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Evaluation Performance of Improved Sorghum Varieties (Sorghum *Bicolor* L. *Moench.*) and Their Response to Blended Fertilizer at Tole, Western Ethiopia

Segni Belissa*, Temesgen Bacha

Department of Plant Science, Wallega University, Gimbi, Ethiopia

Email address:
segbelissa@gmail.com (Segni Belissa)

*Corresponding author

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Abstract: Lack of suitable varities and decline of soil can cause asubstantial yield loss in Sorghum in Ethiopia. An experiment was conducted at Tole Kebele 2022/2023 main cropping season. Three Sorghum Varieties (Merera, Jaba, Local) and Five rates of NPS fertilizer (0, 50, 100, 150,200 kg ha^{-1}) were laid out in randomized complete block design (RCBD) with factorial arrangement with three replications. Days to heading (P>0.01) was signifantly affected by varities but not affected signifantly by NPS rate. The earliest day to head was recoreded at Jaba Variety while the longest day was recorded at local Variety. Plant height also Significantly affected by intrercation between Variety and NPS fertilizer rate. The highest (218.3 cm) plant height was recorded at Local with 200 kg ha^{-1}NPS. Varierty and NPS was significantly affected by Panicle length. The height panicle length was recorded at Local varierty and 200 kg NPS. Leaf area was (P>0.001) affected by interaction between variety and NPS fertilizer rate. The Maximum leaf area (2549 cm^2) was recorded at local variety with 200 kg while the lowest leaf area (1161 cm^2) was recorded at Jaba variety with 0 NPS. Grain yeild is also (P>0.05) affected by interaction between Variety and NPS rate. the highest Grain yeild (2986 kg ha^{-1})was recorded at Merera variety with 200 kg ha^{-1} while the mimium yeild (1141 kg ha^{-1}) was recorded at Jaba variety with 0 kg ha^{-1}. Regarding economic analysis, the maximum (44678 Birr ha^{-1}) net benefit and the maximum (161.16%) marginal rate of return (MRR) was recorded at the combination of merera 200 kg NPS and Jaba 200 NPS respectively.

Keywords: Sorghum, NPS Rate, Varierty

1. Introduction

Sorghum (Sorghum *bicolor* L. *Moench*) is a cereal crop which belongs to Poaceae family and it is one of the most important cereal crops worldwide. It is the fifth most important cereal crop next to Wheat, Maize, Rice and Barley [10]. It is a staple food in drier parts of tropical Africa, India and china [18]. Sorghum supports about 300 million people in Sub Saharn Africa [4].

Regarding Sorghum production in world in year 2021/2022 United States produced 11.4 million metric tons of Sorghum following by Nigeria and Ethiopia which 6.8 and 5.2 million metric tonnes respectively [20]. In Ethiopia is grown almost in all areas of the country covering an area of 1.8 million areas of land [7]. Sorghum is second important stable crop next to Maize in terms of production and third in terms of productivity per hectare next to Maize and Teff [4]. Similarly it was reported that Sorghum is important cereal crop in terms of area coverage in Gimbi district next to Maize. The productivity of Sorghum is 12 qt ha^{-1} when compared with national average yield and productivity (27.26 qt ha^{-1}) [10]. This is attributed to different biotic and abiotic constrains among these, lack of improved varieties and declined soil fertility the major constraints in Gimbi district.

Lack of improved varieties makes farmers to use low resistant to diseases and low yield producing local varieties. Although Sorghum is second important cereal crop in the district. There is no available improved varieties of sorghum

thus there is lack of information about performance of different varieties of Sorghum in the study area. The other constraints affecting sorghum production is decline of soil fertility. It was reported that soil fertility is major challenge in African agriculture in particular in Ethiopia [19]. Similarly [1] states that moisture stress and low soil fertility are the major constraints of Sorghum production. N deficiency is among the top constraints that affect sorghum production in East Africa including Ethiopia [24]

It was reported that Balanced fertilizer amended with enough amount of nitrogen and phosphorous on sorghum gave the highest yield, nutritional content as well as high economic return [11]. Besides, application of macronutrients in combination with micronutrient increased sorghum yield and at the same time improved N, P and K uptake and its nutrient use efficiency of sorghum varieties [22]. These indicate that it is possible to increase the productivity of Sorghum however the amount of fertilizer to use varies from place to place. Since there is limited information about fertilizer use of the crop in the study area, it is important identify the amount of fertilizer needed to increase the yield of Sorghum therefore the objective of the study will be:

