Evaluation of blended fertilizers and validation of soil fertility map-based fertilizer recommendations in Jamma and Werreillu Districts of South Wollo Zone, Amhara Region

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Abstract

Recently acquired soil inventory data from EthioSIS indicated multi-nutrient deficiencies including nitrogen (N), phosphorus (P), sulfur (S), potassium (K), boron (B) and zinc (Zn) in most Ethiopian cultivated soils. Thus, a field study was conducted in Jamma and Wereillu districts in 2014 and 2015 to evaluate the comparative advantage of the recommended blended fertilizers for the districts over the recommended NP fertilizers and validate the soil fertility map-based fertilizer recommendations. The study comprised five blended fertilizer formulations (F): F1: NPS (100 kg ha^{-1}), F2: NPSB (100 kg ha^{-1}), F4: NPSBZn (100 kg ha^{-1}),

F6BT/tefie(50)0;fkg(NK5SZnBF) ha

recommen(e)4dT949(N)-2(P)948(fertil)-4(izers)1-10(()1369/.46 kg ha

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Introduction

The use of chemical fertilizers, particularly nitrogen (N) and phosphorus (P), in Ethiopia has made a contribution to crop yield growth to date (Asnakew *et. al.*, 1991; Tekalign *et. al.*, 2001) although there is a potential for further improvement. Nitrogen (N) and phosphorus (P) based location-specific fertilizer recommendation (69/46 N/P_2O_5 kg ha^{-1}) for wheat crop was made so far for Jamma and Wereillu districts of South Wollo Zone of Amhara Region (Yared *et. al.,* 2003 unpublished). However, recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) revealed that sulfur (S), potassium (K), born (B) and zinc (Zn) deficiencies are widespread in the country which all potentially limit crop productivity despite the continued use of high analysis N and P fertilizers (EthiosSIS, 2014). Different research findings also showed that nutrients like K, S, calcium (Ca), magnesium (Mg) and all micro-nutrients except iron (Fe) are becoming depleted and deficiency symptoms are observed on major crops grown in different areas of the country (Wassie and Shiferaw, 2011; Asgelil *et al.,* 2009; Abyie *et. al.,* 2003).

Based to the EthioSIS soil fertility maps for Jamma and Wreillu districts, in addition to N and P, S, Zn and B are deficient in major areas of the districts and K is deficient in some pocket areas of the districts (Figure 1 and 2). Accordingly, EthioSIS has made site-specific blended fertilizer recommendations which is Kebele-based balanced-nutrient recommendations. Six fertilizer blends have been recommended in the country that when targeted to deficient soils can dramatically improve fertilizer-use efficiency and crop profitability. Hence, NPSB and NPSZnB blended fertilizers were recommended for the entire area of the two study districts except for some pocket areas where NPKSB and NPKSZnB blends were recommended (Figure 1 and 2).

