Verification of Potassium and Micronutrients on yield of bread Wheat (*Triticum aestivum*) in Jamma and Meket districts of East Amhara

Habtemariam Teshome, Kassa Sisay, Samuel Adissie, Tadesse Hailu, Muluken Lebay and Tesfaye Wubu
Sirinka Agricultural Research Center, Center, P.O. Box 74, Woldia, Ethiopia
Corresponding: Habtemariam Teshome: Mobile: +251 910436351, email: teshomehabte@gmail.com

Abstract

The final soil fertility status map developed for Amhara region by Ministry of Agriculture and Natural Resources and Agricultural Transformation Agency in 2016 indicated 100% of the soils of Jamma and Meket districts are deficient in potassium and other new fertilizer combinations. However, previous studies showed that there was no response to these nutrients. Therefore, this study was conducted in Eastern Amhara, at Meket and Jamma districts in 2017 cropping season to verify the response of bread wheat (Dinkenesh variety) to potassium, Boron and Zinc containing fertilizers. The experiment consists of four treatments including: NPS, NPSK, NPSBZn and NPSKBZn arranged in a randomized complete block design replicated three times. Nitrogen and phosphorus were adjusted by urea and NPS to the recommended rate of location and the crop and were uniformly applied to all treatments. Potassium was applied as a straight fertilizer at the rate of 150 kg KCl ha^{-1}. Nitrogen was applied in two splits half at planting and half at tillering, while the other nutrients were applied at planting. Composite soil samples were collected from 0-20 cm depth for the determination of selected soil properties. All collected agronomic and soil data were subjected to the analysis of variance using SAS version 9.0 (2004) and significant means were separated using least significant difference (LSD) at 5% level. The exchangeable potassium contents ranged from 1.70 to 5.81 cmol$_c$kg^{-1} for Meket and 4.86 to 6.00 cmol$_c$kg^{-1} for Jamma and lies in a very high category. The available phosphorus contents also ranged from 23.1 ppm to 31.2 ppm for Meket and from 39.4 ppm to 54.8 ppm for Jamma and placed in a very high category. Whereas, the total nitrogen and organic matter contents were in a low category for most samples and in medium category for a few. The difference among the treatments in sorghum grain and biomass yields was not statistically significant ($p > 0.05$) indicating that special attention should be given for the improvement of nitrogen and organic matter contents than potassium, boron and zinc to increase sorghum yield. The soil fertility status map should also be improved to a better scale.

Key words: Boron, fertilizer, potassium, soil fertility map, zinc

Introduction

Ethiopia is endowed with abundant agricultural resources and has diverse ecological zones. The two dominant agricultural systems in Ethiopia are the mixed agriculture of the highlands, where both crops and livestock production are integrated, and pastoralism in the lowlands. Agriculture in Ethiopia accounts for about 34.8% of the gross domestic product (GDP) (CIA World Facebook, 2019). However, the production and productivity of the country is highly affected by poor soil fertility resulted in severe deforestation, top soil erosion, over grazing and mining of nutrients. To curb the situation there is a positive response to the applications of nitrogen and phosphorous fertilizers for most crops under all agro ecologies. However, there has been a lack of crop response to potassium and new fertilizer blends (Murphy, 1968; Tadele et al, 2008; Tadele et al., 2018). Contrary to the reports from the aforementioned authors, the final soil fertility status map developed by MoANR and ATA, (2016), showed that 94% of the soils of Amhara Region are deficient in potassium content. Tena and Beyene (2011) also reported that potassium was deficient in Ethiopian soils. The soil fertility status map shows that Jamma soils are 100% deficient in potassium and 100% deficient in NPSB and NPSZnB while soils of Meket were 99% deficient in potassium and 99% deficient in NPSB and NPSZnB (MoANR and ATA, 2016).

Different scholars reported that Ethiopian soils are not deficient in potassium and micro nutrients and rich enough to supply the crop demand (Tadele *et al*., 2018; Abebe *et al.*, 2019, under publication). Blended fertilizers which contain potassium were introduced in different ways to the country starting from 2014 as a balanced fertilizer (Birhane et al, 2017) to all areas of the region including Jamma and Meket districts. MoANR and ATA recommended the application of 100 kg KCl ha^{-1} throughout the districts regardless of crop type and agro-ecology without proven scientific evidence. Based on this the farmers were directed to apply 100 kg KCl ha^{-1} to his land for no return.

