Effect of NPK and Blended Fertilizer Application on Nutrient Uptake and Use Efficiency of Selected Sorghum (*Sorghum bicolor* (L.) Moench) Varieties Under Rain-fed Condition in Sheraro District, Northern Ethiopia

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ABSTRACT

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop and stable food for the semi-arid small scale farming communities in the third world. Even though, it is highly adapted to different agro-ecological conditions, its yield is constrained by different factors including declining soil fertility and improper utilization of fertilizer. Results of the research conducted in Shire-Mytsebri Agricultural Research Center at Sheraro sub-site during the main cropping season of 2016 are presented in the paper. The aim was to investigate the effect of NPK; and blended fertilizer on nitrogen, phosphorus, and potassium uptake; and nutrient use efficiency of selected sorghum varieties. The treatments are comprised of factorial combination of ten levels of fertilizers including the recently recommended **[**N, P, Blanket recommendation (NP), NPK, NPS, NPKS, NPKSZn, NPKSZnB, NPKSZnB (after Agricultural Transformation Agency, ATA) and Control (0**)].** Two sorghum varieties (Melkam and Dekeba) were tested in a Factorial Randomized Complete Block Design with three replications. The data were computed using four agronomic indices, which are commonly used to describe nutrient (N, P and K) uptake and use efficiency. The results indicate that there is a significant interaction effect of fertilizer treatments and sorghum varieties on majority of the parameters studied. Application of NPKSZn blended fertilizer significantly enhanced nutrient uptake and use efficiency. The highest total N (78.70 kg ha^{-1}), P (51.19 kgha^{-1}) and K (74 kg ha^{-1}) uptake and use efficiency in Melkam variety treated by fertilizer contained NPKSZn brought higher yield (5541 kg ha^{-1}). Increasing uptake of the major nutrient elements ensured ample nutrient availability for normal growth and high yield of sorghum. Thus, application of macronutrients in combination with micronutrients increased sorghum yield and concomitantly improved N, P and K uptake, and nutrient use efficiency for the sorghum varieties used in the study. Therefore, it is recommended that in the study area and other similar areas blended fertilizer 41N-46P-13.7K-9.25S-1.72Zn kg ha^{-1} be used to achieve higher yields.

Keywords: Blended fertilizer, Nutrient uptake, Nutrient use efficiency, Sorghum, Ethiopia.

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) belongs to the family Poaceae which is the fifth most important world cereal in production after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.) in the world (Doggett, 1970; FAO, 1985).

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It is one of the most important cereal crops grown in arid and semi-arid parts of the world, evolved in semi-arid tropical Africa, India and China where it is still used as a major food grain (Taye, 2013). Sorghum, because of its drought resistance and wide range of ecological adaptation, is the crop of choice for dry regions and areas with unreliable rainfall (Taye, 2013) and it is found growing in areas unfavorable for most of the cereals (Onyango et al., 1998).

In Eastern Africa, more than 70% of sorghum is cultivated in the dry and hot lowlands where serious water deficit is the major production constraint. Most East African sorghum is grown between the altitude of 900 and 1,500 m. In Ethiopia, it is grown all over the country across various agro ecologies (12 of the 18 that cover nearly 66%); from high altitude with sufficient amount of rainfall to low lands receiving low rainfall (Taye, 2013; Geremew et al., 2004). In Ethiopia, annually 1.8 million ha of land is allotted for sorghum production and 4.3 million ton of grain is produced (CSA, 2015).

Nowadays, sorghum is attracting industries beyond animal feed elsewhere and human consumption in Africa. It is gaining commercial value in malting and brewing industries. Grain sorghum is a major cereal crop with multi-purposes in lower and mid altitude regions of Ethiopia. It is a staple food crop in the rural areas where it grows. Grain sorghum in Ethiopia is used primarily to prepare local foods such as *'injera'*, bread, thick porridge, soup, boiled grains and pop, medicinal values for some landraces is also common (Rooney and Murty, 1982).

Still the productivity of sorghum is very low, where in sorghum dominated area of Tigray 11289 kg ha-1 was obtained from the nil fertilizer (Gebremeskel et al., 2017). On the other hand, above 5100 kg ha^{-1} yield was obtained under intensive management in the same (Geremew et al., 2004). The major problem for low productivity is a decline in the soil fertility due to high soil erosion, blanket application of NP fertilizer, accompanied by lack of proper blended or balanced fertilizer application are among the major limiting factors to sorghum production in north Ethiopia. Fertilizer use in the study area has focused mainly on the application of N and P in the form of urea and di-ammonium phosphate (DAP) 100Kg ha^{-1}for almost all cultivated crops based on the blanket recommendation. Such unblended or unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, S and micronutrients (Zn and B) (EEA, 2005).

