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Communication

Physicochemical characteristics of the rhizosphere soils of some cereal crops in Ambo Woreda, West Shoa, Ethiopia

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Abstract: In this study, physicochemical properties of rhizosphere soils of some cereal crops in Ambo Woreda, West Shoa in Ethiopia have been investigated. Soil samples were collected from four different localities, viz. Awaro, Senkele, Meja and Guder, and their edaphic characteristics are determined. The soils are dominated by clay (40.4-45.8%) along with coarse particles of sand. Bulk density, organic carbon (1.52-1.81%) and electrical conductivity (1.3-1.9 dSm) are low in all the soil samples. The soils are acidic with pH varying from 6.2 to 6.7. There are similarities in the relatively low content of available phosphorus (1.4-2.4 mg kg^{-1}) and high available nitrogen content (480-986 mg kg^{-1}) in all the soil samples while available potassium content (240-496 mg kg^{-1}) is found to be medium in Awaro soil but high in the other three soil samples. Deficiencies are observed in the levels of available micro-nutrients (Cu: 1.2-1.8 μg g^{-1}, Zn: 1.2-1.8 μg g^{-1} and Mn: 3.2-3.8 μg g^{-1}) while the Fe content is sufficient in all the soil samples (340-496 μg g^{-1}). With proper soil management, the farmlands studied are recommended for the cultivation of cereal crops.

Keywords: rhizosphere soil, cereal crops, nutrients, edaphic characteristics

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Introduction

The importance of soil fertility and plant nutrition to the health and survival of all life cannot be overstated. Understanding of the diversity, distribution, characteristics and processes of soil is important for agricultural development and productivity of agricultural systems. Rhizosphere, the region of soil in the vicinity of the root and under its constant influence, is a dynamic soil environment. In general, there is a higher nutrient availability in rhizosphere soil than in non-rhizosphere soil [1-2]. Soils differ widely in the ability to meet plant requirements. Most soils have moderate natural soil fertility but can be considerably improved by soil amelioration. For successful farming, the natural fertility of the soil is often less important than its potential productivity after the removal of its inherent limiting factors. Soils with high natural fertility can produce substantial crop yields without added fertilisers and can achieve even higher yields with additional supply of critical nutrients. Good soil fertility provides the basis for all other measures for successful farming.

Cereal crops such as wheat, teff, maize and corn can grow in many soil types ranging from heavy clay to almost pure peat or sandy soils. These crops require well-aerated soil in which roots and water can move easily to a certain depth. One of the basic limiting factors for cereal crop yield including that of wheat in Ethiopia is poor soil fertility. Two macro-nutrients, i.e. nitrogen and phosphorus, are deficient in most of the soils of the highland plateau [3]. According to Aydemir [4], 50% of nitrogen in the fertiliser which is applied to soil is taken by the plants in the first year. Of this, 30% is fixed by microorganisms, 15% is lost by denitrification and 5% is lost by leaching. Although the role of micro-nutrients in plant nutrition is as vital as that of macro-nutrients, under subsistence farming system like the one in Ethiopia where farmers cannot afford to buy the recommended doses of primary macro-nutrients (N, P, K), application of micro-nutrients to crops are not usually considered as a priority in alleviating soil fertility problems. Considerable variation in micro-nutrient content of soils in Ethiopia has been reported by Desta [5]. The ability of soil to supply nutrients for crop growth and maintain soil physical conditions to optimise crop yield is known to be an important component of soil fertility that determines the productivity of an agricultural system [6]. This ability of soil decreases with increase in soil erosion, which involves detachment and transportation of soil particles, exposing relatively infertile subsoil which is poor in biological and chemical processes and resulting in decreased crop production [7-8].

Gunes et al. [9] have evaluated the soil fertility status in Ankara district of Turkey for the production of cereal crops. Physicochemical properties of soils under vegetable cultivation in the highland of Cameroon have been investigated by Salubin et al [10]. The variation in the physico-chemical properties of a series of soils in south-western Nigeria has been reported by Olatunji et al [11]. Udotong et al. [12] has reported the microbiological and physicochemical properties of wetland soils in Eket, Nigeria. This communication reports the evaluation of the physicochemical characteristics of rhizosphere soils in some areas of Ambo Woreda, West Showa, Ethiopia during the dry season and their suitability for the cultivation of some common cereal crops in this area.