Hence, Amhara Agricultural Research Institutes developed a regional project to verify the responses of different crops including bread wheat to potassium, boron and zinc containing fertilizers.

Material and methods

Study site

The research was conducted on farmers' field at Meket and Jamma districts in the Eastern Amhara region in 2017/18 main cropping season. Jamma is located about 520 km away from the capital city, Addis Ababa via Dessie, in the north east direction. The geographical location of the district lies between 10° 23' to 10° 27' N latitudes and 39° 07' to 39° 24' E longitudes and altitude of 2630 meters above sea level in South Wollo Zone of the Amhara National Regional State. The dominant soil type of the district is Vertisols. The soil is characterized by poor drainage and difficulty to work, but high potential for wheat production with proper soil management. The mean annual rain fall of the district was 868 mm and the mean minimum and maximum temperatures were 9°C and 21.6°C respectively. While Meket is located in the western parts of North Wollo Zone at a distance of about 740 km away from Addis Ababa via Dessie. The geographic position of the district lies 11° 54' to 12° 00' N Latitude and 38° 50' to 39° 10' E longitude at an altitude of 2650 meter above sea level. The mean annual rain fall ranges from 790 to 1250 mm with the annual average rain fall of 1105 mm. The mean minimum and maximum temperatures of the district were 12°C and 24°C respectively. The dominant soil type is Regosols followed by Leptosols and acidic in reaction. Alike Jamma, Meket also receives a unimodal type of rain fall.

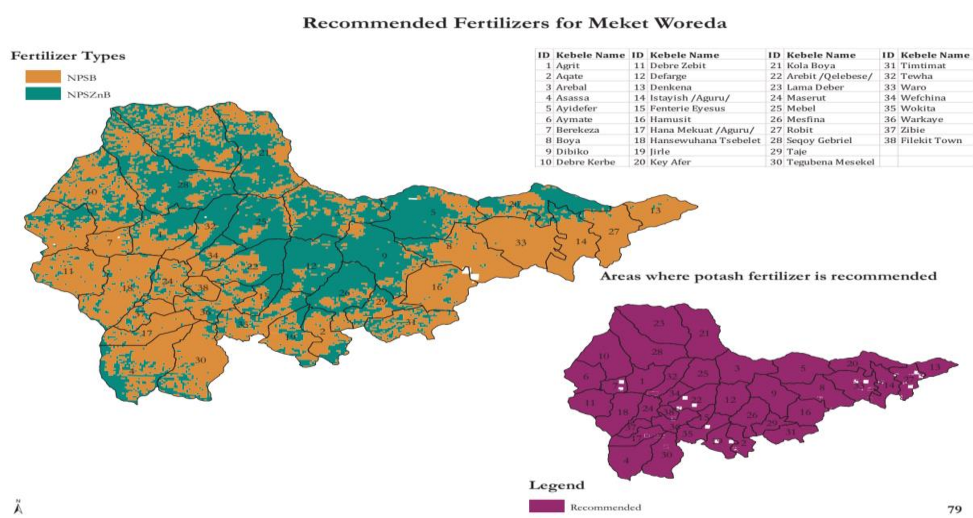

Figure 1. Fertilizer recommended areas of Meket district (Source, MoANR and, ATA 2016).