To increase production of cereal crops, increasing appropriate use of all essential nutrients is an option. Fertilizers are efficient exogenous sources of plant nutrients (Akram et al., 2007). Since plant growth and crop production require an adequate supply and balanced amounts of all nutrients (Mengel and Kirkby, 1987) in order to maximize productivity by optimizing the plant nutrient uptake, adding micronutrients such as Zn, B and Fe to NPK fertilizer can increase fertilizer use efficiency and grain yield for different cereal crops (Malakouti, 2008).

Therefore, improving the nutrient content of the fertilizer that fits to the needs of the crops is required to improve the productivity of sorghum. Blended fertilizers containing both macro and micro elements may possess this characteristic. Thus, the present study was planned with the objective to investigate the effect of NPK and blended Fertilizer on nitrogen, phosphorus, and potassium uptake, and nutrient use efficiency of sorghum.

According to the Soil Fertility Status and Fertilizer Recommendation Atlas, Ethiopian soil lacks macro- and micronutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013), in the study area in Tahtay-adyabo (lemlem), the soil lacks nutrient elements of sulfur, boron and zinc in addition to nitrogen, phosphorous and potassium. So, it is necessary to improve the nutrient content of the fertilizer that suits the needs and the productivity of the crops. Use of balanced fertilizers containing both macro- and micronutrients is one of the solutions suggested to address the problem. But, use of the balanced fertilizers demands an understanding of the interaction of the nutrient elements that applied together. Thus, a study was designed to investigate the nutrient uptake and use efficiency of sorghum varieties under the current fertilizer use and recommend suitable balanced fertilizer for the study area based on the nutrient levels in the soil and crop needs.

1.1. The Study Area

The experiment was conducted at the experimental station of Shire-Mytsebri Agricultural Research Center (SMARC) at Sheraro sub-site, which is located in southern Tigray, northern Ethiopia (Fig 1). The research was conducted during the cropping season of 2016 (July-Nov). The experimental site is situated at an altitude of 1006 m a.s.l., $14^0$24'00" N, $37^0$56'00" E. The area is characterized by hot to warm semi-arid low land plains, with a Mono-modal rainfall pattern between May and September. The mean annual rainfall for the growing season was about 676 mm. Average annual rainfalls for the last previous 2007-2016 years was 683 mm and ranges from 428 mm to 836 mm. The mean maximum and minimum air temperature of the site was 40.5^0C and 13.3^0C respectively. The soil at the test site is vertisol and the system of farming in the area is crop and livestock mixed farming system. Though, sorghum is the dominant crop in the area, it is cultivated together with sesame, finger millet, pearl millet, and legumes like chickpea by rotation in the main season. Other popular field crops in the area are vegetables, mango and papaya.

