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Evaluation of Balanced Fertilizer Types and Validation of Soil Fertility Map Based Fertilizer Recommendations

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Abstract
Recently acquired soil inventory data from EthioSIS indicated that sulfur (S), born (B), zinc (Zn) and potassium (K) deficiencies are widespread in addition to nitrogen (N) and phosphorus (P) in most of Ethiopian cultivated soils. Thus, a field study was conducted to evaluate the yield response of wheat to K, S, B and Zn fertilizers as compared to the conventional recommended NP fertilizers. The study was undertaken in Jamma and Wereillu Districts of South Wollo Zone of Amhara region in 2014 and 2015. The study comprised six blended fertilizer formulas (F1: NPS (100 kg ha^{-1}), F2: NPSB (100 kg ha^{-1}), F4: NPSBZN (100 kg ha^{-1}), F6: modified F4 (150 kg ha^{-1}), F7: modified F5 (NPKSZnB) (150 kg ha^{-1})) and the recommended NP fertilizers (69/46 kg ha^{-1} N/P_2O_5). Nitrogen was applied as urea in split half at planting and half at tillering. In the first year K, S and P were applied all at planting as muriate of potash (KCl), calcium sulphate (CaSO4) and Triple Super Phosphate (TSP), respectively, while, Zn ($ZnSO_4$) and B (Borax) were sprayed as foliar application at 45 and 60 days after planting, respectively. While, in the second year, all fertilizers were applied as blended fertilizer except N and K, which were applied as urea and KCl forms, respectively. Results indicated that there was no significant ($p>0.05$) yield response to the application of S, K, B and Zn nutrients as compared to the recommended NP fertilizers. This might be due to either the optimum level of the nutrients in the soil or the insufficient level of the nutrients used in the study might have failed to influence the yield of wheat. With this study, it is hardly possible to conclude those nutrients were not limiting for the growth of wheat in the study districts. Further comprehensive study with higher rates of the nutrients and with the support of soil and plant tissue analysis apart from yield data should be done.
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Introduction
Studies show that the use of chemical fertilizers in Ethiopia have 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. For example, fertilizer is applied by less than 45% of farmers, on about 40% of area under crop, and most likely at below optimal dosage levels (Dercon and Hill, 2009; Gete et al., 2010).

However, recent research reports indicated that nutrients like potassium (K), sulfur (S), calcium (Ca), magnesium (Mg) and all micro-nutrients except iron (Fe) are becoming depleted and deficiency symptoms are observed on major crops in different areas of the country (Wassie *et. al.,* 2011; Asgelil *et al.,* 2009; Abyie *et. al.,* 2003). Recently acquired soil inventory data from EthioSIS (Ethiopian Soil Information System) revealed that in addition to nitrogen (N) and phosphorus (P), S, born (B), zinc (Zn) and K deficiencies are widespread which all potentially limit crop productivity despite continued use of N and P fertilizer as per the recommendation.

Balanced fertilizers containing N, P, K, S, B and Zn in blended form are recommended to ameliorate site specific nutrient deficiencies and thereby increase land, water and labor productivity. The need for site-specific fertilizer prescriptions is increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients are rare in Ethiopia. Although there is general perception that the new fertilizer blends are better than the conventional fertilizer recommendation (Urea and DAP), their comparative advantages is not explicitly examined and understood under various production environments. This proposal was therefore initiated with the objective of evaluating the comparative advantage of blended fertilizers with macro- and micro-nutrients over the recommended NP fertilizers and validate the new soil fertility map developed by EthioSIS.

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 (masl). It receives a mean annual rainfall of 1130 mm, while the mean minimum and maximum

temperatures of the district are 9 and 21 °C, respectively. The other study district, Wereillu, is located within the geographical coordinates of 10°50' N - 10°33' N latitudes and 39°10'E - 39°16'E longitudes and with altitudinal ranges of 1700 to 3200 masl. The dominant soil type in both Districts is Pellic Vertisols with physico-chemical characteristics as described in Table 1 below and the cropping lands of the districts are characterized by poor drainage and water-logging but high potential for crop production like wheat and tef crops (Getachew, 1991).

