are in high to very high range for the studied soils (Table 2). The higher CEC of soils could be attributed to more amounts of clay in the soils.Given the higher CEC, the soils have good potential to maintain the steady supply of nutrients to the crops. The CEC values in excess of 10 cmol(+) kg^{-1} have been linked with high yields in most agricultural soils and are also considered satisfactory for most crops (FAO, 2012).

Micronutrients

The concentrations of available micronutrients viz., Fe, Mn and Cu were sufficiently high in all the soils as ascertained by the ratings given for DTPA extractable micronutrients by Lindsay and Norvell (1978) and Havlin *et al.* (1999). The concentrations of Zn, however, were shown to be at the critical level. There are similar earlier reports which stated that Zn contents were variable and, Fe and Mn contents were usually at an adequate level in Ethiopian soils (Fisseha, 1992; Abayneh, 2005). Therefore, except Zn, there is no need of fertilization with micronutrients for the soils to realize higher yield potentials.

Conclusion

The cotton is grown in Ethiopia for domestic consumption as well as for exports. The level of production, however, is low due to smaller area under cultivation and low crop productivity. The soil-related constraints could be one of the factors for low productivity. There is little information, if any, on the different soil characteristics governing crop growth for the Arba Minch ZuriaWoreda, an important cotton growing area in the southern part of Ethiopia. Accordingly, study was taken up in three kebeles of woreda, namely ZeyseElgo, Genta Kanchama and Shelle Mella, to bridge up the information gap. The soil physical characteristics like texture, bulk density and porosity looked favourable for plant growth. The low to medium organic carbon and medium nitrogen status may necessitate additions of N fertilizers and organic manure to the soils. The moderate to very strongly alkaline soils showing deficiency of Zn may also require application of Zn. TheGenta Kanchama and Shelle Mellakebeles were affected by soil salinity and would require appropriate control measures. All the soils with high CEC promised good soil fertility. The soils were adequately supplied with available phosphorus, potassium, calcium, magnesium, Fe, Mn and Cu.

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