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Soil characterization and evaluation of blended (YaraMila cereal) fertilizer for bread wheat (*Triticum aestivum* L.) production at Aleltu areas in North Shewa Zone of Oromia region

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The main objective of the study was to characterize the soils on the basis of selected soil physicochemical properties and to evaluate the effects of blended fertilizer (YaraMila cereal) applications on yield and yield components of bread wheat on the major soil types in the study area. The field experiment involved 5 treatments (control, three rates of blended fertilizer and recommended nitrogen and phosphorus fertilizers) laid down in randomized complete plot design with three replications. Soil samples were collected from the experimental field before planting and from 2 freshly opened soil profiles to study selected soil physicochemical properties. The results showed that the textural classes for both profiles were clay. The bulk density of the surface composite soil for sites was 1.18 g cm^{-3} and that of profiles increased consistently with depth. The particle density value of the surface composite soils was 2.31 g cm^{-3}. The pH value of the composite surface soils was neutral and increased with profile depth. Low organic matter and total nitrogen, very low to high available phosphorus (0.06 to 19.17 mg kg^{-1}) and very high available potassium, cation exchange capacity and percent base saturation was obtained at the experimental site. The applied fertilizers significantly influenced most of the crop parameters. The grain yield (4383.3 kg ha^{-1}) was obtained due to the application of the highest rate of blended fertilizer while the minimum was from the control.

Key words: Soil, composite soils, profiles.

INTRODUCTION

No single resource is more important in achieving a sustainable agriculture than the soil which contains essential nutrients, stores the water for plant growth and provides the medium in which plants grow (FAO, 1998). However, the total quantity and particularly plant availability of the essential nutrient elements (soil fertility) is a complex quality of soils that is closest to plant nutrient management. It is the component of the overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own

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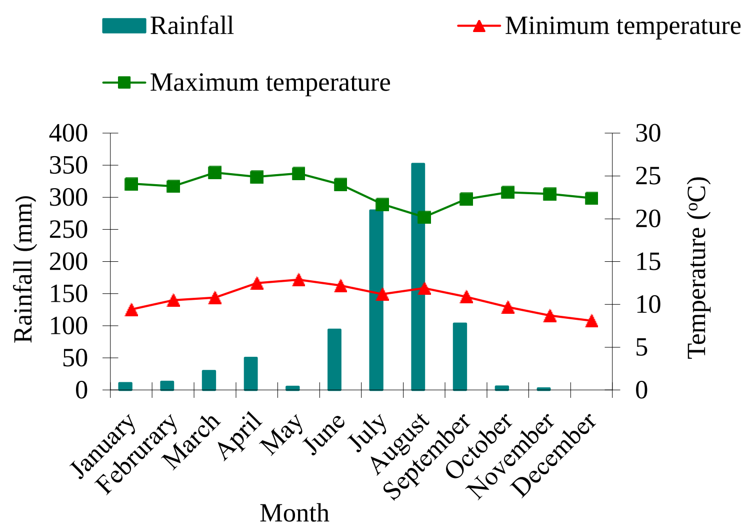

Figure 1. Monthly total rainfall, and mean maximum and minimum temperatures at the study area during the 2013.

reserves and through external applications for plant growth and production. It combines several soil properties (biological, chemical and physical), all of which affect directly or indirectly nutrient dynamics and availability.

Soil nutrient depletion and related low agricultural productivity are serious problems particularly in small scale farmers of sub-Saharan Africa and most other developing countries (Tilahun et al., 2001). In a study on soil nutrients balances at national and regional level, Haileslassie et al. (2005) reported large variations in the nutrient balances of different cropping systems, ranging from nutrient accumulating systems (e.g. enset, *Ensete ventricosum*) to nutrient depleting including cultivation of most cereals (e.g. teff, *Eragrostis tef*) with strongly negative nutrient balances.