Materials and Methods

Description of the study site

This study is conducted on 4 locations (Awaro, Senkele, Guder and Meja) in Ambo district of West Shoa, Ethiopia, which is about 115 km from Addis Ababa, the capital city (Figure 1). About 88% of its terrain having gradients between 0.5 and 15%, which favours mechanised farming, the West Shoa zone is endowed with a high potential for agriculture. The soil samples were collected from farmlands at

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a depth of 0-15 cm during the dry-season months of October-December, 2008. The average maximum temperature in all the study areas was 29.6°C during the year of study.

Awaro is located 5 km in the eastern direction from Ambo town. It has a moderate slope and the land has been cultivated for vegetables with some grass-covered areas mainly used for the grazing of cattle. Senkele, which is about 6 km west of Ambo, has a gentle slope and the land has been used for only 3 years for the cultivation of maize. Guder, located within 7 km of the town, is a nearly flat slope and its farmland has been cultivated for 13 years primarily for maize, teff and wheat. Meja is 4 km in the southern direction of Ambo town. It has a moderate slope and has been cultivated continuously for 11 years for teff and wheat.

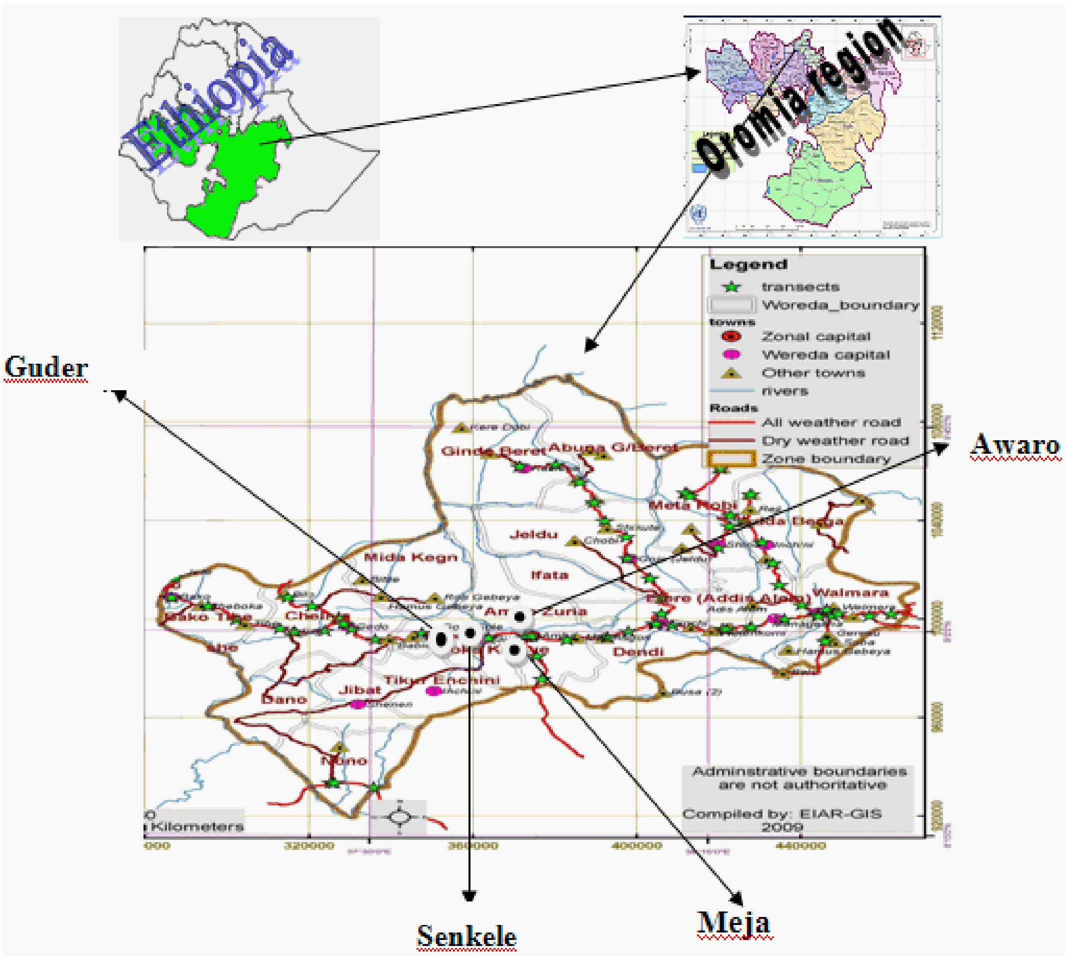

Figure 1. Location map of West Shoa zone in Oromia region of Ethiopia

Sample analysis

The soil samples were air-dried, crushed and passed through a 2-mm sieve and then mixed thoroughly to obtain a homogeneous mixture. Particle size analysis was performed using the Bouyoucous hydrometer method [13]. Soil pH and electrical conductivity were determined in a soil:water (1:2.5) mixture using a pH meter. Soil organic carbon was assessed according to Piper [14]. Moisture content, bulk density and nitrogen were determined according to the method of Jackson [15].