1. To evaluate the performance of adaptability of improved varieties
2. To identify the optimum fertilizer rate of sorghum Varieties in the study area.
3. To identify the economically feasible fertilizer use rate for higher yield of Sorghum

2. Litrature Review

2.1. Botanical Description and Importance of Sorghum

Sorghum (*Sorghum bicolor* (L.) Moench) is an important crop which belongs to a grass family *Poaecae.* It is C4 plant which is diverged from Maize 15 million years ago [8]. It is an annual plant, monoecious, tall, with one to many tillers originating from the base or stem nodes. The stem (culm) is solid, usually erect; leaves alternate, simple, long leaf sheath often with waxy bloom with band of short white hairs at base near attachment and articulated, ligule short, blade lanceolate or linear lanceolate, initially erect later curving, margins flat or wavy [16]. The inflorescence of sorghum is a compact panicle. The peduncle is usually straight and its length varies from 75 to 500 mm. Each panicle contains from 800 to 3 000 kernels which are usually partly enclosed by glumes. The color of the glumes may be black, red, and brown or tan [17].

Sorghum is used in various ways in Ethiopia its grain is used for human consumption such as Injera, bread, porridge, nifro, infant food, syrup, local beverages like "tella "and "Arake" [19]. The stove remaining after harvesting the grain is cut and fed to cattle, sheep and goats, or may be grazed. Some farmers grind harvested stover and mix it with sorghum bran or salt to feed livestock

2.2. Effect of Nitrogen and Phosphorus Fertilizer Rate on Yield and Yield Component of Sorghum

Nitrogen, Phosphorus and Potassium are macronutrients these nutrients are taken by plants in large amount. Nutrients from the soil can be lost due to leaching of nitrogen, phosphorus fixation, soil erosion and removal by crops [13]. The removed nutrients can be maintained through crop rotation, addition of organic and inorganic fertilizer [23]. Inorganic fertilizers are important inputs in any agricultural production system because they supply the required nutrients in a readily available form for immediate plant use[12].

Different experiments were conducted on Sorghum performance under different doses of nitrogen and phosphorus fertilizers. Experiments conducted on Derashe woreda indicated that plant height and plants with heading were not significantly affected by N-P fertilizer rate whereas Biomass weight and grain yield was significantly affected by N-P fertilizer rate. The maximum yield (3895.8 kg ha $^{-1}$) was recorded at 92 kg N and 30 kg P_2O_5 although it is not significant at 46 kg N and 10 P_2O_5 [18]. On the other hand, experiment conducted in Miesso district for two seasons indicated that rate of Phosphorus fertilizer rate did not affected the yield and biomass of sorghum but the grain yield was affected by Nitrogen rate, the maximum yield was recorded at a rate of 46 kg ha^{-1} N [3]. [14] reported that number of tiller, grain yield and Stover yield showed significantly affected by Nitrogen rate and the maximum yield (3.7 t ha^{-1}) was recorded at N rate of 87 kg ha^{-1} In general this findings show that the rate of fertilizer rate at which maximum yield recorded varies from area to area thus there should be specific fertilizer recommendation for specific area.

3. Material and Methods

3.1. Description of Study Area

The Experiment was conducted at Gimbi district in Tole Kebele. The experimental area is 46 km far from Gimbi Town. The study area has an altitude of 1870 m.a.s.l, the maximum and minimum annual temperature is 26 and 13.2°C respectively and the annual rainfall of the area is 1920 mm.

3.2. Experimental Materials

The experimental materials used for these experiments will be Two improved Sorghum varieties and a local variety and their description is listed in the table below.

Table 1. *List of Varieties used for the experiment.*

Varieties	Year of release	Released by
Merera	2020	NA
Jaba	-	BARC
Local	NA	NA

Source: [15]

NPS fertilizer will be used to supply Nitrogen and Phosphorus

3.3. Experimental Design and Treatments

The treatment consists of sorghum Varieties as one factor and five different NPS rate (0, 50, 100, 150, 200 kg ha^{-1}). The experimental design was laid out in Randomize Complete Block design in Factorial arrangement with three replications. The number of treatments will be Fifteen

3.4. Experimental Procedure

The experimental site was ploughed and harrowed before sowing. The crop was sown June 12, 2022. Plot size was 3 m x 4 m (12 m^2) and the spacing between plant was 20 cm whereas between row was be 75 cm. The space between block and plot was 1.5 m and 0.5 m respectively. 9.6 m^2 (3.2 m x 3 m) was net plot size was used for the collection of data. Fertilizer NPS will be applied at a planting all other agronomic practices will be applied to each plot equally.