In Ethiopia, soil fertility is one of the factors limiting the yield of crops, including wheat. It may be caused as result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farm land, and lack of proper crop rotation program (Tamire, 1982). Micronutrients like zinc (Zn) and boron (B) and secondary nutrients like sulfur (S) are needed in small quantities by crops but are as important as nitrogen (N), phosphorus (P) and potassium (K) for plant growth and increasing the quality and quantity of crop yields. Insufficient soil micronutrients is affecting both crop yield and produce quality and it is partly responsible for decreasing efficiency of N, P and K fertilizers. In rainfed areas, in spite of subsistence agriculture over a long period, soils are depleted not only major nutrients but also micro-and secondary nutrients (FAO, 2006).

Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa. Wheat is one of the major cereal crops in the Ethiopian highlands that lie between latitude 6 and 160 north and longitude 35 and 420 east and is widely grown from 1500 to 3000 m.a.s.l. The most suitable areas for wheat production, however, fall between 1900 and 2700 m.a.s.l (Hailu, 1991). Wheat is the 4th most important crop in both the total area and in production in Ethiopia (CSA, 2012). The high yield levels obtained in cereal crops on many highly productive soils are a result of suitable crop growth conditions, optimal and balanced nutrient management and adoption of best management practices (FAO, 2006).

In Ethiopia, application of micronutrient containing fertilizers is not a common practice and experiment has not been conducted on these fertilizer rates and the response of wheat crop to their application. Therefore, pre-assessment of crop response to these fertilizers is required for development of their optimal recommendation rates. Thus, this study was initiated to characterize the soils at the Aleltu area on the basis of selected soil physicochemical properties and to evaluate the effects of blended fertilizer (YaraMila cereal) applications on yield and yield components of bread wheat on the major soil types in the study area.

MATERIALS AND METHODS

The study was conducted during the 2013 main cropping season under rain fed conditions at Maru kebele of farmers' fields in Aleltu District, North Shewa Zone of Oromia Regional State. Aleltu is located in the central highlands of Ethiopia at about 55 km north of Addis Ababa on the main road to Mekelle. Geographically, this area is situated at 9° 19′ 43″ to 9° 4′ 43″ north east latitude and 39° 16′ 16″ to 39° 1′ 16″ east longitude. The altitude of the District ranges between 2200 and 2900 masl. The study area is characterized by a unimodal rainfall pattern. The average annual rainfall ranges from 800 to 1170 mm (Figure 1). Based on color, the soils of the study area are black soil covering 21%, red soil 20% and brown soil 59%.

Mixed crop-livestock production system is the common farming system in the District.

Experimental materials, treatments and design

The experiment comprised of 5 treatments namely 0, 135.5 kg YaraMila cereal + 22.4 kg urea, 271.0 kg YaraMila cereal + 45 kg urea, 406.5 kg YaraMila cereal + 67.4 kg urea of YaraMila cereal fertilizer (16-17-17 N-P_2O_5-K_2O + 4.5 S + 0.25 B_2O_3 + 1 Zn) and combined recommended rates of N (64 kg N ha^{-1}) and P (46 kg P_2O_5 ha^{-1}) fertilizers. The field experiment was laid down in a randomized complete block design with three replications. Plot size was 4 m × 2.4 m (9.6 m^2). During the different growth stages of the crop, the necessary cultural and recommended agronomic management practices were all carried out.

Agronomic and yield data collection

Days to heading were recorded by counting the number of days required for the expression of the particular phonological stage. Similarly, days to physiological maturity were recorded as the number of days elapsed from planting until when 90% of the plants within a plot have physiologically matured; grain filling period was computed as the difference between the number of days to heading and number of days to maturity. Plant height was measured from 10 randomly taken plants at late flowering stage; number of fertile tillers was recorded at the late flowering stage from 0.5 m row length at two random spots in the sampling rows and then extrapolated for the total number of plants in the net plot area. The numbers of spikes per 6 m^2 was counted at maturity by taking the total number of spikes or ears from 0.5 m row length within the middle two rows of the net plot. The number of spikelets per spike and spike length were recorded as average values over 10 spikes taken randomly from the net plot.

At physiological maturity, the plants in the net plot area of each replication was harvested and left in open air for about 10 days until it attains a constant weight before threshing and then weighed for the determination of straw yield by subtracting the grain yield per plot. Grain yield was determined from the net harvested plot area after harvesting and threshing and after adjusting the grain moisture content to 12%.