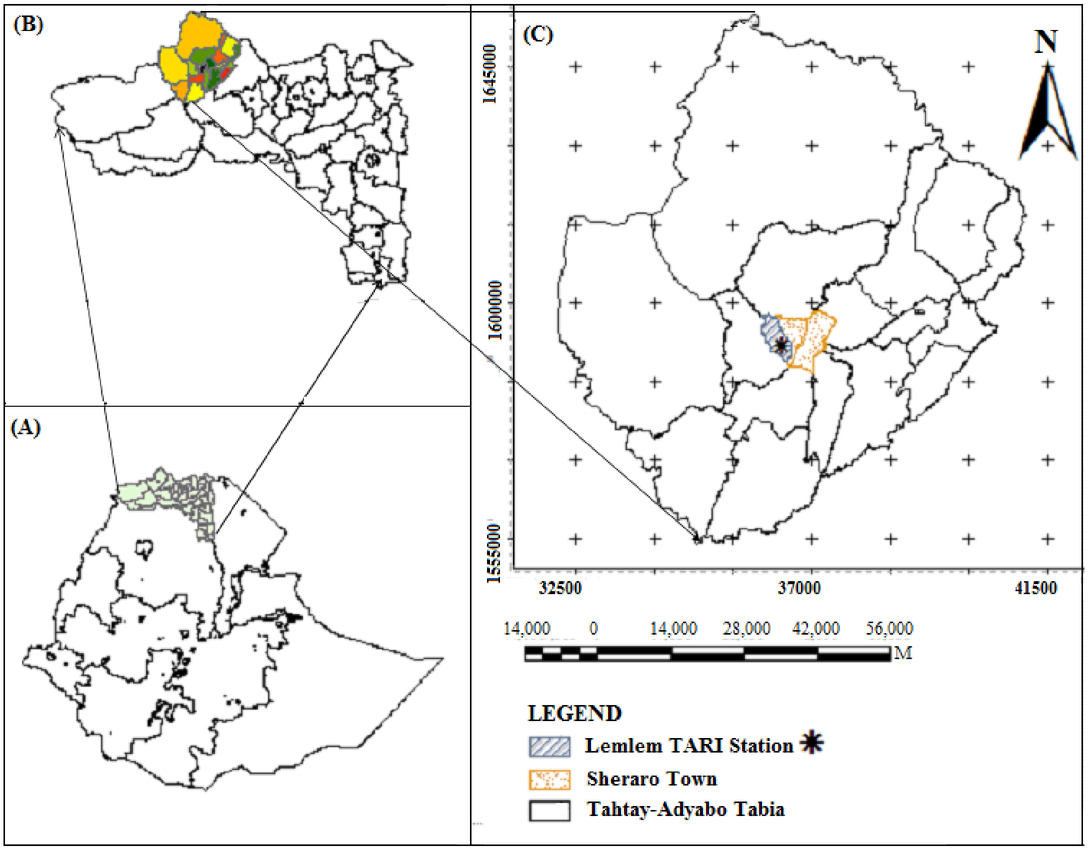

Figure 1. A) Ethiopia, B) Tigray region, and C) Study area.

2. MATERIALS AND METHODS

2.1. The Study Method

At the site, the soil type is vertisol. The soil physical and chemical properties soil used for the experiment are listed in table 1. Twenty treatment combinations *viz*., two sorghum test verities [Melkam (MSV387) and Dekeba (ICSR24004)] (Table 2) and ten fertilizer levels including the control were laid out in a factorial randomized block design with three replications (Table 3).

Table 1. Soil physical and chemical properties of the experimental soil.

pH	*Total N (%)*	*Pav (ppm)*	*K Ex (ppm)*	*CEC (meq/100g)*	*OM (%)*	*Particle size distribution*			
						Sand (%)	*Silt (%)*	*Clay (%)*	*Textural class*
7.16	0.120	27.295	618.4	21.9	1.136	14	21	65	Clay

Table 2. Description of the two improved sorghum varieties.

No	***Variety Name***	***Code***	***Year of release***	***Area of adaptation (Agro-ecology)***	***Maturity days***	***Average yield q/Ha***	***Maintaining center***
1	Melkam (MSV387)	V1	2009	Low land	118	33-45	Melkassa
2	Dekeba (ICSR24004)	V2	2012	Low land	119	41	Melkassa

Table 3. List of all combination treatment for the experiment.

Treatments	***Treatment name, composition of the fertilizer and combination***		***Code of treatment***
	Blended fertilizer (Kg/ha)	***Variety use***	
Treatment -1	41 N	Melkam	NV1
Treatment -2	46 P	Melkam	PV1
Treatment -3	Blanket recommendation (41N-46P2O5)	Melkam	NPV1
Treatment -4	41N-46P-13.7K	Melkam	NPKV1
Treatment -5	41N-46P-0K-8.47S	Melkam	NPSV1
Treatment -6	41N-46P -13.7K-8.47S	Melkam	NPKSV1
Treatment -7	41N-46P-13.7K-9.25S-1.72Zn	Melkam	NPKSZnV1
Treatment -8	41N-46P-13.7K-9.25S-1.72Zn -0.3B	Melkam	NPKSZnBV1
Treatment -9	36N-26.6P-13.7K-5.68S-1.72Zn -0.3B	Melkam	NPKSZnBV1(ATA)
Treatment -10	Control	Melkam	ControlV1
Treatment -11	41 N	Dekeba	NV2
Treatment -12	46 P	Dekeba	PV2
Treatment -13	Blanket recommendation(41N-46P2O5)	Dekeba	NPV2
Treatment -14	41N-46P-13.7K	Dekeba	NPKV2
Treatment -15	41N-46P-0K-8.47S	Dekeba	NPSV2
Treatment -16	41N-46P -13.7K-8.47S	Dekeba	NPKSV2
Treatment -17	41N-46P-13.7K-9.25S-1.72Zn	Dekeba	NPKSZnV2
Treatment -18	41N-46P-13.7K-9.25S-1.72Zn -0.3B	Dekeba	NPKSZnBV2
Treatment -19	36N-26.6P-13.7K-5.68S-1.72Zn -0.3B	Dekeba	NPKSZnBV2(ATA)
Treatment -20	Control	Dekeba	ControlV2

Note: ATA= Agricultural Transformation Agency, Ethiopia.

