Effect of Potassium and micronutrient on Sorghum (*Sorghum bicolor* L. Moench) yield in the lowland areas of Eastern Amhara

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Abstract

Ministry of Agriculture and Natural Resources and Agricultural Transformation Agency developed soil fertility map (multi nutrient status and potassium status) for Amhara Region and demonstrated to farmers without research data. Field experiment was conducted in 2017/18 main cropping season at Kobo and Dawa-Chefa districts, east Amhara, to verify the response of sorghum to the application of potassium, boron and zinc containing fertilizers. The treatments were composed of NPS, NPSK, NPSZnB and NPSZnBK and arranged in a randomized completed block design with three replications. Nitrogen and phosphorus were adjusted to the location specific recommended rates using urea and NPS respectively. Potassium was applied as a straight fertilizer at the rate of 150 kg KCl ha^{-1}. All other nutrients were applied at planting while nitrogen was applied in splits; half at planting and half at forty five days after planting. Girana1 sorghum variety was used as a test crop for both districts. Composite soil samples were collected from 0-20 cm depth to determine selected soil parameters following standard laboratory procedures. Agronomic data were also collected and subjected to analysis of variance using SAS software and mean separation was done using least significant difference at 5%. The available phosphorus (33 to 45 ppm) and exchangeable potassium (4.9 to 5.6 cmol$_C$kg^{-1}) contents of the soil in both districts were very high. While the total nitrogen and organic matter contents were low for both districts. In addition, sorghum grain yield was not significantly affected by the application of potassium, boron and zinc containing fertilizers at Kobo and Dawa-Chefa districts. Moreover, in support of the crop response and soil analysis, the soil fertility map developed for the exchangeable potassium content (excluding the K:Mg) showed that more than 70% of Kobo and 99% of the Dawa-Chefa have optimum and more exchangeable potassium content. Therefore, special attention should be given to improve the soil organic matter content and nitrogen fertilizer management to boost sorghum yield. Moreover, the soil fertility map of the region as well as of the study districts should be refined and improved based on reliable data.

Keywords: Fertilizer, Grain yield, Kobo, Potassium, Sorghum, Total nitrogen

Introduction

The agriculture sector in Ethiopia is dominated by smallholders, who until recently used little technology and rely predominantly on traditional practices. Soil fertility is highly depleted from time to time due to many factors among others loss of the top soil by erosion, nutrient leaching, continuous residue removal, competing use of organic residues for different purposes. However, the status of the soil fertility of the country in general and of the region in particular was not known. Ethiopian Agricultural Transformation Agency was established since 2012 and brought soil fertility to the front and make an issue by the policy makers. MoANR and ATA developed soil fertility map of the country and regions since 2014 to 2016. The soil fertility map of Amhara region was finalized in 2016 identifying seven fertilizer types for the region.

Sorghum (*Sorghum bicolor* L. Moench) is the most important cereal crop in Ethiopia, Amhara region, North and South Wollo zones in area coverage and total production. In Amhara region, sorghum ranked second in area coverage following teff and third in total production following maize and teff (CSA, 2017/18). In North Wollo zone and Oromo special zone it ranked first both in area coverage and total production (CSA, 2016/17). Kobo and Dawa-Cheffa districts are the potential areas of the North Wollo zone and Oromo special zone where sorghum is largely produced (Aleminew *et al.*, 2015). However, the yield attained per hectare was and is by far below the national and regional average as well as the attainable yield (CSA, 2016/17 and CSA, 2017/18) due to poor soil fertility and nutrient management coupled with moisture stress.

Based on the initial soil fertility map, different blended fertilizers and K were demonstrated on farmers field by MoANR and ATA since 2014. The final soil fertility and potassium status maps developed by Ministry of Agriculture and Natural Resources and Agricultural Transformation Agency (MoANR and ATA, 2016) showed that Amhara soils are 47% deficient in NPSZnB, 46% in NPSB, 94% in K and 100% in N. The map also showed that soils of Kobo district are 95% deficient in potassium, 45% deficient in NPSZnB, 35% deficient in NPSZn, 15% deficient in NPSB and 5% deficient in NPS and Dawa-Chefa district is 95% deficient in potassium, 75% deficient in NPSB and 20% deficient in NPS. Farmers in the country and the region were advised by the Ministry and ATA to apply new blended/compound fertilizers based on the fertility maps to the specific locations and 100 kg KCl ha^{-1} to all cultivated lands in Amhara region without research data. However, the previous and recent research reports didn't support the recommendations (Murphy, 1968; Tadele *et al.*, 2008; Tadele *et al*, 2018). Therefore, the present investigation was undertaken to examine the crop response to potassium, boron and zinc fertilizers in relation to soil fertility map of the districts.