3.5. Data Collected

1. Days to heading (days): was counted when 50% of plot shows heading is observed.
2. Plant Height (cm): was measured by taking five plants and their average will be taken.
3. Panicle length (cm): was measured by taking five plants and their average will be taken.
4. Leaf area (cm^2): was calculated by the following formula
5. length × width of leaf no. 4 ×6.18 (6.18 LW_4) after multiplying the constant 0.75×leaf no. 4 constant [9].
6. Grain Yield (Kg ha^{-1}): was recorded from the net plot area. The yield (kg ha^{-1}) was adjusted at 12.5% moisture content of the grains by using the following formula.

Yield (at 12.5% grain moisture) = Grain yield × (100 – actual grain moisture %) /87.5

3.6. Statistical Analysis

Data collected was subjected to Analysis of Variance using Genstat software (GenStat® for Windows™15th ed., 2012). A significant difference between treatments will be delineated by LSD (Least significance difference) test at 5% level of significance.

3.7. Economic Analysis

The economic analysis was carried out by using the methodology described in [6] in which prevailing market prices for inputs at planting and for outputs at harvesting used. All costs and benefits were calculated on hectare basis.

4. Result and Discussion

4.1. Days to Heading (Days)

Anaylsis of Variance indicates that days to heading was significantly (P<0.05) affected by Sorghum varieties. Jaba produced has the earliest day of emergence while the latest number of heading was recorded at Local variety. this might be due difference in genetic make up of varieties. This result is inline with [21] also reported that days to heading was significantly affected by sorghum varieties varieties and the local varities have the longest day to heading. However, Days to heading was not significantly affected by differnent rate of NPS rate.

Table 2. *Effect of Sorghum Varities on days to heading.*

Treatment	Days to heading
Jaba	104.0 [a]
Merera	119.7[b]
Local	124.2[c]
LSD (5%)	8.086
CV(%)	4.2

Means in the columns and rows followed by the same letters are not significantly different from each other at 5% level of significance according to LSD's test.

4.2. Plant Height (cm)

Anaylsis of Variance indicates that Plant height was significantly (P>0.01) affected by interaction of Varieties and NPS rate. The highest plant height was recorded at Local variety with 200 kg NPS rate (248 cm). This might be due the combination effect of genetic varabiility and higher rate of NPS while the lowest height was recorded Merera variety at 0 kg (175 cm). this result is inline with [2] maximum plant height was recorded at plants treated with NPS fertilizer when compared with control plot. similarly [11]. reported that Plant height increases with increment of fertilizer application from nil to blended fertilizer type, however, [5] reported that Plant height was not significantly affected by NPS rate.

Table 3. *Efffect of different Sorghum varities and NPS rate on Plant height.*

NPS Rate Kg ha^{-1}	Varities		
	Merera	Jaba	Local
0	175.5 [d]	121.2 [f]	197.7[c]
50	194.3 [c]	153.3 [e]	197.9[c]
100	220.2 [b]	150.0 [e]	220.2[b]
150	213.3 [b]	150.7 [e]	243.7[a]
200	218.3 [b]	193.7 [c]	248. [a]
LSD (5%)	11.49		
CV(%)	3.6		

LSD (Least Significant difference), CV (Coefficient of variation). Means in the columns and rows followed by the same letters are not significantly different from each other at 5% level of significance according to LSD's test.

4.3. Panicle Length (cm)

Analysis of variance indicates that varieties and NPS rate were significantly affected by panicle length however there interactaction effect is not significant. The highest panicle length was recorded at local variety next to local variety Merera variety produced the highest pancle length which is statistically as par with Jaba variety. This is due to genetic differences varieties the local variery has vigorous growth than other varities.

Regarding the effect of NPS rate, the highest pancle length was recorded at 200 kg ha^{-1}(12.09) which is statically as par with 150 NPS rate. The lowest panicle length was recorded at control plot. The result was in conformity with the finding reported that tallest panicle length was recorded from the plot treated by NPKSZn fertilizer and the shortest panicle length was recorded from the control [22].

Table 4. *Effect of different sorghum varieties and NPS rate on Panicle length (cm).*

Treatment	Panicle Length (cm)
Varerity	
Merera	10.21^{b}
Jaba	10.33^{b}
Local	13.61^{a}
NPS rate Kg ha^{-1}	
0	10.71 ^{c}
50	10.70 ^{c}
100	11.59 ^{b}
150	11.84 ^{ab}
200	12.09 ^{a}
LSD (5%)	0.8617
CV(%)	4.5

LSD (Least Significant difference), CV (Coefficient of variation). Means in the columns and rows followed by the same letters are not significantly different from each other at 5% level of significance according to LSD's test.