Surface soil and profile sampling and sample preparation

Two soil profile pits (1 m width, 1.5 m length and 1.8 m depth) were opened at the experimental site for laboratory characterization of soil physical and chemical properties and before sowing, surface soil samples (0-15 cm depth) were collected for soil fertility evaluation.

Soil particle size distribution (texture) was analyzed by the Bouyoucos hydrometer method. Bulk density was determined from the undisturbed (core) soil samples collected using core samplers, weighed at field soil moisture content and then dried in an oven at 105°C to a constant weight (Baruah and Barthakur, 1997). Similarly, particle density was measured by the Pycnometer method. Finally, soil total porosity was estimated from the bulk density (BD) and particle density (PD) values as:

$$\text{Total porosity (\%)} = \left(1 - \frac{\text{BD}}{\text{PD}}\right) \times 100$$

Soil pH was measured in 1: 2.5 soil to water ratio. The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon. Similarly, total N was analyzed using the Kjeldahl digestion and distillation method. Available P was carried out by the Olsen method. Available Zn was extracted with the DTP.

The exchangeable bases (Ca, Mg, K and Na) in the soil were determined from the leachate of 1 molar ammonium acetate (NH_4OAc) solution at pH 7.0. Cation Exchange Capacity (CEC) was measured after leaching the ammonium acetate extracted soil samples with 10% NaCl solution and determining the amount of ammonium ion in the percolate by the Kjeldahl procedure and reported as CEC (Hesse, 1972). The percent base saturation (PBS) was computed as the percentage of the sum of the exchangeable bases to the CEC of the soil: Finally, the fertility statuses of the soils of the experimental fields (study areas) were evaluated by comparing the values or concentrations of the respective parameter obtained from the laboratory analyses (both physical and chemical properties) with established ratings and/or critical levels for different classes of the respective soil parameter.

Statistical analysis

The yield and crop agronomic data were subjected to analysis of variance (ANOVA) appropriate to randomized complete block design using SAS software program (SAS Institute, 2000). The analysis result of the soil was interpreted using descriptive statistics. When significant differences were observed, comparisons of means were performed using the least significant difference (LSD).

RESULTS AND DISCUSSION

Characterization of the soils of study area at Aleltu

Soil physical properties

Soil texture: The data in Table 1 showed that the mean particle size distribution of the composite surface (0 to 15 cm) soil sample was clay loam although there were variations among the values of sand, silt and clay contents of the blocks. Moreover, the textural class for the profiles opened in both profiles and throughout their depths was clay (Table 1). This differentiation in the relative distribution of clay content with depth may be attributed to the variability in the degree of weathering, parent material and soil erosion and deposition of eroded sediments.

Bulk density, particle density and total porosity**:** The mean bulk density value of the composite surface (0-15 cm) soil samples was 1.18 g cm^{-3} (Table 1). However, the bulk density values of both soil profiles opened increased consistently with increasing soil depth. The relatively lower bulk density values at the surface composite soil samples and the surface layers of the profiles could be due to OM content (Table 1) which led to the relatively higher total porosity. While the highest bulk density at thebottom subsurface layers of both profiles could be due to compaction caused by the weight of the overlying soil material, reduced root penetration and relatively lower OM contents than the overlying layers (Brady and Weil, 2002). However, the bulk density values of the soils studied were within the ranges

Table 1. Selected physical properties of the soil profile and composite surface soil samples of the study area

Depth (cm)	Particle size (%)			Textural class	BD (g cm^{-3})	PD (g cm^{-3})	TP (%)
	Sand	Silt	Clay				
Profile 1							
0-35	19	17	64	Clay	1.33	2.27	41.40
35-80	13	19	68	Clay	1.34	2.41	44.81
80-180^{+}	23	37	40	Clay	1.47	2.51	41.40
Composite surface (0-15 cm) soil samples before planting							
Block 1	16	23	61	Clay	1.14	2.30	50.40
Block 2	40	37	23	Loam	1.21	2.31	47.60
Block 3	50	19	31	Sandy clay loam	1.20	2.32	48.30
Mean	35.3	26.3	38.3	Clay loam	1.18	2.31	48.90
Profile 2							
0-50	11	21	68	Clay	1.28	2.35	45.53
50-120	15	13	72	Clay	1.33	2.34	43.16
120-185	19	15	66	Clay	1.48	2.35	37.00

BD= Bulk density; PD = Particle density; TP = Total porosity.

reported by Brady and Weil (2002) for agricultural and/or mineral soils which is in the range of 1.0 to 1.65 g cm^{-3} and by Miller and Donahue (1995) who reported that for good plant growth, the bulk densities should be below 1.4 and 1.6 g cm^{-3} for clay and sandy soils, respectively.

