RESEARCH ARTICLE

Differential productivity response of rain fed sorghum (*Sorghum bicolor* L.) genotypes in relation to graded levels of nitrogen in Kellem Wollega zone of Ethiopia, East Africa

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ABSTRACT

Field experiment was conducted at Haro Sabu Agricultural Research Center using three sorghum genotypes (Lalo, Chemada and Local) during the rainy cropping season of 2014 with an objective to determine the effect of nitrogen rates on growth and yield parameters of sorghum genotypes. The treatments consisted of factorial combination of four nitrogen rates (0, 46, 92 and 138 kg N ha^{-1}) and three sorghum genotypes (Lalo, Chemada and Local variety) tested in a Randomized Block Design with four replications. The results revealed that there was significant effect of N rates on days to 50% flowering, days to 50% physiological maturity, plant stand, Lodging percentage, leaf area at 90 and 120 DAS, leaf area index, number of green leaves/ plant , biological yield, grain yield, and harvest index. There was significant interaction effect of N rates and sorghum genotypes on most of the parameters studied. Significantly higher grain yield was obtained in response to the application of 92 kg N ha with Lalo genotype, which was comparable with Local variety fertilized with 92kgN/ha. The genotype chamada exhibited response up to 46kgN/ha .The superior productivity performance of genotype Lalo could be attributed to better growth in terms of plant stature, more productive tillers, more assimilatory surface,LAI,1000seed weight, and panicles/plant leading to better harvest index than the other genotypes. Across genotypes, increased N rates delayed flowering, physiological maturity ,increased lodging ,enhanced plant height, tillers /plant, leaf area, panicles /plant, grain yield, harvest index; but showed no discernible influence on leaf number/plant, LAI, and test seed weight.

Key words: Growth, yield, nitrogen rates, Sorghum varieties.

INTRODUCTION

Sorghum (*Sorghum bicolor* L.) is an important drought tolerant rain fed cereal largely cultivated for food, feed and fodder by subsistence farmers in some African countries Mali, Ghana and Ethiopia. In some parts of the world, it is consumed as staple food and is also used in the production of a variety of by-products like alcohol, edible oil, and sugar. Cereals are the major food crops in Ethiopia, both in terms of the cover and volume of production (CSA, 2006). Sorghum is the fifth most important cereal crop worldwide. In the year 2005, sorghum was grown worldwide on 43,727,353 ha with an output of 58,884,425 metric tons (FAO, 2005). Of the total grain crop production area, 79.46 % (8.1million hectares) was under cereals. Teff, maize, sorghum and wheat share 22.08% (2.2 million hectares), 15.00% (1.5 million hectares), 14.43% (nearly 1.5 million hectares) and 14.35% (nearly 1.5 million hectares) of the grain crop area, respectively (CSA, 2006). Cereals contributed 86.86% (more than 116.2 million quintals) of the grain production. Maize, wheat, Teff and sorghum made up 24.93% (33.4 million quintals), 16.58% (22.2million quintals), 16.26% (21.8 million quintals) and 16.24% (21.7 million quintals) of the grain production in the same order and the Ethiopian national average yield was14.81 kg/ha (CSA, 2006).

Nitrogen is very transitory in the soil, due to its susceptibility to leaching, de nitrification, and volatilization. Over use of N fertilizer can lead to pollution of water streams and may result in soil acidification. The efficient use of applied N should be considered more seriously in the overall nutrient management than any other plant nutrient in order to reduce its negative impact on the environment. In addition, even under the best management practices, 30%-50% of the applied N is lost through different routes (Stevenson, 1985), and hence more fertilizer has to be applied than actually needed by the crop to compensate for the loss. The loss of N not only causes loss to the farmer but also causes hazardous impact on the environment (Kessel *et al.*, 1993; Gosh and Bhat, 1998). High inputs of chemical fertilizer cause environmental pollution (William, 1992). Thus, it calls for a need to optimize the level of N fertilizer to be applied, and the genotypes may have differential response to this major nutrient, especially under rain fed farming situation.