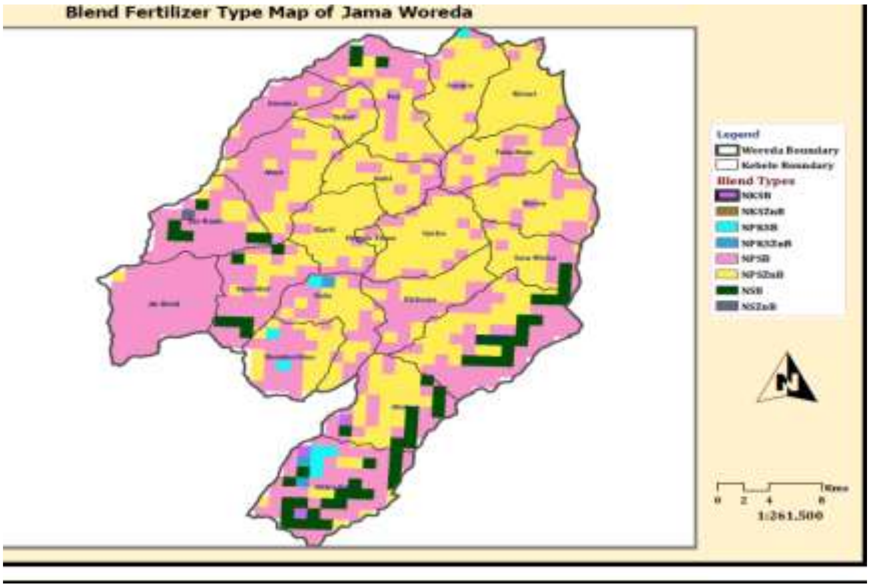

Figure 1: Recommended fertilizer blend types for Jamma district

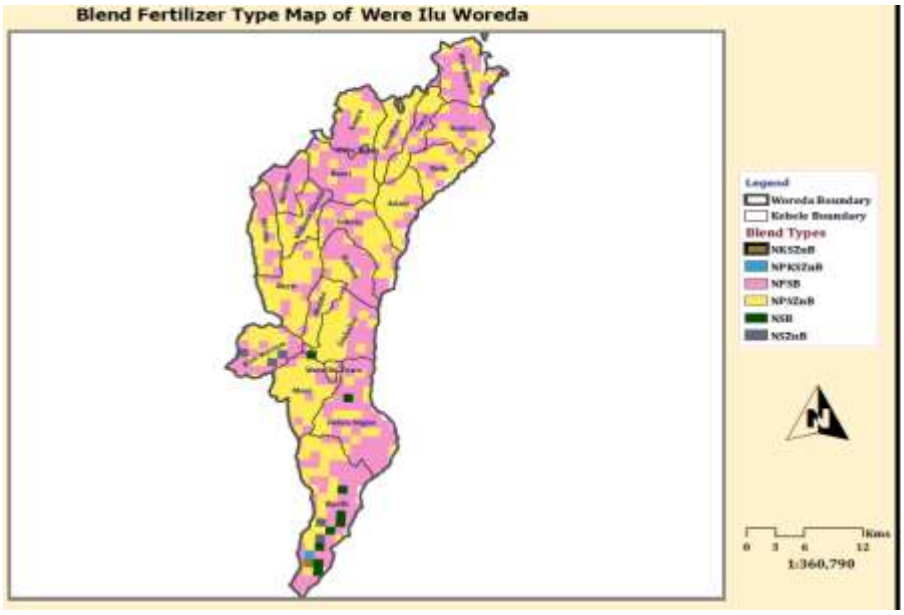

Figure 2. Recommended fertilizer blend types for Wereillu district

However, the new fertilizer blends have not been explicitly examined and understood under various production environments and nutrient response studies involving multi-nutrient blends that include micronutrients were rare in the present study areas. This research was therefore initiated to evaluate the comparative advantage of the recommended blended fertilizers for the two study districts over the recommended NP fertilizers and validate the new soil fertility map-based fertilizer recommendations made by EthioSIS (EthioSIS, 2014).

Materials and methods

Study site description

The study was carried out in 2014 and 2015 main cropping seasons in Jamma and Wereillu Districts of South Wollo Zone of Amhara Region. Jamma district is situated within the geographical boundaries of 10^{o} 06’ 24’’ - 10^{o}35’ 45’’ N latitudes and 39^{o}04’ 04’’ - 39^{o}23’ 03’’ E longitudes and altitudinal ranges of 1428 - 2752 meters above sea level. It receives a mean annual rainfall of 1130 mm, while the mean minimum and maximum temperatures of the district are 9 and 21 ^{o}C, respectively. Wereillu district is located within the geographical coordinates of 10^{o}50’ N - 10^{o}33’ N latitudes and 39^{o}10’E - 39^{o}16’E longitudes and with altitudinal ranges of 1700 to 3200 m.a.s.l. The dominant soil type in both Districts is Pellic Vertisols with physico-chemical characteristics as described in Table 1 and the cropping lands of the districts are characterized by poor drainage and intense water-logging (Getachew, 1991).