2.1.1. Plant Materials

The sorghum varieties used in the study are Melkam (MSV387), and Dekeba (ICSR24004). They are selected because they are well adapted to the agro-ecology of the study area (lowlands of northern Ethiopia). Seed rate was 10 kg ha^{-1} and sown manually with a spacing of 75 cm between rows and 15 cm between plants (Wilson and Myers, 1954; Adugna et al., 2005). The nutrient uptake (N, P, K), nutrient use and recovery efficiency were recorded when the crop reaches as the prescribed level.

2.1.2. Data Collection and Analysis

Crop samples of grain and stalk were taken per each treatment from each replication during harvesting time and analysis was made for N, P and K contents of the stalk and grain. The analyses were carried out at Mekelle Soil Research Center laboratory service.

2.1.2.1. Plant Tissue Analysis Method

The plant samples from above ground portion were randomly sampled from each plot at physiological maturity as described by Vanderlip (1993). During each sampling, the leaves were separated from the stems and were put in a coded paper bag. In addition, heads and the above ground vegetative parts were dried at 60°C in a forced air oven for 72 hours to a constant weight. The oven dry samples were ground using rotor mill and allowed to pass through a 0.5 mm sieve to prepare a sample of 10 g. The stalk and grain samples were analyzed for nutrient concentrations mainly for total nitrogen, P and K from each plot separately. Nitrogen was determined by the modified Kjeldahl method as described by Jackson (1958) and the concentration of P was measured using spectrophotometer after its extraction by the Olsen method (Olsen et al., 1954), whereas K was determined with flame photometer after Pratt (1965).

Nutrient uptake in grain and stalk were calculated by multiplying N content with the respective stalk and grain yield ha^{-1}. Total nutrient uptake by whole biomass was obtained by summing up the nutrient uptake by grain and stalk and was expressed as kg ha^{-1}. The following empirical formula is used to determine the nutrient uptake:

Nutrient uptake by Grain or Stalk (Kg/ha) =

(GY or SY (Kg/ha)* Nutrient concentration (Kg/ha))/100 ………………...…1

Where, GY is grain yield and SY is stalk yield

Nutrient use efficiency was calculated in the present study following Mosier et al. (2004), who reported four agronomic indices that are commonly used to describe nutrient use efficiency: the partial factor productivity (PFP, kg crop yield per kg nutrient applied); agronomic efficiency (AE, kg crop yield increase per kg nutrient applied) apparent recovery efficiency (RE, kg nutrient taken up per kg nutrient applied); and physiological efficiency (PE, kg yield increase per kg nutrient taken up).

ANUE = GY of treatment-GY of control (Kg)/Amount of nutrient applied on treatment (Kg) ………….2
NRE = (N uptake of treatment-N uptake of control (Kg)/Amount of nutrient applied (Kg))*100 ……….3
PE = Yield increase in (KG)/ Total nutrient taken up in (Kg)….………………………………...4
PEP = Crop yield in (Kg)/ Nutrient applied (Kg) ……………………………………………5

Where, ANUE = is agronomic nutrient use efficiency; PE =is Physiological Efficiency;
NRE $_{\%}$= is recovery Efficiency (%); PEP = is partial factor productivity.

2.1.2.2. Data Analysis

The collected data were subjected to statistical analysis. The analysis of variance (ANOVA) was carried out using Gen State version14 computer software Gomez and Gomez (1984). Mean separation was carried out using least significance difference (LSD) test at 5% probability level.

3. RESULTS AND DISCUSSION

3.1. Nitrogen Uptake by Grain and Stalk

The results presented in tables 4 and 5 indicates significant (P<0.001) difference in N uptake for grain both by varieties and fertilizer treatments. Similarly, wide variation in N uptake by stalk among verities is also recorded which is significantly (P<0.001) affected by the fertilizer treatments. Among the sorghum varieties, higher uptake of N is recorded from Melkam both in grain and stalk than that of Dekeba.

Due to fertilizer treatment the highest N uptake by grain (38.56 kg ha^{-1}) and stalk (37.28 kg ha^{-1}) was obtained in plot treated by NPKSZn (Table 5). While the lowest N uptake by grain (10.16 kg ha^{-1}) was recorded in control and the lowest N uptake by stalk (14.75 kg ha^{-1}) was recorded from the plot treated by P alone and statistically the same with treatment that applied N alone and control. Due to the interaction of the two factors (Table 6), highest N uptake by grain (40.15 kg ha^{-1}) and stalk (38.54 kg ha^{-1}) is recorded for Melkam treated by NPKSZn, which recorded the highest yield (5305kg/ha^{-1}). The lowest N uptake (8.72 kg ha^{-1}) in grain is recorded for Dekeba with control and stalk from Melkam treated by P alone.

