Response of Sorghum (*Sorghum Bicolor* L. Moench) To Potassium, Zinc, and Boron Fertilizers in Wag-Lasta, Northern, Ethiopia

Tilahun Esubalew (✉ tilahun1215@gmail.com)

Sekota Dryland Agricultural Research Center

Workat Sebnie

Sekota Dryland Agricultural Research Center

Research

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Abstract

Background

In Ethiopia using fertilizer started in the early 1960. But it still depended solely on urea and DAP. Today, according to ATA and Ministry of Agriculture and Natural Resources K, Zn, B, S, and Cu are in deficit in Ethiopia and Amhara Region as well as in Wag-Lasta areas. But some studies conducted in Wag-Lasta and throughout the region in different crops indicate that these nutrients had no response on crop yields. So, this experiment was conducted in 2017 rain feed cropping season on five farmers' parcels per location to verify the response of sorghum to potassium, zinc, and boron fertilizers.

Methods

The treatments were: NPS, NPSK, NPSZnB, and NPSZnBK, with the recommended rate of 46 and 23 kg ha⁻¹ N and P₂O₅ respectively for Sekota, 23 kg ha⁻¹ N, and P₂O₅ for Lasta. Moreover, 150, 1.47, and 0.07 kg ha⁻¹ KCl, Zn, and B respectively used uniformly for both locations. The experiment was laid out in randomized complete block design (RCBD) with three replications. The collected data were analyzed by SAS software version 9.0.

Results

Analysis of variance revealed that the application of potassium, zinc, and boron had no significant effect ($P \leq 0.05$) on sorghum yield and yield components at all sites. The exchangeable potassium content in the soil of the study sites is high and very high. The result disagrees with the soil fertility map which showed more than 98% of potassium deficiency and more than 80% NPSZnB deficiency. Hence, the application of K, Zn, and B fertilizers had no yield advantage over the recommended N and P fertilizers in the Wag-Lasta areas.

Conclusions

Therefore, currently to increase production and productivity of crops in Wag-Lasta areas using of recommended rate of nitrogen and phosphorous with organic fertilizer sources for each district is the best option rather than using K, Zn, and B fertilizers.

Background

Agriculture is the master king of Ethiopia's economy, accounting for 34% of GDP and 85% of employment (Baye, 2017). However, the sector is not effective due to low soil fertility and inappropriate nutrient management practice. Sorghum (*Sorghum bicolor* (L.) Moench) is a viable food grain for many of the

World's most food-insecure people who live in marginal areas with poor and erratic rains and poor soils (Onyango et al., 1998). In Ethiopia, sorghum is a major staple food crop, ranking second after maize in total production. It ranks third after wheat and maize in productivity per hectare, and after teff and maize in area cultivated. It is grown in almost all regions of Ethiopia, In Sekota and Lasta districts the crop is dominant. Sorghum production and productivity have been far below the potential. Currently, the average regional productivity is 2448 kg ha⁻¹, but, in the Waghimera zone, it was 1520 kg ha⁻¹, (CSA, 2017). The reasons were poor soil fertility, moisture stress, and inappropriate inorganic fertilizer rate (Amelework et al., 2016; Sebnie and Mengesha, 2018).

In Ethiopia, fertilizer use had been started since the early 1960s (Murphy, 1968). In the past three decades, Ethiopian agriculture depended solely on imported fertilizer products of urea and di-ammonium phosphate (DAP), sources of N and P. Today, according to the Agricultural Transformation Agency (ATA) and ministry of agriculture and natural resources (2016), soil fertility inventory conducted in some woredas of the country and the region from 2012-13 not only N, and P but also K, S, B, Cu, and Zn deficiencies are widespread. The fertility map of Wag-Lasta indicates that nearly 80% NPSZnB, 47% NPSB, and 98% K were deficit in the area. But the result of diagnostic nutrient omission trial conducted in Dehana and Lasta districts on wheat and teff and the validation studies on new fertilizers across the region for different crops indicated that potassium and new fertilizers did not affect the yields of the studied crops, (SDARC, unpublished; Amare *et al.*, 2010; Amare *et al.*, 2018).