The mean particle density value of the composite surface (0-15 cm) soil samples of the experimental site was 2.31 g cm^{-3} (Table 1). The values of particle density of the profile 1 increased consistently with depth. However, the particle density at profile 2 did not show consistent relationship with soil depth. Generally, the particle density values measured for the composite surface soils of experimental field and that of both soil profiles studied were lower than the commonly quoted standard average value (2.65 g cm^{-3}) for mineral soils worldwide.

The mean total porosity of the composite surface (0-15 cm) soil samples was 48.9%. However, the values of total porosity of the profile 1 did not show consistent relationship with soil depth however, at profile 2, it decreased consistently with increasing depth. The relatively lower (37.00%) and higher (48.9%) total porosity values were observed at the bottom (120-185 cm) subsoil layer of profile 2 and the mean composite surface soil samples of the experimental site, respectively. Thus, higher values of total porosity may be due to the relatively lower bulk density values and for the lower values could be the relative higher bulk density value observed at this layer. Hence, the value of total porosity lies almost in the usual range (30 and 70%).

Soil chemical properties

Soil pH: The pH of a soil is one of the most important properties influencing plant growth and production as it affects ion exchange capacity and nutrient availability. The mean pH value of the composite surface (0-15 cm) soil samples was neutral (pH = 7.00) for the experimental sites, as per the classification set by Tekalign (1991). On the other hand, the pH values of both profiles increased consistency with increasing depth ranging. Generally, increase in pH with increasing profile depth in both profiles could be increase in basic cations with depth and hence, percent base saturation. The increase in basic cations concentration with depth, in turn, may suggest the existence of downward movement of these constituents within the profile.

Organic matter: The mean soil organic matter (OM) content of the composite surface (0-15 cm) soil samples of experimental site was 1.13% (Table 2). On the other hand, the OM content of both profiles decreased consistently (Table 2). According to the OM content rating established by Tekalign (1991), the mean composite surface (0-15 cm) soil sample, surface layers of both profile with OM content of 1.6 and 2.12% and the upper subsoil layer with OM content of 1.58% at profile 2 could be rated as low while the remaining subsurface layers of both profiles and field experimental site fall under the very low soil OM content category.

The reasons for the very low content of organic matter (OM) could be intensive cultivation of the land and the total removal of crop residues for animal feed and source of energy. Moreover, there is no practice of organic fertilizers' addition, such as farmyard manure and green manure that would have contributed to the soil OM pool in the study area. Generally, the findings of the present study are in agreement with Yihenew (2002) who stated that most cultivated soils of Ethiopia are poor in their OM

Table 2. Selected soil chemical properties of the soil profiles and composite surface soils of the study areas.

Depth (cm)	pH (H_2O)	OM (%)	Total N (%)	AP (mg kg^{-1})	AK (mg kg^{-1})	Exchangeable bases and CEC (cmolc kg^{-1}) Ca	Mg	K	Na	CEC	PBS	Ex. Zn (mg kg^{-1})
Profile 1												
0-35	6.3	1.60	0.180	4.18	ND	50.03	10.61	0.61	0.00	57.42	106.7	1.740
35-80	8.0	0.62	0.080	1.92	ND	58.99	10.15	0.70	0.00	54.50	128.0	1.910
80-180$^+$	8.1	0.18	0.020	1.60	ND	59.04	9.26	0.64	0.00	46.66	147.8	0.640
Composite surface (0-15 cm) soil samples before planting												
Block 1	7.0	1.16	0.074	7.40	375.00	40.21	11.83	0.96	0.00	39.01	135.8	0.490
Block 2	7.1	1.13	0.073	6.72	371.45	41.64	10.81	0.95	0.35	40.72	132.0	0.410
Block 3	6.9	1.10	0.074	8.06	340.17	42.01	14.01	0.87	0.00	43.26	131.5	0.550
Mean	7.0	1.13	0.073	7.39	362.20	41.28	12.21	0.92	0.11	40.99	133.0	0.483
Profile 2												
0-50	6.6	2.12	0.180	4.64	ND	40.44	10.28	0.55	0.00	57.55	89.0	1.370
50-120	7.7	1.58	0.110	0.98	ND	46.64	10.18	0.59	0.00	61.51	93.0	1.490
120-185	7.9	0.57	0.040	0.06	ND	49.44	10.41	0.73	0.00	55.60	109.0	1.100