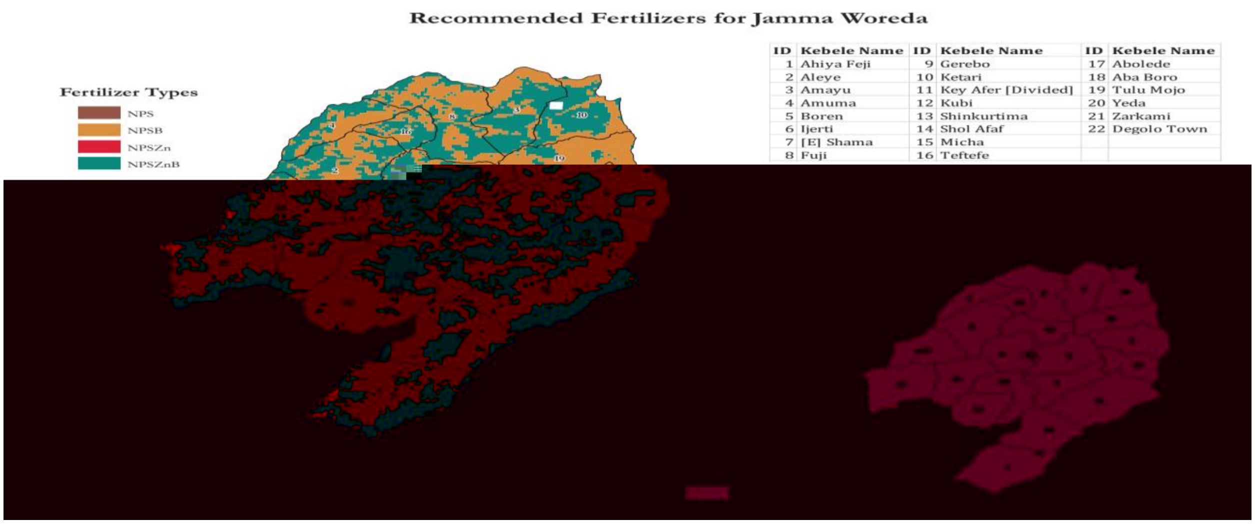

Figure 2. Fertilizer recommended areas of Jamma district (Source: MoANR and ATA, 2016).

Treatment setup

The treatments were composed of NPS, NPSK. NPSBZn and NPSKBZn arranged in a randomized complete block design (RCBD) with three replications. The site and crop specific recommended nitrogen and phosphorus for Meket were 69 kg N ha^{-1} and 69 kg P_2O_5 ha and for Jamma were 115 kg N ha and 69 kg P_2O_5 ha^{-1}. The recommended N and P were uniformly applied to all plots. Potassium was applied at the rate of 150 kg KCl ha^{-1}. Nitrogen was applied in two splits half at planting and half at tillering while phosphorus and potassium were applied at planting. Foliar application of B and Zn fertilizers was done at a rate of 1 kg Borax ha^{-1} and 1 kg Zinc sulphate ha^{-1} at fifth week after planting.

The plot size was 25 m^2 (5 m * 5m) for Meket and 24 m^2 (4.8 m * 5m) for Jamma. At Jamma broad bed furrow with 80cm by 40cm was used. The space between plots and replications were 0.5m and 1 m respectively. Soil and crop management were applied uniformly to all plots. The test bread wheat variety was Dinkenesh with a seed rate of 125 kg ha^{-1}.

Soil Sampling and Analysis

Composite soil samples at a depth of 0-20 cm were collected from each farm at planting. Samples were air-dried and ground to pass through 2 mm sieve (for the determination of most soil properties) and 0.5 mm sieve (for the determination of total N). Soil texture was determined by hydrometer method (Bouyoucos, 1962). The soils pH was measured with a glass electrode in water (1: 2.5 soils to water ratio) (Page et al., 1982). The organic carbon content of the soil was determined following Walkley and Black procedures (Walkley and Black, 1934). The total nitrogen was determined by Kjeldahl method (Bremner and Mulvaney, 1982). The available soil phosphorus was determined by the Olsen method (1954) and Exchangeable potassium was extracted by ammonium acetate at pH 7 (Sahlemedhin and Taye, 2000) and determined by Atomic absorption spectrometer.

Agronomic data collection

Plant height was measured at maturity from five random plant samples of the harvestable rows from the ground to the tip of the spike. The harvestable rows were harvested at full maturity, sun dried and weighed to determine the above ground biomass in kg per plot and then converted to kg per hectare. Then the grains were separated from the straws and grain yield in kg per plot was determined and then converted to kg per hectare. The moisture content of the grain was collected simultaneously with the grain yield and finally the grain yield was adjusted to 12.5% moisture content.

Data analysis

The collected data were subjected to analysis of variance using SAS statistical software (SAS version 9.0) to evaluate the degree of variations between treatments using. Significant mean differences were separated using least significant difference at 5% level.

P

result which showed very high potassium content result in the soils of both districts and less likely response to their application (Table 1). Adding potassium, boron and zinc fertilizers did not bring any observable yield advantage over recommended NP fertilizers. Our finding is in agreement with Birhane et al., (2017) who reported non-significant yield difference among potassium rates up to 150 kg ha^{-1}.