4.4. Leaf Area (cm^2)

Anaylsis of variances indicates that Leaf area was significantly (P> 0.01) by the interaction effect of variety and NPS rate. the largest leaf area was recorded at local at 200 NPS kg ha^{-1} (2549 cm^2) which is satataically as par with Merera variety with 200 and 150 kg NPS while the lowest leaf area is recorded at Jaba with 0 kg ha^{-1} NPS. this is might be associated with genetic differnces among the vareties as well as response to NPS fertilizer. similarly [25] reported that The lowest leaf area index was observed on control treatments and highest value was observed on 46 kg N and 100 kg NPS ha^{-1}. The increase in leaf area due to the application of nitrogen and NPS fertilizer may be due to the addition of nitrogen, phosphorus and sulfur fertilizer which might contribute to the availability of soil nutrients to.

Table 5. *Effect of different sorghum varieties and NPS rate on leaf area (m^2).*

NPS Rate Kg ha^{-1}	Varities		
	Merera	Jaba	Local
0	1553 ^{ef}	1161 ^{g}	1713 ^{e}
50	1591 ^{ef}	1625 ^{ef}	2034 ^{d}
100	1601 ^{ef}	1625^{ef}	2714 ^{a}
150	2438 ^{abc}	1570 ^{ef}	2194^{cd}
200	2359 ^{bc}	1614 ^{ef}	2549 ^{ab}
LSD (5%)	300.9		
CV(%)	9.6		

LSD (Least Significant difference), CV (Coefficient of variation). Means in the columns and rows followed by the same letters are not significantly different from each other at 5% level of significance according to LSD's test.

4.5. Grain Yeild (kg ha^{-1})

Anaylsis of variance indicates the grain yield was significantly (P> 0.05) affected by interaction between varieties and NPS rate. The highest grain yield(2986 kg ha^{-1}) was recorded at Merea with 200 kg ha^{-1} which is statically as per with Merera 150 kg ha $^{-1}$ while the lowest yield recorded at Jaba with 0 kg NPS. This is might be due to merera has more number of kernel when compared with other variety and also it less susceptible to pests when compared with other varieties. regarding the rate of NPS the highest yeild was recorded at NPS 200 kg ha^{-1} while the minimum yeild was recorded at control plot this result agrees with [11] who reported that the maximum grain yield was obtained from the fertilizer types blended NPSZn, while the lowest yield was obtained in unfertilized plots.

Table 6. *Effect of different sorghum varieties and NPS rate on Yeild (kg ha^{-1}).*

NPS Rate Kg ha^{-1}	Varities		
	Merera	Jaba	Local
0	2071 ^{d}	1141^{h}	1172 ^{gh}
50	2350 ^{c}	1166 ^{h}	1189 ^{fgh}
100	2529 ^{bc}	1288 ^{fgh}	1226 ^{fgh}
150	2704 ^{ab}	1416 ^{f}	1276 ^{fgh}
200	2986 ^{a}	1745 ^{e}	1408 ^{fg}
LSD (5%)	241.59		
CV(%)	8.4		

LSD (Least Significant difference), CV (Coefficient of variation). Means in the columns and rows followed by the same letters are not significantly different from each other at 5% level of significance according to LSD's test.

4.6. Economic Anayisis

Partial budget analysis was calculated to determine economic feasibility of different rate of NPS fertilizer as shown in (Table 7). The highest variable cost was at 200 Kg ha^{-1} NPS treatment (6802.5 Birr ha^{-1}). The economic analysis indicated that the highest net benefit (44678 Birr ha^{-1}), was obtained Merera Variety with 200 kg ha-1 followed by the application 150 kg with merera variety. Application of Jaba Variety with 200 kg ha-1resultedin maximum marginal rate of return (161.16%). According [6] the minimum acceptable range of Marginal rate of return should range between 50 to 100 %. In general, cost benefit analysis showed that application of jaba and merera variety with 200 kg NPS Kg ha^{-1} results high economic return.