OM = Organic matter; AP = Available phosphorus; AK = Available potassium CEC = Cation exchange capacity; PBS = Percentage base saturation; Ex. Zn = Exchangeable Zinc; ND = Not determined.

contents due to low amount of organic materials applied to the soil and complete removal of biomass from the field for various purposes.

Total nitrogen: The mean total N content of the composite surface (0-15 cm) soil samples was 0.073% at the experimental sites (Table 2). The concentrations of total N in both profiles decreased consistently with increasing depth (Table 2). As per the classification of Tekalign (1991), the surface layers of both profiles with total N of 0.18% could be rated as medium while the subsurface layers of the soil of both profiles fall under the low total N category. Thus, the low total N contents indicate that the soils of the study area are deficient in nitrogen to support proper growth and development of crops, which confirms that the site must be fertilized with external nitrogen inputs. Furthermore, other research works (Tekalign et al., 1988; Mesfin, 1998; Eylachew, 1999, 2000; Engdawork, 2002; Mohammed, 2003) done in Ethiopia on Vertisols also indicated that N is the most deficient nutrient element than any other essential element in these soils and has called for the application of inorganic fertilizers and need for a sound management of soil OM through addition of organic fertilizers sources.

Available phosphorus: The mean soil available P content of the composite surface (0-15 cm) soil sample value was 7.39 mg kg^{-1} at the experimental site (Table 2). However, the available P content of both profiles displayed a decreasing pattern with depth. The relatively lower values of available P (0.98 and 0.06 mg kg^{-1}) contents were obtained at the upper subsoil layer and bottom subsurface layer at profile 2 while the highest (7.39 mg kg^{-1}) of available P was obtained at the mean composite surface soils. Tisdale et al. (2002) have indicated that for Olson extractable P below 3 mg kg^{-1} is considered as very low; between 4 and 7 mg kg^{-1} as low; between 8 and 11 mg kg^{-1} medium as and greater than 12 mg kg^{-1} as high. Thus, the available P content of the mean composite surface soil sample and the surface layers of both profiles could be rated as low. While the remaining subsurface layers of the soil of both profiles could be rated as very low soil available P.

In line with the available P contents of the profiles, observed in this study, Tekalign et al. (1988) reported that topsoil P is usually greater than that in subsoil due to sorption of the added P, greater biological activity and accumulation of organic material on the surface. Mulugeta (2000) also indicated decrease in P content with depth due to fixation by clay and Ca, which were found to increase with profile depth. Also the generally low and very low contents of available P contents in the soils at the study sites could be due to losses through crop harvest and erosion which are characteristic features of agricultural soils in the tropics.

Generally, the available P status of the soils of both the profiles and surface soil of the experimental plots at the experimental site, are very low, even below the critical level (8.5 mg kg^{-1}) indicating that soil P infertility is among the factors that are highly limiting the productivity of the

Table 3. Days to 50% heading, days to 90% maturity and grain filling period of wheat.

Treatment (kg ha^{-1})*	Days to 50% heading	Days to 90% maturity	Grain filling period
Blended 406.5 + 67.4 urea	68.00^{d}	121.00^{d}	53.00^{c}
Blended 271 + 45 urea	68.00^{d}	121.00^{d}	53.00^{c}
Blended 135.5 + 22.4 urea	74.00^{b}	132.00^{c}	58.00^{b}
Recommended urea + TSP	76.00^{b}	133.66^{b}	57.00^{b}
Control	83.00^{a}	143.66^{a}	61.00^{a}
LSD (0.05)	2.58	1.52	1.89
CV (%)	1.90	0.61	1.78

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least Significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

soils. From this observation, it could even be said that available P was highly deficient and it is probably the first limiting nutrient in the study area. In agreement with this observation, many researchers (Harrison, 1987; Warren, 1992; Buehler et al., 2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils.