Table 1. Range of physico-chemical properties of surface soil (0-30 cm) of the study sites

Soil Properties	Values	Rating*
pH (H_2O)	6.5-6.8	Slightly acidic to neutral
Organic matter (OM) (%)	1.36-1.75	Low
Total N (TN) (%)	0.10-0.11	Low
Available P (mg kg^{-1} soil)	3.08-5.20	Low
Exchangeable Ca (cmol$_C$ kg^{-1})	30.6-46.3	Very high
Exchangeable Mg (cmol$_C$ kg^{-1})	9.9-12.9	Very high
Exchangeable K (cmol$_C$ kg^{-1})	0.6-0.7	High
Cation exchange capacity (CEC) (cmol$_C$ kg^{-1})	52.0-61.7	Very high
Percent acid saturation (PAS) %	82.5-97.6	Very weakly leached
Sand %	16.3-17.5	
Silt %	20.0-21.3	
Clay %	62.5	
Textural class	Clayey	

***Source**: Abebe et. al,. 2013. *Ratings are based on pH (Jones, 2003), OM and TN (Tekalign, 1991), Available P (Cottenie,1980), Exchangeable Ca, Mg and K (FAO, 2006), CEC and PAS (Hazelton, Murphy, 2007)*

Experimental procedures

Table 2 below shows the description and formulations used to prepare each blended fertilizer formulas. Six treatments composed of five different blended fertilizers and the recommended NP fertilizer were used in the study (Table 3).

Table 2. Blended fertilizer descriptions, formulations and their source

Formula	Blended fertilizer formulations	Source of each nutrient for blending
1:NPS	19 N + 38 P_2O_5 + 0.0 k_2O + 7 S + 0.0 Zn + 0.0 B	19 kg N + 38 kg P_2O_5 +7 kg S
2:NPSB	18. 1 N + 36.1 P_2O_5 + 6.7 S + 0.71 B	95 kg NPS + 4.9 kg Borax
3:NPSKB	13.7 N + 27.4 P_2O_5 + 14.4 k_2O + 5.1 S + 0.54 B	72.2 kg NPS + 24.1 kg KCl + 3.7 kg Borax
4:NPSZnB	16.9 N + 33.8 P_2O_5 + 7.3 S + 2.23 Zn + 0.67 B	86 kg NPS + 6.4 kg ZnSO4 + 4.6 Kg Borax
5:NPKSZnB	13.0 N + 26.1 P_2O_5 + 13.7 K_2O + 5.6 S+ 1.72 Zn + 0.51 B	68.7 kg NPS + 22.9 kg KCl + 4.9 kg ZnSO4 + 3.56 kg Borax
6:FORMULA 4 MODIFIED	17.5 N + 34.9 P_2O_5 + 0.0 k_2O + 7.6 S + 2.23 Zn + 0.25 B	+1.22 kg Borax
7:FORMULA 5 MODIFIED	13 N + 26.1 P_2O_5 + 14.8 k_2O + 5.6 S + 1.72 Zn + 0.25 B	68.7 kg NPS + 24.7 kg KCl + 4.9 kg ZnSO4 + 1.75 kg Borax

Table 3. Treatments used at both Jamma and Wereillu Districts

Treatments	N	P_2O_5	K_2O	S	Zn	B
T1= Rec. NP (111 kg ha^{-1} urea + 100 kg ha^{-1} DAP)	69	46	0	0	0	0
T2= 100 kg ha^{-1} F1 + 109 kg ha^{-1} urea top dressed	69	38	0	7	0	0
T3= 100 kg ha^{-1} F2 + 111 kg/ha urea top dressed	69	36	0	6.7	0	0.71
T4= 100 kg ha^{-1} F4 + 115 kg/ha urea top dressed	69	34	0	7.3	2.23	0.67
T5= 150 kg ha^{-1} F6 + 109 kg/ha urea top dressed	69	52	0	11.4	3.34	0.38
T6= 150 kg ha^{-1} F7 + 108 kg/ha urea top dressed	69	39	21	7.5	2.23	0.38