Material and methods

Description of the study sites

The research was conducted at Kobo and Dawa-Cheffa districts (where sorghum is widely grown) in the Eastern Amhara region in 2017/18 main cropping season. Kobo is located 540 km Northeast of Addis Ababa and 420 km east of Bahir Dar the national and regional capitals respectively. The geographical location of Kobo district lies between 12^{o} 08'N latitude and 39^{o} 28'E longitude at the elevation of 1468 m above sea level. The district receives a mean annual rainfall of 630 mm, and the mean maximum and minimum temperatures of 29 ^{0}C and 15^{0}C respectively with considerable year to year variation. The area is characterized by seasonal moisture stress and erratic rainfall. Dawa-Cheffa is also located about 325 km away from Addis Ababa to the Northeastern direction and 595 km east of Bahir Dar. The geographical location of the district lies between 10°01' to 11°25' N latitude and 39°41' to 40°24' E longitude with an altitude ranges from 1000 to 2500 meters above sea level. The district receives mean maximum temperature of 33°C and minimum temperature of 12°C. The mean annual rainfall of the area ranges from 600 to 900 mm with a long heavy rainy season from June to September and a short rainy season from March to May.

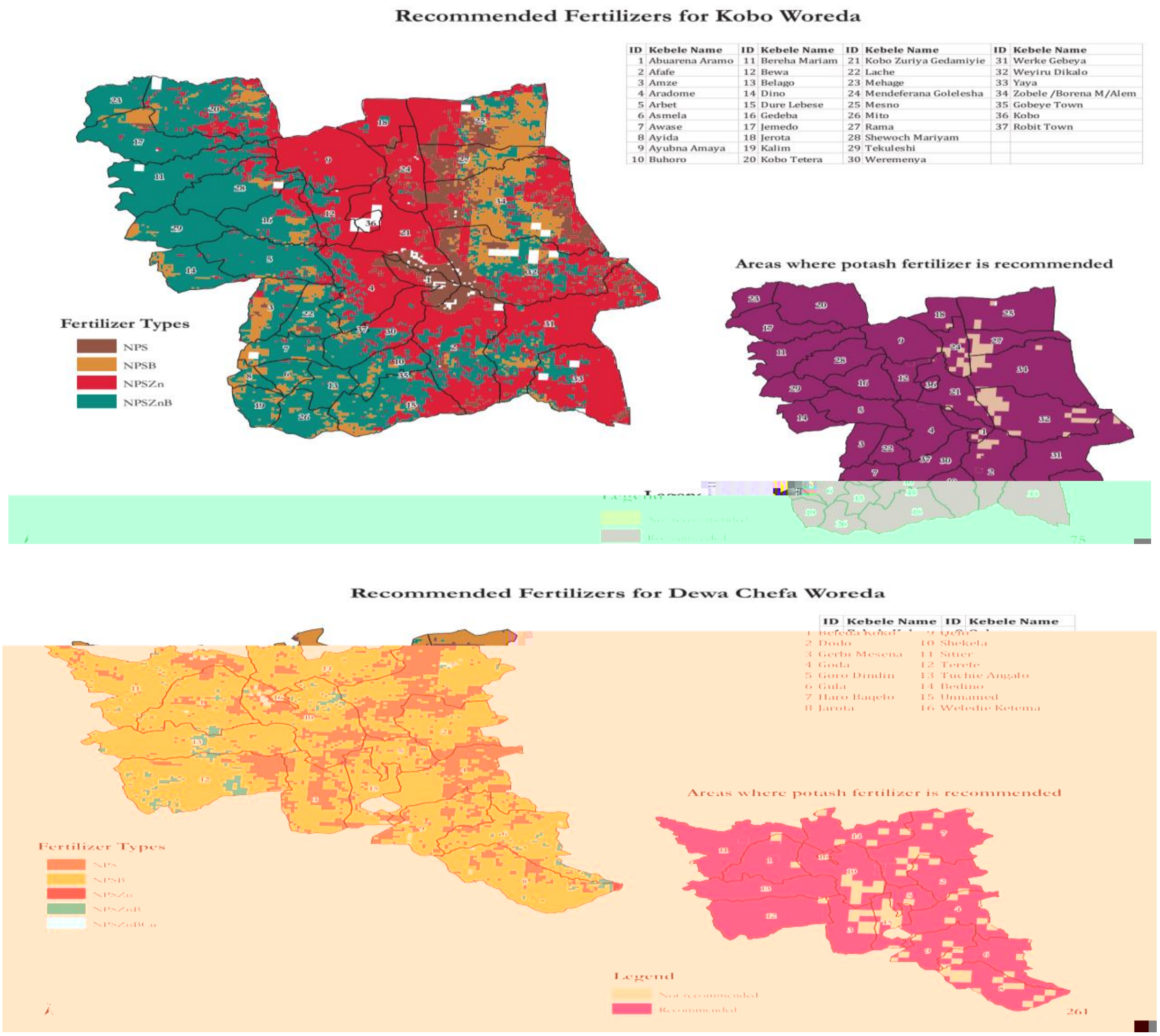

Figure1. Soil fertility maps of Kobo and Dawa-Cheffa district respectively (source; ATA and MoANR, 2016).

Treatment setup

The treatments used for the research were:

1. NPS
2. NPSK
3. NPSBZn
4. NPSKBZn

Treatments were arranged in a randomized complete block design replicated three times. The site specific recommended NP which was adjusted by urea and NPS were used uniformly for all treatments for both districts. Nitrogen, 69 kg ha^{-1} and 69 kg ha^{-1} P_2O_5 were used for both districts. The rate of KCl was 150 kg ha-^{1}. Nitrogen was applied by splitting half at planting and half at knee height. The whole rates of phosphorous and potassium chloride was applied at planting. Foliar application of B and Zn fertilizer at a rate of 1 kg ha^{-1}. Borax and 1 kg/ha Zinc Sulphate was used. The plot size was 24 m^2 (4.8m by 5m) for both districts. The space between plots and replications were 1m each. Soil and crop management practices were applied during the growth period of the crop uniformly to all treatments. Girana one Sorghum variety was used as a test crop for both districts with a spacing of 75 cm between rows and 15cm between plants.