Table 4. Effect of varieties on nutrient uptake.

Treatment	***Nutrient uptake(Kgha^{-1})***								
	Nitrogen			***Phosphorus***			***Potassium***		
	Grain	Stalk	Total	Grain	Stalk	Total	Grain	Stalk	Total
N	15.14e	17.32 d	32.46 e	8.80 f	8.37 e	17.16 f	11.24 d	17.62 d	28.85 e
P	13.37e	14.75 d	28.13 f	10.68 e	10.03 d	20.71 e	12.04 d	20.88 cd	32.92 e
NP	27.42 d	25.53 c	52.95 d	16.48 d	15.29 c	31.76 d	21.20 bc	26.95 bc	48.14 d
NPK	34.78b	35.69 a	70.46 b	23.16 b	22.30 a	45.45 b	27.45 a	38.68 a	66.13 ab
NPS	28.51d	30.93 b	59.45 c	17.91 cd	17.10 b	35.01 c	19.96 c	33.73 ab	53.69 cd
NPKS	29.30cd	29.09 b	58.39 c	17.96 cd	17.59 b	35.55 c	21.71 bc	33.82 ab	55.53 cd
NPKSZn	38.56a	37.28 a	75.84 a	26.50 a	23.02 a	49.52 a	28.84 a	40.00 a	68.84 a
NPKSZnB	30.89c	29.07 b	59.95 c	19.05 c	18.12 b	37.17 c	24.04 b	33.44 ab	57.48 c
NPKSZnB(ATA)	28.35d	28.35 b	56.71 c	17.95 cd	17.77 b	35.71 c	22.51 bc	36.03 a	58.55 bc
Control	10.16f	15.28 d	25.45 f	6.01 g	7.31 e	13.32 g	8.26 e	16.68 d	24.94 e
Sem	0.756	0.982	1.265	0.554	0.557	0.743	0.917	2.500	2.683
LSD	2.165***	2.813***	3.621***	1.587***	1.595***	2.127***	2.627***	7.15***	7.682***

Table 5. The effect of fertilizer treatments on nutrient uptake of sorghum.

Treatment	***Nutrient uptake (Kgha^{-1})***								
	Nitrogen			***Phosphorus***			***Potassium***		
	Grain	***Stalk***	***Total***	***Grain***	***Stalk***	***Total***	***Grain***	***Stalk***	***Total***
Melkam	26.70	26.70	53.40	17.15	15.72	32.87	20.81	30.63	51.44
Dekeba	24.60	25.95	50.55	15.75	15.65	31.40	18.64	28.94	47.58
Sem	0.338	0.439	0.566	0.248	0.249	0.332	0.410	1.118	1.200
LSD	0.968***	NS	1.620**	0.710***	NS	0.951**	1.175***	NS	3.436*

Table 6. The effect of interaction of varieties and fertilizer treatments N, P and K uptake on grain and stalk of sorghum.