Available potassium: The mean value of available K of the composite surface (0-15 cm) soil samples was (362.2 mg kg^{-1}) observed at the experimental site (Table 3). According to classification set by Jones (2003), the mean available K values of the surface composite soil samples (362.2 mg kg^{-1}) could be rated as very high. Generally, the available K contents measured for the soils studied indicated that the soils of the study sites are rich in available K. Thus, K could not be considered as a factor inducing low soil fertility and application of K containing fertilizer is not necessary at least for the time being in the soils of the study area. The result obtained for exchangeable K agrees with the common idea that Ethiopian soils are reach in K.

Cation exchange capacity (CEC): Cation exchange capacity (CEC) value of the mean composite surface (0-15 cm) soil samples was 40.99 cmolc kg^{-1}, (Table 2). On the other hand, the CEC values of the profile 1 decreased consistently with increasing soil depth while did not show consistent relationship with soil depth at profile 2. The relatively lower (40.99 cmol$_c$ kg^{-1}) and higher (61.51 cmol$_c$ kg^{-1}) CEC values were measured at the surface soils and the upper subsoil layer at the experimental sites and at the profile 2, respectively (Table 2).

According to the rating of CEC established by Hazelton and Murphy (2007), CEC values of the surface soils and throughout the profile depths could be classified as very high. The consistent decline of CEC with increasing profile depth at profile 1 may be due to the parallel consistent decline in organic matter content and due to the lower clay contents in the subsurface than in the surface soils.

In line with the findings of the current study, Eylachew (2000) reported that Vertisols identified at Wonji, Ginchi, Sheno and Alemaya areas were found to have high CEC values commonly ranging from 37 to 67 cmolc kg^{-1}. Moreover, Fisseha (1992) reported CEC values ranging from 50 to 73 cmolc kg^{-1} for the Vertisols at Shoa Robit areas. Although the OM content of the soil is low, the amount and type of clay might have been very important in contributing to the very high CEC observed in the soils of the study areas. Moreover, overestimation of Ca in the exchange site due to the dissolution of calcite ($CaCO_3$) as a result of the use of NH_4OAc (pH 7.0) as an electrolyte in CEC determination has also apparently contributed appreciably to the measured quantities of CEC in the soils. The high values of CEC offer high buffering capacity to the soil as described by Mohammed et al. (2005).

Exchangeable bases and percent base saturation: According to the classification of exchangeable bases set by FAO (2006), the mean exchangeable Ca and Mg contents of the composite surface soils as well as both profiles studied are classified as very high. Similarly, based the same rating, the exchangeable K contents of the surface and the upper subsoil layer of profile 2 could be rated as medium while the mean value of K of the composite surface soils and the subsurface layers of the soil profiles could be classified as high. In the current study, exchangeable Ca followed by Mg was the predominant cation in the exchange sites of the soil colloidal materials. In summary the concentrations of the basic cations in the exchange sites of the soils studied were in the order of Ca > Mg > K > Na based on their means in composites surface soil samples as well as in the profile of both sites. Mesfin (1998) and Yihenew (2002) also reported a similar order (Ca > Mg > Na > K) for Alfisols of Debre Markos and Bahir Dar area, and for different major soil groups of Adet Research Center and its testing sites, respectively.

According to the classification by Hazelton and Murphy (2007), the percent base saturation (PBS) content of all soils studied were very high and varied from 89.0 to 147.8% and considering the surface soil profiles depths (Table 3). This could be attributed to the very high contents of exchangeable Ca and Mg which apparently have been overestimated by including contents from Ca and/or Ca/Mg carbonates dissolved in the process of extraction.

Zinc (Zn): Micronutrients are required in trace amounts but they are as essential as the macronutrients in the soil and highly indispensable for the productivity of soils. The mean value of Zn in the composite surface (0-15 cm) soils was 0.483 mg kg^{-1} for the experimental site (Table 2). The available Zn contents of both profiles varied inconsistently with soil depth.