Soil Sampling and Analysis

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

Agronomic data collection

The whole plants were harvested from the net plots excluding the border rows, sun dried and dry biomass per plot and per hectare was determined. Then the harvest was manually threshed and the grain was separated from the straw and grain yield per plot and hectare was determined. The moisture content of the grain was measured using moisture tester during threshing and the final yield was adjusted to 12.5% moisture content

Data analysis

All collected data were subjected to the analysis of variance using SAS version 9.3 and means were separated using least significant difference (LSD) at 5% significance level.

Results and Discussion

Soil physico-chemical properties of the study sites

The analysis of variance showed that the soils of both district were clay in texture (Table 1). The soil total nitrogen content ranges from 0.08% to 0.1% and 0.1% to 0.25 % for Dawa-Cheffa and Kobo respectively. Based on the classification made by Tekalign, (1991), the total nitrogen content for Dawa-cheffa was low and for Kobo was medium. The soil organic matter content for soils of Dawa-Cheffa ranges from 0.7% to 2.8 % and classified as low to medium level while that of soils of Kobo ranges from 0.88% to 2.2%, and categorized under low content (Berhanu, 1980). The available phosphorus was ranged from 33.0 ppm to 45.05 ppm for both districts indicating that the available phosphorus content very high in both districts (Marx et. al. 1999, Landon, 1991). The exchangeable potassium also ranges from 4.97 to 5.6 $cmol_c kg^{-1}$ for Dawa-cheffa and 5.1 to 5.6 $cmol_c kg^{-1}$ for Kobo. The level of exchangeable potassium for the both districts was very high (FAO, 2006) and hence crop response to potassium fertilizer is questionable. The soil reaction (pH) of the two districts was ranging from 6.6 to 6.8 and 6.5 to 6.8 for Dawa-Cheffa and Kobo study areas respectively. The soil reaction of both districts was neutral and suitable for any agricultural activity.