Available phosphorus was determined by the method of Kitson and Mellon [16] while potassium was determined by a flame photometer. Other nutrients, viz. copper, iron, manganese and zinc, were analysed by an atomic absorption spectrophotometer (Unicam 919). All results were presented as an average of five determinations (n=5) ± standard deviation (SD).

Results and Discussion

Physicochemical characteristics of the soil samples are presented in Table 1. The particle size reveals the texture of the soils as varying from clay loam to red and black clay loam with sand, silt and clay fractions ranging between 30.7-34.2%, 24.5-28.6% and 40.4-45.8% respectively. The characteristics of a soil largely determine its utilisation [17]. From this result, the texture of the soils under investigation can be classified as loam with excellent properties for crop cultivation. The moisture content of all soils is similar except for Meja soil, which has a slightly lower moisture content (8.5%). The soil pH, which varies from 6.2 to 6.7, lies within the preferred range for most crops.

The fertility of soil is intimately linked with its organic matter which has an influence on the physical, chemical and biological properties of the soil. It is well known that under continuous agricultural practice, the organic matter content in the top soil will decrease. The organic carbon content in all studied soil samples is found to be very low (< 4%). This may be attributed to intensive agricultural practices that aggravate organic carbon oxidation [18]. The bulk density of the studied soils is found to be equal or less than 1.44, which is common in cultivated soils. The low bulk density found in soils from Senkele, Meja and Guder indicates that the soils are not compacted and have more porosity. This is beneficial to root activity, water infiltration into soil, and overall growth of crops. The high bulk density of Awaro soil (uncultivated) is unexpected since the bulk density is generally inversely correlated with organic matter content. Soil with very high bulk density can limit root growth, air circulation and availability of less mobile essential plant nutrients such as P and K [19]. The electrical conductivity values of the saturated extracts of the four soil samples can be classified as Index 0 in the ADAS recommendations [20]. This means that they are within the normal range found for outdoor soils and pose no restriction for field-crop cultivation nor adversely affect crop yield.

The available major nutrients in the soil samples are presented in Table 2. Of all the major nutrients, phosphorus probably has the most complicated chemistry in the soil, at least as far as the assessment of its level and of the fertiliser requirement for it are concerned. Phosphorus occurs in soil in both organic and inorganic forms, the latter being more important for crop nutrition. A low available phosphorus is indicative of acute deficiency. There is a similarity among all the soil samples in a very low phosphorus level which falls between Index 0-1 category [20]. At this level, there is a possibility of failure of arable crops if there is no further application of P fertiliser. The cultivated soils of Senkele, Meja and Guder have a slightly higher phosphorus content than that in the uncultivated Awaro soil. The difference could be accounted for by the P fertiliser application over the years in the cultivated areas. The nitrogen content in all the soils is high, ranging between 460±6.5 - 986±5.2 mg Kg^{-1}. The main source of both N and P in the farmlands is organic matter.

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Table 1. Physicochemical properties of rhizosphere soils of Ambo Woreda

Soil property	Awaro	Senkele	Meja	Guder
Sand (%)	34.2 ± 0.05	32.4 ± 0.02	30.7 ± 0.06	32.8 ± 0.02
Silt (%)	26.5 ± 0.02	24.6 ± 0.04	28.6 ± 0.04	24.5 ± 0.06
Clay (%)	40.4 ± 0.05	44.5 ± 0.05	43.7 ± 0.02	45.8 ± 0.04
Moisture (%)	10.6 ± 0.05	9.5 ± 0.04	8.5 ± 0.04	10.8 ± 0.05
pH	6.2 ± 0.04	6.4 ± 0.05	6.7 ± 0.02	6.2 ± 0.05
Electrical conductivity (dSm^{-1})	1.3 ± 0.02	1.6 ± 0.02	1.9 ± 0.02	1.8 ± 0.02
Bulk density ($g\ cm^{-3}$)	1.44 ± 0.05	0.84 ± 0.02	1.24 ± 0.04	1.27 ± 0.06
Organic carbon (%)	1.81 ± 0.02	1.66 ± 0.02	1.52 ± 0.04	1.62 ± 0.05
Textural class	Clay loam	Clay loam	Red clay loam	Black clay loam