Table 1. Range of physico-chemical properties of surface soil (0-30 cm) of the pellic Vertisol in Jamma District

Soil Properties	Values	Ratings
pH (H_2O)	6.5-6.8	Neutral[a]
Organic matter (OM) (%)	1.36-1.75	Low[b]
Total Nitrogen (TN) (%)	0.10-0.11	Medium[b]
Available P (mg kg^{-1} soil)	3.08-5.20	Very low[c]
Exchangeable Ca ($cmol_C\ kg^{-1}$)	30.6-46.3	Very high[d]
Exchangeable Mg ($cmol_C\ kg^{-1}$)	9.9-12.9	Very high[d]
Exchangeable K ($cmol_C\ kg^{-1}$)	0.6-0.7	High[d]
Cation exchange capacity (CEC) ($cmol_C\ kg^{-1}$)	52.0-61.7	Very high[d]
Percent acid saturation (PAS) %	82.5-97.6	Very high[d]
Bulk density (gm cm^{-3})	1.10	
Sand %	16.3-17.5	
Silt %	20.0-21.3	
Clay %	62.5	
Textural class	Clay	

Source: Abebe *et. al,*. 2013. [a](Jones, 2003); [b](Tekalign, 1991); [c]Cottenie (1980); [d]FAO (2006); [e]Hazelton and Murphy (2007).

Experimental procedures

Table 1 below shows the description of six treatments used in the study, including the recommended NP fertilizer rate and five different blended fertilizers.

Table 1. Blended fertilizer treatments for wheat at 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 (NPS) + 109 kg ha^{-1} urea top dressed	69	38	0	7	0	0
T3= 100 kg ha^{-1} F2 (NPSB) + 111 kg/ha urea top dressed	69	36	0	6.7	0	0.71
T4= 100 kg ha^{-1} F4 (NPSZnB) + 115 kg/ha urea top dressed	69	34	0	7.3	2.23	0.67
T5= 150 kg ha^{-1} F6 (F4 modified) + 109 kg/ha urea top dressed	69	52	0	11.4	3.34	0.38
T6= 150 kg ha^{-1} F7 (F5, NPKSZnB modified) + 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 in to six experimental plots 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 were prepared in each plot to drain the excess water that would be accumulated, 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.

Planting and Fertilizer Application Methods

The test crop bread wheat, improved variety - *Dinknesh,* was planted in rows with 20 cm spacing with a seeding rate of 150 kg ha^{-1} on the raised beds. In the first experimental year, P and S fertilizers were applied as basal by drilling as triple super phosphate and calcium sulfate ($CaSO_4$), respectively. Potassium was applied as muriate of potash (KCl) in a row 5 cm away from 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 sulphate ($ZnSO_4$) 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. In the second experimental year, however, 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.

Data collection and analysis

Grain yield was measured at maturity from the inner most 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 straw sample with the seed spikes, drying in an oven at 105 °C for 12 hours and adjusting the fresh biomass weight in to dry basis by using the moisture content measured after drying.

All the relevant agronomic data recorded 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 treatment means.

Results

Effect of blended fertilizers on the yields of wheat

There was no statistically significant (P>0.05) influence of the balanced fertilizers on the yields of wheat as compared to the recommended NP fertilizers in both experimental years at both study districts, Jamma and Wereilu (Table 2 and 3). Application of S, Zn, B and K fertilizers were not found to significantly affect the yield of wheat as compared to the conventional recommended NP fertilizers.

Table 2. Effect of the blended and recommended NP fertilizers on the grain and dry biomass yields in kg ha^{-1} of wheat at Jamma district

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

*Means with in a column followed by the same letter are not significantly different at 5% probability level. **ns**-non significant.