Table 2. Effect of treatments on grain yield ($kgha^{-1}$) at Jamma

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm5	Mean
NPS	2991	3014	3798	2834	2925	3112
NPSK	3043	3213	3565	2657	3054	3106
NPSBZn	2663	3179	3569	2922	2823	3032
NPSKBZn	2986	3186	3799	2684	3305	3192
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	13.1	5.66	8.4	12.88	11.02	14.0

Table 3. Effect of treatments on biomass yield ($kgha^{-1}$) at Jamma

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm5	Mean
NPS	7722	7611	9556	7111	7889	7978
NPSK	7556	8000	8611	6778	7944	7778
NPSBZn	6833	8056	9278	7444	7444	7811
NPSKBZn	7611	7722	9222	6833	8611	8000
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	12.93	6.36	7.9	9.76	11.51	13.74

Table 4. Effect of treatments on grain yield (kg ha^{-1}) at Meket

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Mean
NPS	2885	3011	3787	1943	2906	2906
NPSK	2485	3611	3979	2136	2964	3035
NPSBZn	3070	2944	3883	1877	2550	2865
NPSKBZn	2722	3033	3882	2091	2679	2881
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	24.32	17.62	4.88	20.12	13.79	27.74

Table 5. Effect of treatments on biomass yield (kgha^{-1}) at Meket

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Combined
NPS	8174	7275	10116	5159	7855	7716
NPSK	7391	8588	10652	5870	8290	8158
NPSBZn	8841	7333	9812	5696	6826	7701
NPSKBZn	8087	8529	10638	5768	7739	8152
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	20.8	17.45	4.42	12.5	13.52	24.59

In addition, our finding didn't support the soil fertility status map developed for the districts (MoANR and ATA, 2016) as well as the application of 100 kg KCl ha^{-1} to each parcel of agricultural land all over the country and the region recommended by ATA and MoANR. Our finding was also not in line with the findings of Wassie and Tekalgn (2013) who reported 41% yield increment over the control due to the application of potassium fertilizer. Unlike our finding, Piri, (2012) reported yield increment due to the foliar application of micronutrients may be attributed to sufficient micro nutrient content in the soils of the study areas.

For soils deficient in potassium, zinc and boron, crop yield increased through proper application of these nutrients (Chaudry et al., 2007; Dash et al., 2015; Gitte et al., 2005; Nadim et al., 2012; Nataraja et al., 2006; Sultana et al., 2016). Among the micronutrients, Zinc (Zn) and Boron (B) played key role in pollination and seed setting processes. So, their deficiency can cause poor seed formation and subsequent yield reduction. However, this effect was not observed in our study. The importance of potassium and other micronutrients including zinc and boron for crop production is clear. However, currently wheat is not responding to the application of these nutrients and resulted in no biological and economic benefits for the famers in the study districts and similar soil and agro-ecologies. The response to potassium may be attributed to the highest amount of potassium available in the soil resulting in no yield response due to the application of additional potassium to the soil (Table 1).

Furthermore, the exchangeable potassium status map developed by MoANR and ATA, (2016) excluding the K:Mg ratio showed that 99% of soils at Jamma had exchangeable potassium contents being optimum and above and 85% of soils at Meket had exchangeable potassium to be optimum and above approving the insignificant yield increment due to the application of potassium and micro nutrients. Therefore, the map developed by MoANR and ATA for the region should be improved based on the feedback from the research system.

Application of potassium, zinc and boron fertilizers are therefore incurring additional cost to the farmers for no yield advantage over the application of nitrogen and phosphorus.

Conclusion and Recommendation

The overall result of this research showed that application of K, B and Zn containing fertilizers did not bring significant yield increment over the crop and site and crop specific recommended nitrogen and phosphorus fertilizers. This indicates that application of recommended nitrogen fertilizer without the addition of K, B and Zn fertilizers is required to increase production and productivity of wheat in the study districts. So that K, B and Zn were not potentially yield limiting nutrients in the study sites and these nutrients were sufficient to support good crop growth for wheat in both areas where these experiments were conducted.

This study confirmed that for this time no need of potassium, Zinc and Boron fertilizer in the aforementioned study areas. Moreover, crop response to new fertilizers and the soil fertility status must be monitored as they will be expected to be yield limiting in the future.

References

Berhanu Debele. 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land use planning and regulatory department, Ministry of Agriculture. Addis Ababa, Ethiopia

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analyses of soils. Agronomy Journal, 54, 464–465.

Birhane Hagos, Mamo Tekalegn, Teka Kassa. 2017. Potassium Fertilization and its Level on Wheat (Triticum aestivum) Yield in Shallow Depth Soils of Northern Ethiopia. J Fertil Pestic 8: 182. doi:10.4172/2471-2728.1000182.