MATERIALS AND METHODS

A field experiment was conducted at Kellem – Wollega zone of Ethiopia to evaluate the effect of nitrogen rates on growth, yield and nitrogen use efficiency of sorghum genotypes during the main cropping season of 2014 at Haro Sabu Agricultural Research Center (HSARC). The center is located in Western Ethiopia ,Oromia Regional state at a distance of 550 km west of Addis Ababa. It lies at an latitude of 8^0 52,51”N,longitude of 35013,18”E and altitude of 1515 m. a. s. l. The center is characterized by a warm humid climate with average minimum and maximum temperature of 14^0C and 30^0C, respectively. The area received an average annual rain fall of 1000 mm with a uni model distribution pattern, most of the rain being received from April to October. The soil type of the experimental site is reddish brown, with a pH of 5.5. The area is characterized by coffee –based crop-live stock mixed farming system in which cultivation of coffee, maize, sorghum, finger millet, haricot bean ,soy bean ,sesame ,banana, mango, sweet potato are practiced.

Sorghum varieties Lalo and chemada and a Local variety, which is adapted to the agro-ecology of the area, were used for the study. Varieties Lalo and Chemada are among the most successful hybrid varieties released by Bako Agricultural Research Centre in 2006 and 2013, respectively. Both varieties have wider adaptability and grow well at altitudes ranging from 1500 to 1900 meters above sea level with annul precipitation of 1100 to 1200 mm. The cultivars need about 199 and 180 days to reach maturity. The seed colors are brownish- red and creamy for Lalo and Chemada, respectively. The potential yield of Lalo was 48 quintal ha^{-1} at research station and 35 quintal ha^{-1} at farmer's field, and the yield of Chemada was 32 quintal ha^{-1} on station and 25 quintal ha^{-1} at farmer's field. Planting was done on June 7, 2014 and seeds were sown at a row spacing of 75 cm and 15 cm plant spacing . The nitrogen fertilizer source used was urea (46% N) which was applied by drilling in two splits, half of the quantity 14 days after emergence and the remaining half at knee height stage along the rows to ensure that N is evenly distributed.

The treatments consisted of factorial combination of three (3) varieties (Lalo, Chamada and Local) with four N rates (0, 46, 92 , and 138 kg N ha^{-1}). The treatments were arranged in Randomized Complete Block Design with three replications. Each plot was 3 m long and 4.5 m wide with 6 rows. The inside four rows were set aside for data collection to eliminate any border effects. Phosphate fertilizers in the form of triple super phosphate (TSP) at the recommended rate of 100 kg P_2O_5 ha^{-1} were equally applied to all plots by drilling in the rows at the time of planting. Finally, sorghum plants in the central net plot area (9 m^2) were harvested at physiological maturity. The heads were harvested manually using sickle and were separately threshed for each variety.

Days to 50 % sorghum flowering was taken as the time from the date of planting until half of the plant Populations in the plot started to flower. Similarly, days to 90 % physiological maturity was taken as the time from date of planting until 90% of the plant leaves turned yellow and the lower most head started drying .Total leaf area was measured at 60, 90 and 120 DAS, and determined by multiplying leaf length and maximum breadth of leaf adjusted by a correction factor of 0.75 as suggested by McKee (1964). Number of leaves were counted from randomly selected five pre-tagged plants after plant emerge and their averages were taken as the number of leaves $plant^{-1}$ .The Leaf Area Index (LAI) was calculated from five randomly selected plants by dividing the leaf area by its respective ground area at 120 DAS. The heights of five randomly selected pre-tagged plants (cm) were measured at 60, 90 and 120 DAS from the ground level up to the head/tip of the plant. Five pre-tagged randomly selected plants were considered for determination of above ground dry biomass weight by drying in sunlight for ten to twelve days till a constant dry weight was attained. Lodging was recorded at the time of harvest from four middle rows and thousand seed weight (g) of sorghum was counted and weighted using sensitive balance from the bulk of the seeds of sorghum and adjusted to 13.5% moisture level. Number of panicles/plant was also recorded from five pre-tagged randomly selected plants. Number of effective tillers per plant was counted at plant physiological maturity. Grain yield (g/plot or quintal/hectare) was recorded after harvesting the central four rows of the net plot of 3 m x 3 m = 9 m^2. Seed yield was adjusted to 13.5% moisture using moisture tester (Dickey-john) and converted to quintal ha^{-1} for statistical analysis.