Treatment	***Nutrient uptake(Kgha^{-1})***								
	Nitrogen			***Phosphorus***			***Potassium***		
	Grain	***Stalk***	***Total***	***Grain***	***Stalk***	***Total***	***Grain***	***Stalk***	***Total***
NV1	16.50 h	16.01 fg	32.51 g	9.60 g	7.48 g	17.08 h	12.43 fg	15.5	27.98 f
PV1	13.05 i	14.07 g	27.12 gh	12.62f	9.27 fg	21.89g	14.21 f	21.13	35.34 f
NPV1	27.32fg	25.56 e	52.88 f	17.77 d	15.41 e	33.18 ef	21.00 de	28.72	49.72 e
NPKV1	36.36 b	37.22 ab	73.57 ab	24.38 b	23.71 a	48.10 b	28.10b	40.13	68.23 ab
NPSV1	29.26d-g	31.31 cd	60.57 d	17.85 d	17.41 de	35.26de	20.81 de	33.40	54.20 cde
NPKSV1	31.14cde	28.41 de	59.54 de	17.78 d	16.74de	34.52de	22.8cde	34.40	57.2b-e
NPKSZnV1	40.15 a	38.54 a	78.70 a	28.51 a	23.68 a	52.19a	31.95a	42.05	74.00 a
NPKSZnBV1	31.23 cd	31.22 cd	62.45 cd	18.57 d	19.22cd	37.79d	24.1bcd	33.25	57.4b-e
NPKSZnBV1(ATA)	30.36c-f	28.89 de	59.25 de	17.95 d	17.20 de	35.14de	24 bcd	41.09	65.09abc
ControlV1	11.61 ij	15.82 fg	27.43 gh	6.49 hi	7.08 g	13.56 i	8.70 gh	16.53	25.23 f
NV2	13.77 hi	18.63 f	32.41 g	8.0 gh	9.25 fg	17.25 h	10.04 gh	19.68	29.72 f
PV2	13.7 hi	15.44 fg	29.14 g	8.74 gh	10.78 f	19.53gh	9.87 gh	20.62	30.49 f
NPV2	27.52 fg	25.49 e	53.01 f	15.19 e	15.16 e	30.34f	21.40 de	25.18	46.57 e
NPKV2	33.20 c	34.15 bc	67.35 c	21.93 c	20.88 bc	42.81c	26.81 bc	37.22	64 a-d
NPSV2	27.76 efg	30.56 cd	58.32 def	17.98 d	16.78 de	34.76de	19.12 e	34.07	53.19cde
NPKSV2	27.47 fg	29.78cde	57.25 def	18.14 d	18.44 d	36.58de	20.60 de	33.24	53.83cde
NPKSZnV2	36.97 b	36.01 ab	72.98b	24.49 b	22.36 ab	46.85 b	25.75bc	37.95	63.7a-d
NPKSZnBV2	30.54 c-f	26.91 de	57.45def	19.53 d	17.01 de	36.54de	23.98 cd	33.62	57.6b-e
NPKSZnBV2(ATA)	26.35 g	27.81 de	54.16 ef	17.95 d	18.34 d	36.29de	21.05 de	30.95	52 de
ControlV2	8.72 j	14.75 fg	23.47 h	5.54 i	7.55 g	13.08 i	7.82 h	16.83	24.64 f
MEAN	25.65	26.33	51.98	16.45	15.69	32.14	19.72	29.78	49.51
SEM	1.069	1.389	1.789	0.784	0.788	1.051	1.297	3.536	3.795
CV	7.2	9.1	6.0	8.3	8.7	5.7	11.4	20.6	13.3
LSD	3.061***	3.978*	5.121***	2.244*	2.256*	3.008*	3.714**	NS	NS

Note: N: Nitrogen, P: Phosphorus, K: Potassium, LSD: least significant difference,
CV: Covariance. Means sharing the same letter do not differ significantly at $P \leq 0.05$ according to the LSD test.

Thus, the difference in N uptake with in the treatment is due to presence of K (Sharma and Ramna, 1993) indicated that application of K released the fixed $NH4^{+}$ from soil and helped the crop for better uptake of nitrogen. A potassium plays an important role as counter ion for nitrate transport in the xylem to the shoot (Marschner, 1995), where stem-feeding of potassium malate induced increase in net uptake of nitrate and the net consumption of protons by the roots. This result is similar with the finding of Fageria et al. (2009) who reported that grain N-uptake increased significantly with nutrient availability. Maximum yield associated with highest dry matter production and stalk N-uptake increased significantly with optimum nutrient application. Similarly, Fageria et al. (2009) reported that adequate and blended form of fertilizer absolutely enhances the total nutrient uptake of N. At the same time, productivity of the crop i.e. treatment that accumulates maximum N nutrient gave highest yield.

3.2. Phosphorus Uptake by Grain and Stalk

The results presented in Table 4 that P uptake in grain and stalk showed significant difference ($P< 0.001$) among varieties. Significantly higher P uptake was obtain in the grain and stalk at Melkam than Dekeba. Due to fertilizer treatment (Table 5), there were highly significant difference ($P<0.001$) among treatments and the highest P uptake by grain (26.50 Kg ha^{-1}) and stalk (23.02 Kg ha^{-1}) was recorded in treatment treated by NPKSZn and the lowest (6.01 and 7.31 Kg ha^{-1}) respectively recorded in control.

Among the interaction of varieties and fertilizer treatments (Table 6), the highest uptake by grain was recorded from Melkam treated by NPKSZn and the lowest P uptake was obtained in Dekeba with control. The morphological traits such as plant height, dry biomass, leaf number and area per plant were significantly higher in Melkam than Dekeba, which can be among the trait variations responsible for grain and stalk nutrient intake (data are not presented here). Likewise uptake by stalk due to the interaction showed significant difference and the highest (23.71 kg ha^{-1}) in treatment Melkam treated by NPK and lowest (7.08 Kg ha^{-1}) recorded for Melkam with control. A treatment that accumulates maximum P nutrient gave highest yield.