Table 1: Soil physic-chemical properties of the study sites before planting

Site	pH	OM (%)	Available P (ppm)	T.N (%)	Ex. K($cmol_c kg^{-1}$)	Textural class
Dawa-Cheffa	6.6-6.8	0.7-2.8	33.55-45.05	0.08-0.10	4.962-5.60	Clay
Kobo	6.5-6.8	0.88-2.2	33.85-44.45	0.10-0.25	5.081-5.60	Clay

Note: pH = power of Hydrogen; OM = organic matter; T.N = total nitrogen; P = phosphorus; Ex.K = exchangeable potassium

Effect of potassium and micro nutrients on straw and grain yields of sorghum

The overall results of this research showed that there was no statistically significant straw and grain yield differences ($p > 0.05$) among and between the treatments for both districts (Table 2,3,4 and 5). The result is in line with the previous validation study made at the same locations by Abebe and his friends (under publication) and Tadele et al., (2008) and Tadele et al., (2018) who reported that there was no significant crop responses to the application newly intrduced fertilizer products (K, B and Zn) to the country in general and Amhara region in particular including. The soil analysis results also showed that the level of potassium was above the critical limit which strength the yield response (Table 1). In addition, the soil fertility status map for both districts showed that exchangeable potassium excluding K:Mg ratio was optimum and more than optimum for more than 90% of the districts (MoANR and ATA, 2016). Adequate plant nutrition with micronutrients depends on many factors including the ability of the soil to supply these nutrients, rate of absorption of the nutrients to functional sites and nutrients mobility within the plants. In support of our result, EFMA, (2003) stated that in soils with adequate amounts of potassium readily available to plant uptake was higher and there may be no response to the application of the nutrient. However, if the nutrients are insufficiently available in the soil, many scholars reported that the response to their application could have resulted in higher grain and biomass yields (Nataraja et al., 2006; Chaudry et al. 2007; Dash et al., 2015; Gitte et al., 2005; Nadim *et. al*., 2011; Sultana et al., 2016; and Choudhary et al., 2017).

Table 2. Effect of treatments on grain yield (kg ha^{-1}) at Kobo

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Mean
NPS	5025	2688	1971	5182	3717
NPSK	5046	3628	2010	4745	3830
NPSBZn	5058	3272	3014	4797	4035
NPSKBZn	4880	3841	2344	4929	3993
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	20.0	19.1	23.2	8.9	21.2

Table 3. Effect of treatments on biomass yield (kg ha^{-1}) at Kobo

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Mean
NPS	10103	6322	5747	12205	8594
NPSK	10250	6369	5544	11522	8421
NPSBZn	10070	6459	5583	12632	8916
NPSKBZn	9394	6275	5923	12272	8460
LSD (5%)	NS	NS	NS	NS	NS
CV (%)	15.6	18.7	15.6	21.2	20.3

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

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Mean
NPS	4412	6860	3373	5690	3342	4852
NPSK	4754	6189	3397	4907	3587	4567
NPSBZn	4190	6520	3320	5803	3701	4707
NPSKBZn	4084	6845	3169	5682	3950	4763
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (%)	14.9	10.5	10.3	11.2	9.5	13.4

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

Treatment	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Mean
NPS	8719	13414	8564.1	16516	9587	11360
NPSK	10573	16269	6982	14898	10614	11867
NPSBZn	8788	11973	6813	12784	11397	10351
NPSKBZn	10318	12848	7047	16428	12080	11744
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (%)	20.4	15.2	19.3	14.3	24.9	17.98

Conclusion and Recommendation

In general, the result indicated that application of potassium, zinc and boron containing fertilizers to the soils of these districts didn’t have impact on yield increment. Hence, capitalizing mainly on the application of crop and site specific recommended nitrogen and phosphorus are still remaining central to the yield increment in both districts. Moreover, improvement of the soil organic matter base is also helps the improvement of nitrogen and phosphorus and other macro and micro nutrients. Moreover, the soil fertility status map developed for the region by MoANR and ATA in 2016 should be revised based on the feedbacks from the research system in a larger scale. However, the status of these nutrients should be monitored periodically for they could be yield limiting sometimes in the future if the soil is not well maintained.

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