Table 3. Effect of the blended and recommended NP fertilizers on the grain and dry biomass yields in kg ha^{-1} of wheat at Wereillu district

	2014		2015		Combined	
Treatment*	**Grain Yield**	**Dry biomass**	**Grain Yield**	**Dry biomass**	**Grain Yield**	**Dry Biomass**
Rec. NP	2320.4c	6687.5	2059.6	7734.4	2204.5	7152.8
NPS	2559.4ab	7093.8	2130.2	7656.3	2368.7	7343.8
NPSB	2523.1abc	7406.3	1801.3	6679.7	2202.3	7083.3
NPSBZn	2415.4bc	7000.0	2130.5	7187.5	2308.6	7083.3
Modf. NPSBZn	2737.6a	7656.3	1751.4	7695.3	2299.3	7673.6
Modf. NPSBZnK	2565.8ab	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

*Means within a column followed by the same letter are not significantly different at 5% probability level. **ns**-non significant.

Discussion

Asgelil et al. (2007) studied the status of some micronutrients in agriculturally important soil types in the country and indicated that the frequency of Zn deficiency was highest in Vertisols and Cambisols (78%) and the lowest in Nitisols. Amsal et al., 2000; Hailu et al., 2015 also underwent micronutrient analysis of wheat flag leaves from ten sites in central highland Vertisols of Ethiopia and concluded that Cu, Fe, Mn and Cl concentrations were sufficient, while Zn was deficient in all samples. In addition, recent nutrient survey conducted by EthioSIS exhibited widespread K, S, B and Zn deficiency across the country (Ethiosis, 2015).

However, the result from the present study showed that application of K, S, Zn and B nutrients did not significantly (P>0.05) influence the yield of wheat as compared the recommended NP fertilizers. 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 its content of expanding type of clay minerals (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. According to Stoorvogel and Smaling (1990); Scoones and Toulmin (1999), the neglect of K application in Ethiopia and the continuous crop removal from the soil without additions has been resulting 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, to meet the crop demand, a sufficiently higher dose of K than the rate used in the present study should have been tested on Vertisols with 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 sulphate resulted in about 1 t ha^{-1} of wheat yield advantage compared to untreated plots. Hailu et al. (2017) also revealed yield response of wheat to K and P fertilization in the central highland Vertisols of Ethiopia. On the contrary, a study in Sinana District of Bale Zone of Oromiya Region by Mulugeta et al, (2018) revealed that wheat yield response to K fertilizer was not significant.

With regard to S, according to Hailu et. al. (2015), 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. 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). K Habitegebriel and H. Singh (2009) carried out a research on Cambisols and Andosols and also indicated that 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.

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 recent finding by Bereket et al. (2011) also indicated Zn deficiency on Ethiopian Vertisols. In line with this, 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 and other fertilizer rates. Moreover, 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 (Graham and Welch, 1995). According to Ranjbar and Bahmaniar (2007), soil and 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 supplied in the study probably due to the inefficient method of Zn and B fertilizer applications. In the first year, Zn and B fertilizer were applied on foliage as a foliar application, while in the second year they were applied as 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).

Conclusion and Recommendation

Several studies showed that there is widespread deficiency of micronutrient and potassium on cultivated soils in Ethiopia. Recent nutrient survey conducted by EthioSIS also exhibited widespread K, S, B and Zn deficiency across the country. Thus, taking these premises in to account, this study was conducted to validate the soil fertility map-based balanced fertilizer recommendation and investigate the yield response of wheat to balanced fertilizers containing N, P, K, S, Zn and B and compare the yield response with the conventional NP fertilizer recommendation. The result showed that there is insignificant yield difference due to the use of balanced fertilizers as compared to the conventional NP fertilizers. However, the rates of S and K fertilizers used in the present study might not be sufficient enough to satisfy wheat nutrient requirement. The insignificant effect of Zn and B on the yield of wheat might be attributable to the inefficient method of application used in the present study. Therefore, further comprehensive study with higher rates of the nutrients, with the right timing and method of application and with the support of soil and plant tissue analysis apart from yield should be done.

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