Potassium, zinc, and boron nutrients are required and indispensable for crop optimum growth, development, and production (Hasanuzzaman et al., 2018), however, in Wag-Lasta these nutrients had no significant effect on crop yield due to the areas' soil had a high amount of exchangeable potassium amount. But the extension agent widely distributes NPSB, SPSZnB fertilizers to the farmers, which expose users to extra cost. Therefore, the study was conducted to verify the response of sorghum to potassium, zinc, and boron fertilizers application and to validate the soil fertility map developed by the Ethiopian soil information system (EthioSIS).

Materials And Methods

Description of the study area

The research was conducted in 2017 rain feed cropping season in Sekota and Lasta districts in 8 kebeles at 8 farmers' fields, found in Amhara National Regional State, Ethiopia. The sites located 12°43'38"N longitudinal and 39°01'08"E latitude with the altitude of 1915 meter, 12° 43' 52.82"N Longitude and 39° 01'22.01"E with an altitude of 1915 for Sekota district, 11° 58' 50.15" N Longitude and 38° 59' 03.22"E latitude with the altitude of 1966 meters above sea level respectively. The district is semi-arid and the undulating land feature has a unimodal rainfall distribution system occurring in June, July, and August. The mean annual rainfall was 673.7 and 818.1 mm, with maximum and the minimum average temperature of 27.22⁰c, 12.77 ⁰c and 24.7 ⁰c, 13.6 ⁰c for Sekota and Lalibela respectively.

In Wag-Lasta areas crop-livestock mixed farming system is dominantly practiced. The major grown crops are wheat (*Triticum aestivum L.*), sorghum (*Sorghum bicolor L.*), teff (*Eragrostis teff (Zucc) Trotter*), barley (*Hordeum vulgar L.*), and faba bean (*Vicia faba L.*). The livestock productions are beekeeping, cattle, sheep, goat, donkey, and poultry. Soil types are: - calcic Xero, cambic Arenosols, chromic Cambisols, eutric Cambisols, eutric Regosols, Leptosols and Orthic solonchaks. Among them Eutric Cambisols are the dominant for Sekota. In Lasta district also eutric Cambisols, eutric Regosols, Leptosols and vertic Cambisols among them Eutric Cambisols and Vertic Cambisols cover most part of Lasta.

Experimental design and treatments

The treatments were NPS, NPSK, NPSZnB, and NPSZnBK. N and P fertilizers amount adjusted by the recommendation rate of 46 and 23 kg ha⁻¹ N and P₂O₅ for Sekota respectively, and 23 kg ha⁻¹ for both N and P₂O₅ for Lasta district, murite potash applied by blanket recommendation of 150 kg ha⁻¹ KCl, Zn, and B uniformly applied 0.7 and 1.47 kg ha⁻¹ for all trial sites respectively. NPS, NPSZnB, and murite potash fertilizer were added at planting time while urea was added in split application half at planting and the remains half after 30 - 45 days planting at knee height. The experiment was laid out in randomized complete block design (RCBD) with three replications. The plot size was 18.75m² (3.75 m X 5 m) and consisted of 5 rows. 1m distance was left for both between plots and blocks. Spacing of 75 and 15 cm was used between rows and plants respectively. The tested variety was Misker. All recommended agronomic crop managements were done for all treatments uniformly at their own appropriate time.

Data collection

The average plant height taking representative ten samples from each plot randomly and measured by tape meter from ground to tip of the head, length of sorghum head, grain yield was collected from central rows, while excluding border rows from each plot separately.

Data analysis

The data obtained from this research were subjected to analysis of variance using SAS software version 9.0 (SAS, 2003) and treatment effects were compared using the Fisher's Least Significant Differences test at a 5% significance level.

Table 1. Soil data at planting

Site	pH	EC	%OC	%TN	Avi.P	Exch.K		
					PPM	cmolkg ¹	S in PPM	Textural class
Tiya	6	0.12	0.80	0.03	4.79	1.26	6.53	sandy loam
Q/Abeba	6.1	0.14	0.49	0.05	23.24	0.86	7.82	sandy loam
shumsha	5.8	0.14	0.49	0.04	15.68	1.35	5.34	sandy clay loam
Rubariya	5.8	0.12	0.45	0.04	7.43	0.85	5.02	sandy loam
Woleh	5.8	0.14	0.37	0.04	7.37	0.84	6.74	lomy sand

Representative composite soil samples were collected from the surface (0-20 cm depth) at planting time from the trial sites, for the analysis of pH, EC, SOC, TN, available P, exchangeable K, S, and textural class. Each composite sample was made up of ten sub-samples. Finally, the analyzed soil data were interpreted to illustrate the current soil fertility status of each trial site. The chemical properties of soils in the experimental fields were determined using different appropriate analytical procedures of Soil in Sekota Dryland Agricultural Research Center and Tigray soil laboratory.