3.3. Potassium Uptake by Grain and Stalk

The analysis of variance (ANOVA) showed that results had significant variation ($P< 0.001$) among fertilizer treatments. The highest K uptake of grain (28.84 Kg ha^{-1}) was recorded from plot treated by NPKSZn fertilizer and the lowest (8.26 Kg ha^{-1}) was recorded in plot with no fertilizer. Due to the interaction of the two factors, the highest K uptake (31.95 Kg ha^{-1}) by grain was observed from the combination treatment of Melkam treated by NPKSZn and the lowest (7.82 kg ha^{-1}) was recorded in Dekeba with control. K uptake by stalk was also significantly different (P< 0.001) among fertilizer types. The highest K uptake (40 kg ha^{-1}) on stalk was recorded in plots treated by NPKSZn and lowest (16.68 kg ha^{-1}) was from control but significant variation was not observed as a result of the interaction of the two factors.

3.4. Total Nutrient Uptake of the Elements (Grain + Stalk)

Nutrient uptake in grain and stalk as total nutrient uptake had a significant response to nutrient application (Table 4). The result showed that variety Melkam was higher total nutrient uptake than Dekeba. This might be due to genetic difference of the varieties to fertilizer demand like in the size difference. This result agreed with that of Kumar et al. (2010) who report that sorghum varieties are known to vary in their response to fertilizers.

Considering the main effect fertilizer (Table 5), higher total nutrients uptake were recorded from the plots treated by NPKSZn and associated with maximum yield. On the other hand, low nutrient uptake was obtained from control, P and N alone. Fageria et al. (2009) reported that in cereals including rice, nutrient accumulation is associated with dry matter production and yield of grain and stalk nutrient uptake increased with optimum nutrient application. The same author reported that a high yield obtained by associated with maximum yield of shoot.

The highest (204.89 kg ha^{-1}) total nutrient uptake was recorded for Melkam treated by NPKSZn and the lowest total nutrient uptake (61.19 kg ha^{-1}) was recorded from Dekeba treated with no fertilizer (Table 6). Both verities treated by N, P alone and no fertilizer were all below the mean (133.62 kg ha^{-1}). The results show that the total nutrient uptake is more important as it contain a combined application of macro- and micro-nutrients fertilizers, especially, S in addition to NPK, because S fertilization helps enhancing the uptake of N, P, K and Zn in the plant (Marschner, 1995). The same is reported by Ahmad et al. (1994) that under S deficient conditions, the efficiency of applied NPK fertilizers may be seriously affected and crop yield levels may not be sufficient and sustainable. Imran et al. (2014) also reported that maize grain increased by 55% when S was supplemented with NPK. Due to its synergistic effect, the efficiency of these elements is enhanced resulting in increased crop productivity. Raza et al. (2005) reported that uptake and efficiency of NPK nutrients was increased due to the application of their enhanced combination of nutrients to maize crop. So, maximum accumulation of N, P and K nutrients gave highest yield. Assefa (2008) reported that grain yield at maximum accumulation of nutrient occurs when nutrient rate is increased.

3.5. On Nutrient Use Efficiency (NPK)

3.5.1. Agronomic Nutrient Use Efficiency (ANUE)

The lowest agronomic efficiency (14.17 kg kg^{-1}) was recorded at the plot with Dekeba in plot received N only and the highest agronomic efficiency was found in Dekeba treated by NPKSZnB (ATA) (30.26 kg kg^{-1}).

Table 7. Effect of balanced fertilizers on ANUE, ANRE% and PNUE.

Treatment code	***Variety***	***Nutrient applied in kg ha^{-1}***	***Total nutrient uptake***	***Yield kg ha^{-1}***	***ANUE kg /kg***	***ANRE %***	***PNUE kg /kg***
NV1	Melkam	41	77.57	3219	17.93	27.68	9.48
PV1		46	84.35	3180	15.13	39.41	8.25
NPV1		87	135.78	4678	25.22	79.95	16.16
NPKV1		100.7	189.9	5168	26.65	122.82	14.13
NPSV1		95.47	150.03	4713	23.35	87.79	14.86
NPKSV1		109.17	151.28	4773	20.97	77.92	15.13
NPKSZnV1		111.67	204.89	5541	27.38	124.18	14.92
NPKSZnBV1		111.97	157.59	5118	23.52	81.60	16.71
NPKSZnBV1 (ATA)		84	159.48	4838	28.02	111.02	14.76
ControlV1		0	66.22	2484	0.00	00	0.00
NV2	Dekeba	41	79.38	2683	14.17	44.37	7.32
PV2		46	79.16	2797	15.11	39.07	8.78
NPV2		87	129.92	4520	27.79	79.00	18.61
NPKV2		100.7	174.19	5047	29.25	112.21	16.91
NPSV2		95.47	146.27	4597	26.13	89.12	17.06
NPKSV2		109.17	147.66	4577	22.67	79.21	16.76
NPKSZnV2		111.67	183.51	5305	28.68	109.54	17.45
NPKSZnBV2		111.97	151.6	5122	26.97	80.74	19.92
NPKSZnBV2 (ATA)		84	142.45	4644	30.26	96.74	17.84
ControlV2		0	61.19	2102	0.00	00	0