According, to the classification of Jones (2003), the available Zn contents of the mean composite surface soil samples of the experimental field could be rated as low while that of both profiles could be rated as high except for the bottom subsurface layer at profile 1 with 0.64 mg kg^{-1} which could be rated as medium soil available Zn. The reason for the low available Zn content could be continuous cultivation of the field which led to removal of zinc without external application.

Response of wheat to the applied fertilizers

Wheat phenology

The results of wheat phenological stages showed that the applied fertilizers had significant effect ($P \leq 0.01$) on days to 50% heading, days to 90% maturity and grain filling period (Table 6). As a result significant variation in number of days to heading was observed due to applied fertilizers at the experimental site. However, application of the higher (406.5 kg ha^{-1} blended + 67.4 urea kg ha^{-1}) and the recommended (271 kg ha^{-1} blended + 45 kg ha^{-1} urea) rates of blended (YaraMila cereal) fertilizer hastened days to heading as compared to the plots which received 135.5 kg ha^{-1} blended + 22.4 kg urea and recommended N + P rates and the control plots (Table 3).

Accordingly, application of the higher and recommended rates of blended fertilizer reduced days to heading by 15 days as compared with the control (Table 3). Thus, in the plots that received higher and recommended rates of blended fertilizer, the wheat crop took shorter period to reach days to heading. This may be due to the higher content of nutrients and presence of macro and micronutrients in the blended fertilizer.

The number of days to 90% physiological maturity also showed significant ($P \leq 0.01$) differences due to the applied treatments (Table 6). The maximum and minimum days to 90% physiological maturity were observed at the higher and recommended rate of blended fertilizer and the control plots, respectively (Table 3). Accordingly, application of the higher and the recommended rates of blended fertilizer decreased days to maturity by 22.7 days over the control (Table 3).

Similarly, the applied fertilizers resulted in significant ($P \leq 0.01$) differences on grain filling period (Table 6). Moreover, there was statistical difference in grain filling period between the means of the blended fertilizer rates and recommended N + P fertilizer. However, the wheat plants which received the highest and the recommended rate of the blended fertilizer reach grain filling period faster than with the lower rate of the blended, recommended N + P and the control plots (Table 3).

Wheat growth parameters

The effect of applied fertilizers on plant height was found significant at experimental site (Table 3). However, there was no statistical difference between the rates of blended and NP treatment means. Although the minimum (28.58 cm) and maximum (72.93 cm) plant height was obtained from the higher rate of blended fertilizer and the control plot, respectively. These maximum plant heights observed might be due to higher nutrient content of the fertilizer.

Number of fertile tiller per plant responded significantly ($P \leq 0.01$) to the applied fertilizers at the experimental site, application of the higher (406.5 blended + 67.4 urea kg ha^{-1}) rate of blended fertilizer and the recommended N + P fertilizers increased the number of fertile tillers per plant by 248 and 117%, respectively, over the control (Table 4).

Wheat yield and yield components

Number of spikes per meter square, spikelets per spike and spike length

The analysis of variance showed that the applied fertilizers had significant ($P \leq 0.01$) influence on the number of spikes per m^2 (Table 6). the highest and the-recommended rates of blended fertilizer resulted in the highest number of spikes (472 and 464 m^{-2}), respectively and the lowest number of spikes (240 m^{-2}) was obtained from the control plot indicating an increment of 97 and93% over the control plot (Table 5). Spike length and spikelets per spike were not significantly ($P > 0.05$) affected by the applied fertilizers at the experimental site (Table 5).

Table 4. Plant height and Number of fertile tillers per plant of wheat

Treatment (kg ha^{-1})*	Plant height (cm)	Number of fertile tillers per plant
Blended 406.5 + 67.4 urea	72.93^{a}	4.52^{a}
Blended 271 + 45 urea	70.78^{a}	3.78^{b}
Blended 135.5 + 22.4 urea	65.60^{a}	2.80^{c}
Recommended urea + TSP	66.02^{a}	3.00^{c}
Control	28.58^{b}	1.30^{d}
LSD (0.05)	9.01	0.35
CV (%)	7.88	6.05

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

Table 5. Number of spikes per m^2; spike length and spikelets per spike.