$$\text{Adjusted yield} = \text{Actual yield x } \frac{100\text{-M}}{100\text{-D}}$$

where,
M, is the measured moisture content in grain and D, is the designated moisture content (13.5%).

Harvest index was calculated as:

$$\text{HI}(\%)\ \frac{S\,Y}{by}\ \text{x100}$$

where,
HI is harvest index, SY is seed yield and BY is above ground dry biological yield.

All the data collected were subjected to the analysis of variance (ANOVA) using SAS (2002) version 9.1. Where treatment means are significant, the Tukey test at alpha= 5% was adopted for mean comparison.
The model for randomized complete block design is:-

$$y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij}$$

where:
Yik - An observation in treatment i, and block jμ - the overall mean τi - the effect of treatment iβj - the fixed effect of block jεij = random error.

RESULTS AND DISCUSSION

Effect of Nitrogen rates on phenology of sorghum genotypes

The days to 50% flowering significantly varied with N levels in genotypes and the interaction ($P< 0.01$) at flowering. Higher levels of nitrogen application tended to delay flowering period, the longest being 141days when 138 kg N ha $^{-1}$ was applied to variety Chemada. Minimum days to flower (124days) were recorded for the control treatment for Lalo variety at 0 kg ha^{-1} followed by the local variety (Table 1). This result is in line with the finding of Getachew (2004) and Mekonnen (2005) who also reported that heading was significantly delayed at the highest N fertilizer rate in wheat and barley crops than at lowest rate respectively. Contrary to the results of the present study, Sewnet (2005) reported early flowering with an increase in the rate of N application in rice. In general, the physiological maturity of sorghum plants was hastened under lower N rates than under the higher rates. Thus, increasing the rates of nitrogen from 0 to 138 kg N ha^{-1} prolonged days to maturity (Table 2). This result is in line with the report of Marschener (1995), Tanaka *et al*. (1995) and Brady and Weil (2002) that N applied in excess than required delayed plant maturity. Consistent with the result of this study, Gobeze (1999) reported that N rates delayed the maturity of sorghum.

Lodging percent

Lodging was significantly influenced by nitrogen fertilizer rates and the genotypes. Increasing the rates of nitrogen increased the lodging of sorghum genotypes across all nitrogen fertilizer rates. The maximum lodging percentage was observed in Lalo, followed by Chemada and the lowest percentage was in Local variety (Table 4). Seyfu (1983) reported that lodging in cereals is considered to be caused by high rates of nitrogen fertilizer application.

Table 1: Interaction effect of nitrogen rates on days to 50% flowering of sorghum genotypes

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	124.33c	136.67b	138.00ba	133
46 kg N ha $^{-1}$	124.67c	135.67b	138.33ba	132.89
92 kg N ha $^{-1}$	126.00c	136.33b	139.00ba	138.33
138 kg N ha $^{-1}$	137.00b	136.67b	141.33a	133.55
Mean	128	136.33	139.17	134.45
CV%		1.73		

Table 2: Interaction effect of nitrogen rates on days to 90% physiological maturity of sorghum genotypes

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	156.33c	167.67b	170.00ba	164.67
46 kg N ha $^{-1}$	156.67c	168.67b	170.33ba	165.22
92 kg N ha $^{-1}$	158.00c	168.33b	170.33ba	165.55
138 kg N ha $^{-1}$	169.00b	168.67b	173.33a	170.33
Mean	160	168.34	170.99	166.44
CV%		1.45		

Table 3: Interaction effect of nitrogen rates on plant stand $plot^{-1}$ of sorghum genotypes