Five representative farmers' fields in each district were randomly selected for the study. The farmers' fields were divided into six experimental plots each of which had an area of 4.8 m x 4.0 m. Four raised beds with a width of 0.80 m and length of 4.00 m and furrow width of 0.40 m, as shown in Fig 3 below, were prepared in each plot to drain excess water, as the soil type of the sites is Vertisols with heavy clay texture. The treatments were randomly assigned to the six experimental plots in a randomized complete block design (RCBD) using the five farmers' fields as replications.

Figure 3. Raised bed preparation to drain excess water and reduce waterlogging problem

Planting and fertilizer applications

Bread wheat, improved variety - *Dinknesh,* was planted in rows with 20 cm spacing and seed rate of 150 kg ha^{-1} on the raised beds. In the first experimental year, P and S fertilizers were applied at basal by drilling as triple superphosphate (TSP) and calcium sulfate ($CaSO_4$), respectively. Potassium was applied as muriate of potash (KCl) in a row 5 cm away from the seeding rows to avoid possible solute-stress effect during germination, while N was applied as urea in split, half at planting and half side dressed 45 days after planting. Zinc sulfate ($ZnSO_4$) and borax, which were used as a source of Zn and B, respectively, were dissolved in water separately and sprayed as foliar application at 45 and 60 days after planting, respectively (Figure 4). In the second experimental year, different formulas of blended fertilizers containing N, P, S, Zn and B were used and K was applied as a straight fertilizer in KCl form. The blended fertilizer and KCl were applied all at planting, while, N was applied in split at half planting and half side-dressed 45 days after planting.

Figure 4. Foliar applications of Zn and B micronutrients in the first experimental year

Data collection and statistical analysis

Grain yield was measured at maturity from the innermost 2 rows in the four raised beds in each plot and was adjusted to a moisture content of 12.5%. Fresh biomass weight was measured by weighing the fresh total above-ground biomass of the harvested rows. The dry biomass weight was measured by taking a straw sample with the seed spikes, drying in an oven at 105^{o}C for 12 hours and adjusting the fresh biomass weight on to dry basis by using the moisture content measured after drying.

All recorded relevant agronomic data were subjected to analysis of variance (GLM procedure) using SAS software version 9.00 (SAS Institute, 2004). The LSD method at 5% probability level was used to separate the significant treatment mean differences.

Results and Discussion

Effect of blended fertilizers on the yields of wheat

There was no statistically significant (P>0.05) influence of the blended fertilizers both on the grain and dry biomass yields of wheat as compared to the recommended NP fertilizers in both experimental years and at both districts (Table 4 and 5). Application of S, Zn, B and K fertilizers were not found to significantly affect the yield of wheat as compared to the recommended NP fertilizers. At Jamma district, the maximum grain (2.7 t ha^{-1}) and dry biomass (7.5 t ha^{-1}) yields in 2014 were obtained from F6 (Modified NPSBZn) but with insignificant difference with the recommended NP and other treatments. While, in 2015, the maximum grain (3.4 t ha^{-1}) and dry biomass (10.6 t ha^{-1}) yields were recorded from F7 (modified NPSBZnK) treatment and F6 (Modified NPSBZn), respectively with non-significant difference from the yields recorded from recommended NP treatment (Table 4).