Soil reaction (pH) was measured from filtered suspension of 1:2.5 soil to water ratio using a glass electrode attached to a digital pH meter. Soil organic carbon was determined following the wet digestion method as described by Walkley and Black (1934). The percentage of soil organic matter was determined by multiplying soil organic carbon value by 1.724. Total nitrogen was determined by the micro-Kjeldahl digestion, distillation, and titration method (Sertsu and Bekele, 2000). Available phosphorus was determined following the Olsen method (Watanabe and Olsen, 1965). Exchangeable potassium was extracted by ammonium acetate at pH 7 method (Sertsu and Bekele, 2000). Sulfur is also determined by the Turbidity method and soil texture was determined by the bouyoucos hydrometer method (Bouyoucos, 1962; Beverwijk, 1967).

Result And Discussion

Soil analysis result at planting

The soil analysis data was important to identify the level of nutrients in the soil and to determine suitable rates and types of fertilizer for the recommendation. The average soil pH of the trial sites was 5.92, according to Tadesse (1991) it was moderately acidic. Based on the results of soil analysis as shown above in Tablec1, the average total nitrogen (%TN) ranges from 0.02-0.05, based on Tadesse (1991) it was categorized under very low and low. Besides, the available phosphorus (Av. P) was ranged from 4.79-23.24 PPM, based on Cottenie (1980); which grouped under very low, low, medium, and high class. Moreover, soil organic carbon (%OC) of the trial site was ranging from 0.37 - 0.8, as Tadesse (1991), it was very low and low, so improving soil organic amount needs immediate actions through applying

organic fertilizers sources like organic manure, compost, crop residue retention, and crop rotation (Tulema, 2005; Araya, 2010). Soil textural class was also sandy loam, sandy clay loam, and loamy sand both of them were good for crop production activities but due to its high capacity of infiltration rate, it couldn't store water for a long time in dryland areas. The exchangeable potassium of the trial site ranged from 0.84-1.35, according to FAO, (2006) it is very high and high.

Table 2
Effect of K, Zn, and B fertilizers on PH and HL of sorghum in Sekota district

	Fikreselam		Rubariya		Tiya		Woleh	
Trts.	PH.cm	HL.cm	PH.cm	HL.cm	PH.cm	HL.cm	PH.cm	HL.cm
NPS	157.97	18.56	164.07	18.4	134.65	17.33	147.8	21.07
NPSK	152.17	17.88	160.07	18.46	142.05	16.81	155.48	19.87
NPSZnB	158.22	18.24	166.17	20.4	141.2	17.46	150.4	21
NPSZnBK	149.12	18.46	156.27	17.92	138.18	17.13	158.12	19.51
LSD 5%	NS	NS	NS	NS	NS	NS	NS	NS
CV	2.62	2.48	3.1	4.02	2.84	1.48	7.8	5.6
Where: Trts presents treatment, PH refers plant height, HL stands for head length, NS represents non significant								

Table 3
Effect of K, Zn, and B fertilizers on grain yield of sorghum in Sekota district

	Fikreselam	Rubriya	Tiya	Woleh
Trts	GY Kg ha ⁻¹	GY Kg ha ⁻¹	GY Kg ha ⁻¹	GY Kg ha ⁻¹
NPS	1480	2670	1420	3230
NPSK	1370	2560	1570	3070
NPSZnB	1240	2610	1460	2910
NPSZnBK	1230	2400	1450	3100
LSD 5%	NS	NS	NS	Ns
CV	5.87	4.5	4.01	4.8
Where: GY refers to grain yield				

Table 4
Effect of K, Zn, and B fertilizers on PH and the HL of sorghum in Lasta district.