Table 2. Available macro- and micro-nutrients in the rhizosphere soils of Ambo Woreda

Location	Macro-nutrient ($mg\ kg^{-1}$)			Micro-nutrient ($\mu g\ g^{-1}$)			
	N	P	K	Cu	Zn	Mn	Fe
Awaro	480 ± 6.5	1.4 ± 0.2	240 ± 3.2	1.2 ± 0.02	1.3 ± 0.04	3.8 ± 0.2	60.2 ± 0.8
Senkele	645 ± 4.6	1.6 ± 0.4	340 ± 4.4	1.8 ± 0.02	1.4 ± 0.04	3.4 ± 0.4	96.5 ± 0.8
Meja	648 ± 5.2	1.8 ± 0.02	395 ± 4.8	1.6 ± 0.02	1.2 ± 0.02	3.2 ± 0.06	98.4 ± 1.6
Guder	986 ± 5.2	2.4 ± 0.08	496 ± 4.8	1.6 ± 0.04	1.8 ± 0.02	3.6 ± 0.04	108 ± 1.8

Available potassium content is medium (240±8.2 mg Kg^{-1}) in the Awaro soil but high in the other three soil samples (>281.6 mg Kg^{-1}) [21], which could be attributed to the continuous use of animal waste (farmyard manure) for several years in those three locations. According to the farmers, good yields are obtained for maize and corn crops in both Senkele and Meja farms. Similarly, wheat yield obtained from Guder is also good, although its maize yield is poor.

The availability of trace elements for plants is influenced by many soil and environmental factors as reported by Jones [22]. The concentrations of Cu, Zn, Mn and Fe in all the soil samples indicate deficiencies in Cu, Zn and Mn (Table 2). Available Fe content (60.2±0.8 - 108 ±1.8 $\mu g\ g^{-1}$) in all the soil samples is considered sufficient [22]. As reported by Sillanpaa [23], total Cu content in soil generally falls in the range of 2-100 ppm. The strong interaction which is generally held to occur between Cu and soil organic matter does not affect Cu availability to plants, although it does influence

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the concentration of Cu in soil solutions [24]. From the above results, Cu level is low in all the soils as compared to the critical value given for Nigerian sandy soil [25-26]. This is in agreement with the conclusion made based on the assessment of Ethiopian soils [27]. Cereal plants such as wheat and maize are particularly sensitive to Cu deficiency. The low Cu content (<2ppm) in the soils may account for the poor yield in maize crops experienced in the Guder farmland.

A wide range of crops are sensitive to Mn deficiency, which is common in calcareous soils and soils of high pH. In soil, Mn originates primarily from the decomposition of ferromagnesium rocks and its content varies from 20 to 10,000 ppm with an approximate mean of 1,000 ppm as reported by Lindsay [28]. The deficiency in Mn observed in the studied soil samples may be attributed to the low organic carbon content, the mildly acidic soil pH and the potential adsorption of Mn on Fe or aluminum oxide present in the soils [29].

Plants vary in their zinc requirement as well as their ability to extract zinc from soil. Cereal crops such as maize are sensitive to Zn deficiency. The usual range of Zn in soil (1-900 ppm) with an approximate mean of 90 ppm has been reported by Davies [30] and Fairbridge and Finkl [31]. On the other hand, total zinc content in soil generally falls within the range of 10 to 300 ppm according to Sillanpaa [23]. From Table 2, a very low level of Zn is obtained for all the soil samples. Zn availability is mainly related to pH and complexation, and as pH increases organically-bound Zn decreases, which could be responsible for the apparent Zn deficiency in the soil samples [32].

Conclusions

The physicochemical characteristics of Ambo Woreda rhizosphere soils of some cereal crops have been determined. Results show that two macronutrients (N, K) are found optimal while available P is deficient for major crops such as maize, wheat, teff and corn grown in the area. In order to obtain optimal yield for the cereal crops in the farmlands studied, therefore, the deficiencies in the available P and micronutrients (Cu, Zn and Mn) along with the low organic carbon content of the soils should be remedied by appropriate soil management through improved drainage and application of minerals and organic fertilisers.

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