***Note*:** ANUE: Agronomic efficiency, ARE: apparent recovery efficiency,
PNUE: Physiological nutrient use efficiency**.**

This may be due to the increased nutrient uptake through application of combination of macro-nutrients with micronutrients appropriately to nutrient deficient soil as a result enhanced the nutrient use efficiency as well as grain productivity of sorghum. In line to this finding, Jones et al. (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. Fertilizer use efficiency for different crops increased by the application of suitable micronutrients (Malakouti, 2008). The result shows that the lowest value for agronomic nutrient use efficiency was recorded for both varieties in the plot which treated by macro nutrient P and N alone. Results showed that with increasing combination of nutrient application increased ANUE (Table 7).

3.5.2. Apparent Nutrient Recovery Efficiency (ANRE %)

Apparent Nutrient Recovery Efficiency is a measure of the ability of the crop to extract nutrients from the soil, or is portion of the applied nutrient that is taken up by the crop (NPK uptake in kg/NPK applied in kg) (Mosier et al., 2004). It is the primary index to describe the characteristics of nutrient uptake and utilization in crops. As indicated in table 7 highest agronomic efficiency was found in Melkam treated by NPKSZn (124.2%) and the lowest agronomic efficiency and was recorded at the plot with Melkam in plot received N (27.7%) and P (39.4%) only. The increment is due to application of combined macronutrients with micronutrients in appropriate form of fertilizer. Similar to this finding, Jones et al. (2011) stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. This may be due to the effectiveness of Zn functions in plant physiology, Uchida (2000) reported that lowest value was recorded in treatments that receive one single fertilizer [N and P alone i.e. N41 (36%), P46 (39.24%)]. In general, it has been shown the increment of fertilizer use efficiency for different crops by the application of suitable micronutrients (Malkouti, 2008).

3.5.3. Physiological Nutrient Use Efficiency (PNUE)

The highest value was recorded in plots where variety Dekeba treated by NPKSZnB (19.92 Kg Kg^{-1}) and the lowest value was recorded in plot Dekeba treated by N (7.32 Kg Kg^{-1}). This indicates the synergic effect of the elemental combination in mineral intake. Most of the fertilizer treatments showed high PNUE with increasing combined nutrient application especially with Zn. The result showed that yield increased per kilogram nutrient accumulated in sorghum plant was increased with increasing a combination nutrient application. This result is similar to reported by Malkouti (2008) adding micronutrients to NPK fertilizer can increase fertilizer use efficiency and grain yield for different cereal crops. It is also reported that the micronutrient deficiency specifically Zinc resulting in severe losses in yield and nutritional quality particularly areas of cereal production in rain fed production in many parts of the world (Alloway, 2008; Srinivasarao et al., 2009).

4. CONCLUSION

In the study area, use of fertilizer has focused mainly on the use of nitrogen and phosphorous fertilizers in the form of urea and di-ammonium phosphate (DAP) for almost all cultivated crops. Such unbalanced application of plant nutrients with least study might have aggravated the depletion of nutrient elements in soils including the recently identified K, S and micronutrients (Zn, B). The results of this experiment has substantiated the importance of micronutrients (Zn and B) in combination with macronutrients NPK fertilizers in improving nutrient concentration and uptake and has confirmed the significant yield increase in sorghum varieties. The total nutrient uptake and fertilizer use efficiency in Melkam variety treated by fertilizer containing NPKSZn brought significantly higher yield (5541 kg ha^{-1}). Therefore, it can be concluded that application of macronutrients in combination with micronutrient increased sorghum yield and concomitantly improved N, P and K uptake and its nutrient use efficiency of sorghum varieties. Among the microelements the contribution of boron in yield increment was relatively low. Therefore, NPKSZn blended fertilizer can be recommended for increased sorghum productivity particularly in the study area. Further studies are also recommended for fertilizer rate and time of application in sorghum production.

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