Table 4. Effect of the blended and recommended NP on the grain and dry biomass yields (kg ha^{-1}) of wheat at Jamma district

Treatment/Formula*	2014		2015		Combined	
	Grain Yield	Dry Biomass	Grain Yield	Dry biomass	Grain yield	Dry biomass
Rec. NP	2583.8	7250.0	3082.1	9570.3	2774.6	8281.3^{ab}
F1: NPS	2371.3	6625.0	3017.2	8945.3	2632.2	7656.3^{b}
F2: NPSB	2316.6	6562.5	3342.3	9453.1	2806.6	7847.2^{b}
F4: NPSBZn	2358.4	6718.8	3299.7	9531.3	2798.3	7968.8^{b}
F6: Modified NPSBZn	2734.2	7531.3	3387.1	10625.0	2982.5	8906.3^{a}
F7: Modified NPSBZnK	2612.8	7281.3	3473.1	9687.5	2974.5	8350.7^{ab}
LSD (5%)	Ns	Ns	Ns	Ns	Ns	700.4
CV (%)	8.7	8.3	11.5	9.9	10.6	9.0
Treatment*Year	-	-	-	-	Ns	Ns

Means within a column followed by the same letter are not significantly different at p = 0.05;* ***Ns* *- non significant at p = 0.05.*

At Wereillu district, in 2014, the maximum grain (2.7 t ha^{-1}) and dry biomass (7.6 t ha^{-1}) yields were recorded from F6 (modified NPSBZn) statistically at par with the recommended NP fertilizers. While, in 2015, the maximum grain (2.1 t ha^{-1}) and dry biomass (7.7 t ha^{-1}) yields were obtained from F4 (NPSBZn) and recommended NP, respectively (Table 5).

Table 5. Effect of the blended and recommended N and P on the grain and dry biomass yields (kg ha^{-1}) of wheat at Wereillu district

Treatment/Formula*	2014		2015		Combined	
	Grain Yield	Dry biomass	Grain Yield	Dry biomass	Grain Yield	Dry Biomass
Rec. NP	2320.4^{c}	6687.5	2059.6	7734.4	2204.5	7152.8
F1: NPS	2559.4^{ab}	7093.8	2130.2	7656.3	2368.7	7343.8
F2: NPSB	2523.1^{abc}	7406.3	1801.3	6679.7	2202.3	7083.3
F4: NPSBZn	2415.4^{bc}	7000.0	2130.5	7187.5	2308.6	7083.3
F6: Modified NPSBZn	2737.6^{a}	7656.3	1751.4	7695.3	2299.3	7673.6
F7: Modified NPSBZnK	2565.8^{ab}	7468.8	2043.3	7656.3	2333.6	7552.1
LSD (5%)	237.1	Ns	Ns	Ns	Ns	Ns
CV (%)	7.1	8.8	11.0	9.0	9.9	9.3
Treatment*Year	-	-	-	-	Ns	Ns

Means within a column followed by the same letter are not significantly different at p = 0.05.* ***Ns* *- non significant at p = 0.05.*

However, in contrast to the results from this study, different studies indicated Zn deficiency in the central highland Vertisols of Ethiopia (Amsal *et. al.*, 2000; Asgelil *et. al.*, 2007; Hailu *et. al.*, 2015). Though the present study showed insignificant yield response to the application of Zn and B, Abera and Kebede (2013) reported deficiency of Zn in 98% of the soil samples collected from central highland Vertisols of Ethiopia. A finding by Bereket *et. al.* (2011) also indicated Zn deficiency on Ethiopian Vertisols. In contrary to this finding, Fayera *et. al.* (2014) carried out a study on tef crop on clay loam soil of Didessa District, Southwestern Ethiopia and revealed that application of blended fertilizer at a rate of 200 kg ha^{-1} of Zn + B blended (14N $21P_2O_5$ $15K_2O$ 6.5S 1.3Zn 0.5B) + 23 kg N ha^{-1} gave a statistically significant and higher yield than the recommended NP fertilizer. Moreover, Graham and Welch (1995) reported that Zn deficiency is one major micronutrient deficiency in humans particularly in developing countries where cereals contain very low levels of Zn are the primary staple foods for human consumption.