Chaudry, E.H., Timmer, V., Javed, A.S., and Siddique, M.T. 2007. Wheat response to micronutrients in rain-fed areas of Punjab. Soil & Environ. 26: 97-101.

Dash, A.K., Singh, H.K., Mahakud, T., Pradhan, K.C. and Jena, D. 2015. Interaction Effect of Nitrogen, Phosphorus, Potassium with Sulphur, Boron and Zinc on Yield and Nutrient Uptake by Rice Under Rice – Rice Cropping System in Inceptisol of Coastal Odisha . Int. Res. J. Agric. Sci. Soil Sci. 5(1):14-21

Gitte, A.N., Patil, S.R. and Tike, M.A. 2005. Influence of zinc and boron on biochemical and yield characteristics of sunflower. *Indian journal of plant physiology*, *10*(4), pp.400-403.

Haile Wassie and Mamo Tekaligne. 2013. The effect of potassium on the yields of potato and wheat grown on the acidic soils of Chencha and Hagere Selam in Southern Ethiopia. International Potash Institute Research Findings, 35, pp.3-8.

International Potash Institute (IPI), 2016. Technical manual on potash fertilizer.

Mandal, A., A.K. Patra, D. Singh, A. Swarup and R.E. Masto. 2007. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresour. Technol. 98: 3585-3592.

Marx, E. S. Hart, J.and Stevens, R. G. 1996. “Soil Test Interpretation Guide,” *Oregon State Univ. Serv.*

Ministry of Agriculture and Natural Resources and Agricultural Transformation Agency of Ethiopia. 2016. Soil Fertility Status and Fertilizer Recommendation Atlas of Amhara National Regional State, Ethiopia: 297 pages.

Murphy, H. F. 1968. A report on fertility status and other data on some soils of Ethiopia. Experimental Station Bulletin No. 44. Hailesilassie College of Agriculture. Oklahoma State University, 551P.

Nadim, M.A., Awan, I.U., Baloch, M.S., Khan, E.A., Naveed, K. and Khan, M.A. 2012. Response of wheat (Triticum aestivum L.) to different micronutrients and their application methods. *Journal of Animal and Plant Science 22*(1), pp.113-119.

Nataraja, T.H., A.S. Halepyati, B.T. Pujari and B.K. Desai. 2006. Influence of phosphorus levels and micronutrients on the physiological parameters of wheat. *Karnataka J. Agri. Sci.* 19**:** 685–687.

Olsen, S. R. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington: United States Department of Agriculture.

Page J.R., Miller, R.H., Keeney, D.R., Baker, D.E. and Roscoe, E.J.R. 1982. Methods of soil Analysis. II. Chemical and microbiology properties 2nd (eds.) Wisconsin, USA.

Piri, I. 2012. Effect of phosphorus fertilizer and micronutrients foliar application on sorghum yield. Annals of Biological Research, 3(8), pp.3998-4001.

Sultana, S., Naser, H.M., Akhter, S. and Begum, R.A. 2016. Effectiveness of soil and foliar applications of zinc and boron on the yield of tomato. *Bangladesh Journal of Agricultural Research*, *41*(3), pp.411-418.

Tadele Amare, Zerfu Bazie, Erkihun Alemu, Asmare Wubet, Birhanu Agumas, Mengstu Muchie, Tesfaye Feyisa and Desalew Fentie. 2018. Crop response to balance nutrient application in north western Ethiopia. Blue Nile Journal of Agricultural Research (1), pp1-14.

Tadele Amare, Tesfaye Feyisa and Yihenew G/Selassie. 2008. Response of maize, malt barely and tomato to potassium. In: Birru Yitaferu, Teshome Tessema, Zewdu Ayalew (eds.). Proceedings of the third Annual Regional Conference on Completed Research activities on soil and water management, Forestry and Agricultural Mechanization 1-4 September 2008, Amhara regional agricultural research institute ARARI, Bahir Dar, Ethiopia, pp 67-75.

Tena, W. and Beyene, Sheleme. 2011. Identification of growth limiting nutrient (s) in alfisols: Soil physico-chemical properties, nutrient concentrations and biomass yield of maize. American Journal of Plant Nutrition and Fertilization Technology, 1(1), pp.23-35.

Walkley, A., and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37, 29–38.