Treatment (kg ha^{-1})*	Number of spike per m^2	Spike length (cm)	Spikelets per spike
Blended 406.5 + 67.4 urea	472.00^{a}	6.70^{a}	13.00^{a}
Blended 271 + 45 urea	464.00^{a}	6.49^{a}	14.00^{a}
Blended 135.5 + 22.4 urea	400.00^{ab}	5.60^{a}	12.33^{a}
Recommended urea + TSP	384.00^{b}	5.96^{a}	13.66^{a}
Control	240.00^{c}	5.38^{a}	12.00^{a}
LSD (0.05)	77.40	ns	Ns
CV (%)	10.50	14.31	8.14

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

Table 6. Mean square estimates of crop phenology, growth, yield components and yield of wheat for randomized complete block design.

Parameter	Mean squares for source of variation†		
	Treatment (4)	Error (8)	Coefficient of variation (%)
Days to 50% heading	128.93**	1.88	1.90
Days to 90% maturity	274.40**	0.65	0.62
Grain filling period	36.27**	1.02	1.78
Plant height (cm)	1001.28**	22.94	7.88
Fertile tillers per plant	4.34**	0.03	6.05
Spikes per m^2	26112.00**	1690.00	10.50
Spike length (cm)	0.96ns	0.74	14.31
Spikelets per spike	1.73 ns	1.13	8.14
Grain yield (kg ha^{-1})	3950905.07**	304911.97	16.07
Straw yield (kg ha^{-1})	8086144.72**	536794.80	14.64
Total biomass (kg ha^{-1})	22816746.91**	95833009.00	11.59
Harvest index	0.0015ns	0.003	13.47

Grain yield and thousand grains weight

Grain yield responded significantly ($P \leq 0.01$) to the applied fertilizers at experimental sites (Table 6). However, no statistically difference between the means of blended fertilizer rates and recommended N + P fertilizers and the highest mean grain yield (4383.3 kg ha^{-1}) was obtained from the maximum (406.5 kg blended + 67.4 kg

Table 7. Grain yield, straw yield, biomass yield and harvest index of wheat.

Treatments (kg ha^{-1})*	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Bio mass (kg ha^{-1})
Blended 406.5 + 67.4 urea	4383.3^{a}	6166.6^{a}	10550.0^{a}
Blended 271 + 45 urea	4276.7^{a}	6055.5^{a}	10332.2^{a}
Blended 135.5 + 22.4 urea	3550.0^{a}	5972.2^{a}	9524.2^{ab}
Recommended urea + TSP	3444.3^{a}	4500.0^{b}	7944.3^{b}
Control	1525.3^{b}	2333.3^{c}	3860.8^{c}
LSD (0.05)	1039.7	1379.5	1843.2
CV (%)	16.07	14.31	11.59

*Means within a column and the same site sharing common letter(s) are not significantly different at P > 0.01; LSD = Least significant difference; CV = Coefficient of variation; TSP = Triple super phosphate.

urea) rate with an increment of 187% yield advantage over the control plot (Table 7).

Straw yield, total biomass yield and harvest index

The applied fertilizers were significant ($P \leq 0.01$) at the experimental site (Table 6). As indicated in Table 7 the highest (6166.6 kg ha^{-1}) and lowest (2333.3 kg ha^{-1}) mean straw yield were revealed at the highest rate of blended fertilizer and the control plot, respectively. The increment in straw yield obtained with highest blended fertilizer rate over the control was 164.3%. In line with the grain and straw yields, total biomass yield was also significantly ($P \leq 0.01$) affected by applied fertilizers at experimental site (Table 6). The relative highest (10550 kg ha^{-1}) mean total biomass yield was obtained from the maximum (406 kg blended + 67.4 kg urea) rate with an increment of 173% total biomass yield advantage over the control (Table 7).

Conclusion

The results of the current study provide basic information for further research and development efforts in soil fertility management for sustainable utilization of the soil resources as well as fertilizer recommendations in the area. Also the highest grain yield was obtained from the maximum application of blended rate but it is difficult to give concrete recommendation for the sites of the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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