According to Ranjbar and Bahmaniar (2007), soil or foliar applications of Zn fertilizer alone were not found as effective as soil + foliar applications to increase yield. Thus, the insignificant yield response of wheat to Zn and B micro-nutrients in the present study might be attributed to the low recovery efficiencies of Zn and B fertilizers applied. In the first year, Zn and B fertilizer were applied on foliage, while in the second year they were applied at basal with the blended fertilizer. It could have been effective if the fertilizers were applied as basal + foliar application in both experimental years as this is supported by Ranjbar and Bahmaniar (2007).

Concerning S, in contrast to the finding in this study, available sulfur (SO_4^{2-}-S) in the Vertisols of the central highlands of Ethiopia ranged from 1.2 to 2.1 mg $kg^{-1}$and it was found to be deficient assuming 5 mg kg^{-1} S as critical level (Hailu *et. al.*, 2015). In line with this, a study conducted at six sites in Arsi, East Shewa and Oromia *Liyuu* zones indicated that about 50% of the studied fields showed highly significant response and 22% showed marginal-response to S (Assefa, 2016). Habitegebriel and Singh (2009) conducted research on Cambisols and Andosols and also indicated that the application of S fertilizer along with N fertilizer significantly increased the yield and nitrogen use efficiency (NUE) of bread wheat. The insignificant (P>0.05) yield response to S in the present study districts might be due to the optimum level of available S (SO_4^{2-}-S) in the surface soil or due to the low level of S used in the study which might be insufficient to meet the crop's S requirement.

The insignificant yield response to K in the present study might be attributed to the K-fixing characteristics of the pellic Vertisols in the study districts due to the expanding nature of the minerals that make up these soils (Getachew, 1991; Abunyewa *et. al.*, 2004). The other reason might be accounted for the low level of K (21 kg K_2O ha^{-1}) used in the study, which might not be sufficient to satisfy the K hunger of the soil let alone to be available for the crop. This is supported by Hagos *et. al.* (2017) who concluded that the level of K in the blended fertilizers was not sufficient to meet the yield requirement of wheat. Application of K did not receive due attention, as most Ethiopian soils were believed to be adequate in native supply. However, according to Stoorvogel and Smaling (1990) and Scoones and Toulmin (1999), the neglect of K application in Ethiopia and the continuous crop removal from the soil without additions has resulted in continuous depletion and negative balance (-26 to -33.2 kg K ha^{-1} $year^{-1}$) of the nutrient reserve. Moreover, the K: Mg ion ratio, 0.05 to 0.06, in the present study sites was in the range leading to Mg-induced K deficiency according to the rating by Loide (2004). Thus, a sufficiently higher dose of K than the rate used in the present study should have been tested on Vertisols with a high tendency of K-fixation. This is supported by Astatke *et. al.,* (2004) who conducted a study in the highland Vertisols of central Ethiopia and revealed that application of potassium sulfate resulted in about 1 t $ha^{-1}$of wheat yield advantage compared to untreated plots. Hailu *et. al.* (2017) also revealed the yield response of wheat to K and P fertilization in the central highland Vertisols of Ethiopia. In agreement with the result in this study, a study in the Sinana District of Bale Zone of Oromiya Region by Mulugeta *et. al.,* (2018) revealed that wheat yield response to K fertilizer was not significant.

Conclusion and Recommendation

The result revealed that the use of blended fertilizers with micro and macro-nutrients did no provide a significant yield difference over the recommended NP fertilizers. However, there were some limitations in this study; 1. The rates of K and S fertilizers (21 kg K_2O ha^{-1} and 14 kg S ha^{-1}) used in the study were too low to meet wheat nutrient requirements. Besides, the insignificant effect of Zn and B on the yield of wheat might be attributable to the low recovery efficiency of these nutrients. Therefore, further comprehensive study with sufficient rates K and S, with the right application method of micro-nutrients and with the support of soil analysis and plant nutrient uptake data should be done.

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