	Genet Mariam		Qechn abeba 1		Qechn abeba2		Shumsha	
	PH.cm	HL.cm	PH.cm	HL.cm	PH.cm	HL.cm	PH.cm	HL.cm
NPS	159.39a	18.83	140.47	18.82	131.1	17.4	158.4	21.26
NPSK	146.27b	17.93	146.47	20.16	131.3	16.16	171.31	22.53
NPSZnB	146.47b	17.33	143.27	17.36	126.36	17.4	164.91	22.26
NPSZnBK	147.53b	17.43	145.87	18.9	132.84	17.2	149.96	18.58
LSD 5%	7.4	NS	NS	NS	NS	NS	16.05	NS
CV	6.9	3.68	2.6	4.4	2.31	2.82	2.75	9.1

Table 5
Effect of K, Zn, and B fertilizers on grain yield of sorghum at Lasta district

Trts.	Genet Mariyam	Qechn abeba1	Qechn abeba2	Shumsha
	GY kg ha ⁻¹	GY kg ha ⁻¹	GY kg ha ⁻¹	GYkg ha ⁻¹
NPS	1710a	1080	1200	3300
NPSK	1040b	1240	860	4010
NPSZnB	940b	910	940	2860
NPSZnBK	1406a	1140	1090	3160
LSD 5%	0.3	NS	NS	NS
CV	8.4	11.75	14.16	8.43

Plant Height And Head Length

Potassium, zinc, and boron fertilizers had no significant effects, among and between treatments on plant height and head length of sorghum in Sekota and Lasta districts at ($p \leq 0.05$) Table 2 and 4. Thus the resulting matched with soil analysis results as mentioned in Table 1. When the available K in the soil was deficient or not supplied adequately, the growth would be stunted. But the amount of readily available (exchangeable) potassium in the soil to provide the crop was high. This result was in line with (Amare *et al.*, 2018; Hasanuzzaman *et al.*, 2018). Furthermore, zinc and boron have a great role in plant growth and development. However, in the case of these experimental fields, it had no significant effect on plant height and head length. It might be due to the soil full filling the required amount of Zn, and B for sorghum. This

result agreed with (Ayalew and Beyene, 2011; Amare *et al.*, 2018; Kassie *et al.*, 2019; G.Selassie *et al.*, 2020) who reported that K fertilizer application had no significant effect on crop growth parameters of sorghum, maize, wheat, potato and tef in northwestern, southern, and northeastern, Ethiopia. Though, it was contradicted with (Markos *et al.*, 2015; Berhe, 2017; Tesfaye *et al.*, 2021) who reported that K had a response on maize and wheat agronomic parameters. Similarly, it disagreed with (Pholsen and Somsungnoen, 2004; Bayu *et al.*, 2006) who reported that boron and potassium fertilizers had a significant effect on sorghum height.

Grain yield

The application of K, Zn, and B fertilizers did not significantly affect grain yield in Sekota and Lasta districts (Tables 3 and 5). The highest grain yield was obtained from the application of NPS fertilizer in most experimental fields. Whereas the lowest yield was recorded from K, Zn, and B combined with NPS. This might be due to the overdose applications of these nutrients. This finding positively correlated with soil analysis data of experimental fields as illustrated above in Table1. Although the overall yield except for Shumsha, Rubariya, and Woleh sites was low due to low soil fertility status and moisture deficit problems. But the yield was equal with (CSA, 2017; Assefa *et al.*, 2020) results. Shumsha and Rubariya sites yield similar to Sebnie and Mengesha (2018) who found 3822 and 2959 kg ha⁻¹ by using 23 kg N ha⁻¹ and P₂O₅ for Shumsha, and 46 and 23 kg N ha⁻¹ and P₂O₅ for Rubaria. There were yield variations among sites due to soil fertility variation.

K, Zn, and B has a role in growth, development, yield increment, diseases resistance, formation of different enzymes for crops (Brady and Weil, 2002), but in the wag-Lasta areas it had no yield advantage on sorghum, rather than the recommended rate of nitrogen and phosphorous fertilizers. This might be due to the soil having enough (high) amount of exchangeable potassium, the current result of this research was agreed to the diagnostic nutrient omission trial result of (SDARC, unpublished; Amare *et al.*, 2010; Amare *et al.*, 2018). Similarly, the current finding in line with Wag-Lasta areas results using 72 kg K₂O, ha⁻¹ had no significant effect on teff and wheat yield. Also, this finding is in line with G.selassie *et al.* (2007), who investigated potato tuber yield had no response for K fertilizer application in western Amhara Region, Ethiopia. Similarly, it was agreed with (Kassie *et al.*, 2019) who reported that the application of 150 kg KCl ha⁻¹ had no yield increment advantage on sorghum, bread wheat, and food barley crops in the north Shewa zone of Amhara region, Ethiopia. Simultaneously, (Ayalew and Beyene, 2011) reported that adding different rate levels of K fertilizer had no potato tuber yield increment in southern Ethiopia.