Table 7. *Effect of variety and NPS fertilizer rate on relative economic return of Sorghum at Tole Kebeble.*

	Treatment	Adj. GY	GFB	TVC	NB	MRR %
1	Merera + 0 kg ha^{-1}	1863.9	37278	-	37278	-
2	Merera +50 kg ha^{-1}	2115	42300	2267.5	40032.5	121.47
3	Merera + 100 kg ha^{-1}	2276.1	45522	4535	40987	42
4	Merera + 150 kg ha^{-1}	2433.6	48672	6802.5	41869.5	38.9

	Treatment	Adj. GY	GFB	TVC	NB	MRR %
5	Merera + 200 kg ha^{-1}	2687.4	53748	9070	44678	123.85
6	Jaba + 0 kg ha^{-1}	1026.9	20538	-	20538	D
7	Jaba + 50 kg ha^{-1}	1049.4	20988	2267.5	18720.5	D
8	Jaba + 100 kg ha^{-1}	1159.2	23184	4535	18649	D
9	Jaba + 150 kg ha^{-1}	1274.4	25488	6802.5	18685.5	1.6
10	Jaba + 200 kg ha^{-1}	1570.5	31410	9070	22340	161.16
11	Local + 0 kg ha^{-1}	1054.8	21096	-	21096	D
12	Local + 50 kg ha^{-1}	1070.1	21402	2267.5	19134.5	D
13	Local + 100 kg ha^{-1}	1103.4	22068	4535	17533	D
14	Local + 150 kg ha^{-1}	1148.4	22968	6802.5	16165.5	D
15	Local + 200 kg ha^{-1}	1267.2	25344	9070	16274	4.78

Price of Sorghum 20 birr kg; Price of NPS 4535 birr / 100

5. Summary and Conclusion

An experiment was conducted at Tole Kebele to evaluate the performace of Sorghum varieties with different rate of NPS fertilizer in 2022/2023 main cropping season. The experimnets consists of three Sorghum varieties (Merera, Jaba & local) with five differnent rate of NPS fertilizer (0, 50, 100, 150, 200 kg ha^{-1}) were laid in factorial arrangement in a randomized complete block design (RCBD) with three replications.

Days to heading was significantly (P>0.001) affected by Sorghum varieties the earliest day to heading was recorded at Jaba variety. Plant height also Significantly (P>0.01) affected by interaction between varierty and NPS the maximum plant height (248 cm) was recorded at local variety with 200 kg ha^{-1} NPS. Although there is no interaction effect between Variety and NPS, Pancle length also significantly affected bv both Variety and NPS rate. Maximum Panicle was recorded at Local varierty and 200 kg NPS. Interaction between Variety and NPS rate was significantly affected by Grain yield, The maximum Grain yield (2986 kg ha^{-1}) was recorded at Merera 200 NPS kg ha^{-1}, while the minimum (1141 Kg ha^{-1})grain yeild was recoreded at Jaba with 0 Kg ha^{-1}.

Regarding economic analysis, the maximum (44678 Birr ha^{-1}) net benefit and the maximum (161.16%) marginal rate of return (MRR)were recorded at the combination of merera 200 kg NPS and Jaba 200 NPS respectively

In general, it could be concluded that application of 200 Kg ha^{-1} NPS with Jaba and Merera variety was found optimal for high net benefit and marginal rate of return. However, as the experiment was conducted for one season, the experiment has to be repeated at different locations and seasons to get conclusive results and recommendation.

List of Accronyms and Abbrevation

ANOVA: Analysis of Variance

Assosa ARC: Assosa agricultural research center

BARC: Bako Agricultural research center

CIMMYT: The International Maize and Wheat Improvement Center

CSA: Central Statistical Agency

FAO: Food and Agriculture Organization

ICARDA: International Center for Agricultural Research in the Dry Areas

LSD: Least signifant difference

MoEF & CC: Ministry of Environment, Forest and Climate Change

N: Nitrogen

P: Phosphorus

ORCID

009-009-0661-1594 (Segni Belissa)

Conflicts of Interest

The authors declare no conflict of interest.

Appendix

Table 8. *ANOVA table for growth parameters of Sorghum as affected by Varieties and NPS at Tole in 2023 main cropping season.*

Source of variation	DF	Mean Square				
		DH	PH	PL	LA	GY
Block	2	67.09	11.40	0.4608	46301	33088
Variety	2	1685.091**	18351.92**	55.734**	2296110.**	7542663**
NPS rate	4	20.92^{ns}	3935.97**	3.7643**	746289.**	450292 **
Variety x NPS rate	8	18.42^{ns}	380.22**	1.1700^{ns}	232527.**	59199*
Error	28	23.37	47.22	0.2654	32374	20866
CV			3.6	4.5	9.6	8.4

Where, DH = Days to heading; PH= Plant height; PL= Pancle Length; LA = Leaf area; ns= non – significant,* Significant, ** highly Significant.

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