The finding of this research contradicted with soil fertility map of the Sekota and Lasta districts. The maps were developed by ATA and the ministry of Agriculture and Natural Resources (2016). It showed more than 98% of potassium deficiency and more than 80% NPSZnB deficiency. But, this study proves that K Zn and B nutrients are not a deficit in Wag-Lasta districts, rather they are inadequate amount to provide for crop optimum growth, development, and yield in the areas as shown in table 1. This study

result was contrasting with Tilahun *et al.* (2015), who reported that Zn is optimal and B below the critical level in Alichu-Woriro, woreda, Siltie zone, Southern Ethiopia. Simultaneously, it was disagreed with (Berhe, 2017; Tesfaye *et al.*, 2021) reported K fertilizer had a yield advantage on wheat in southern, Ethiopia. However, this finding disagreed with (Gebrekorkos *et al.*, 2017; Redai et al., 2018), who reported that NPKSZn, NPK, and NPSZn had yield advantage by melkam variety of sorghum than NP fertilizer in Tigray Region, Ethiopia, and Bekele (2018) who found using 120 kg ha⁻¹ K₂O increases onion yield in Jimma, Southwestern Ethiopia. Similarly, (Anjum, 2017; Nadim et al., 2012), examined that Foliar application of 1% Zn and 0.5% B had to pronounce results on maize yield and boron 2 kg ha⁻¹ recorded more grains spike⁻¹, higher grain weight, and increased grain yield of wheat.

Conclusion And Recommendations

Application of K Zn and B fertilizers had an insignificant effect on plant height, head length, and grain yield of sorghum, in Sekota and Lasta districts. In most trial sites yields obtained from NPS fertilizer are better than NPSK NPSZnB and NPSZnBK, as a result, these fertilizers had no yield advantage in the districts because the districts' soil has a sufficient amount of exchangeable potassium for optimum crop production. Soil fertility maps of Sekota and Lasta district are unrelated to the current soil status of potassium zinc and boron nutrient content. Currently to increase production and productivity of sorghum in Wag-Lasta areas using of recommended rate of nitrogen and phosphorous with organic fertilizer sources for each district is the best option rather than using K Zn and B fertilizers, and the effect of K Zn Cu B and other essential nutrients should be checked as they will be expected deficit from the soil in the long run.

Declarations

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Authors' contributions: Tilahun Esubalew and Workat Sebnie conceptualized and collected the necessary data of this study, Tilahun Esubalew analyzed, interpreted the data, and wrote the manuscript. Both authors read and approved the final manuscript.

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Figures

Recommended Fertilizers for Sekota Woreda

Fertilizer Types

ID	Kebele Name	ID	Kebele Name	ID	Kebele Name	ID	Kebele Name
1	Addis Alem	9	Edeget Chora	17	Melake Genet	25	Tiya Kidane Meheret
2	Akime	10	Etekinu	18	Mikun	26	Tsata
3	Arisheriwa	11	Fekere Selam	19	Rubaria	27	Tsemara
4	Bade	12	Finewa	20	Sewena	28	Wale Mariam
5	Berbere	13	Gebre Selam	21	Saida	29	Kebele 2 Woleh
6	Chireye	14	Hamusit	22	Selamegie	30	Yehun Abeba
7	Dabila	15	Mahebere Genet	23	Seriyal	31	Zenziba
8	Debre Berihan	16	Mehebere Selasie	24	Shemila Alebata	32	Zuna Chirkose

Areas where potash fertilizer is recommended

Legend

Figure 1
Soil fertility map of Sekota district developed by ATA

Recommended Fertilizers for Lasta Woreda

Fertilizer Types

ID	Kebele Name	ID	Kebele Name
1	Abune Yosefe	11	Nakuto Le Ab
2	Bilbela	12	Shalo Giyorgis
3	Degosach	13	Shumisheha
4	Debre Loza	14	Sorba
5	Genete Mariyam	15	Tadiyos Amiba
6	Getere Medana Ameba Tsion	16	Telfetit
7	Grareya	17	Wedebea
8	Geleset	18	Yimrah
9	Anejefate	19	Lalibela Town
10	Medage

Areas where potash fertilizer is recommended

Legend

Recommended

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Figure 2

Soil fertility map of Lasta district developed by ATA.