Nitrogen rates	Sorghum varieties			*Mean*
	Lalo	Local	Chamada	
0 kg N ha^{-1}	65.33ef	69.67abcde	64.33f	68.11
46 kg N ha^{-1}	68.33bcdef	70.67abcd	68dcef	69.00
92 kg N ha^{-1}	70.33abcd	73.67a	69abcdef	69.33
138 kg N ha^{-1}	73ba	72bac	66.67def	70.56
Mean	69.25	71.5	67	69.25
CV%		4.16		

Table 4: Interaction effect nitrogen rates on lodging percentage of sorghum genotypes

Nitrogen rates	Sorghum varieties			*Mean*
	Lalo	Local	Chamada	
0 kg N ha^{-1}	10.65c	8.63d	10.43c	9.9
46 kg N ha^{-1}	12.2b	9.1dc	12.33b	11.21
92 kg N ha^{-1}	12.9b	9.68c	12.59b	11.72
138 kg N ha^{-1}	15.33a	10.63c	13.2b	13.05
Mean	12.77	9.51	12.14	11.47
CV%		5.8		

The maximum plant stand was obtained in Local variety followed by Lalo and Chemada varieties (Table 3). Nitrogen application rates significantly ($P<0.001$) influenced plant height at 90 DAS, but the effect was not significant at 60 DAS and 120 DAS. Sorghum genotypes differed significantly in plant height (Table 5) at different growth stages. Plant height increased linearly with the increase in the rate of nitrogen application. When the rate of nitrogen increased from 0 through 138 kg N ha^{-1}, plant height increased, but the increase was significant up to 46 kgN/ha.

The increase in plant height following increased N application rate indicates maximum vegetative growth of the plants under higher N availability. These results are in agreement with the results obtained by Akbar et al. (1999) who found that plant height in maize increased with increase in N rate. However, Sadeghi and Bahrani (2002) reported that increase in N rate had no significant effect on plant height which could be due to the difference in the population stand, soil fertility status, and the crop varieties used**.**

Number of green leaves plant

Nitrogen rates had no significant influence on leaf number /plant , whereas sorghum genotypes significantly differed in the number of green leaves per plant. There was a significant interaction effect of nitrogen rates and sorghum genotypes on the number of green leaves per plant (Table 6) where the highest number (14.00) was recorded with the application of 46kgN ha^{-1} for Local variety, which was comparable with Chamada fertilized with 92 kg N/ha(14).

Table 5: Effect nitrogen rates on plant height at various stages of sorghum genotypes

Treatment	**Plant height(cm)**		
Nitrogen(N) rates	60DAS	90DAS	120DAS
0 kg N ha^{-1}	34.54b	146.82b	263.33b
46 kg N ha^{-1}	39.39ba	165.77b	275.30ba
92 kg N ha^{-1}	40.72ba	196.30a	284.88a
138 kg N ha^{-1}	41.60a	204.99a	290.90a
Sorghum varieties			
Lalo	43.86a	227.42a	299.73a
Local	38.74ba	158.01b	276.54b
Chamada	34.59b	149.98b	259.53b
CV%	18.06	11.92	7.88

Number of effective tillers/plant

The sorghum genotypes varied distinctly in the number of effective tillers, but the nitrogen fertilizer rates did not show effect on tillers. The number of effective tillers were significantly higher in Local variety (2.18) than Lalo variety (1.2) and Chamada (Table 7).The current result is in agreement with that of Botella *et al*. (1993) who reported that stimulation of tillering with high rates of N application might be due to its positive effect on cytokinin synthesis. Corroborating with the results of this study, Genene (2003) reported higher tillering and maximum survival percentage of tillers with increasing N application in bread wheat.

Total leaf area

There was significant effect of nitrogen rates on leaf area at 90 DAS, but there was no discernible effect at 60 and 120 DAS. Sorghum genotypes significantly ($P<0.01$) differed in leaf area at 60 DAS (Table 8) and 90 DAS, but not at 120 DAS. There was significant interaction between sorghum genotypes and nitrogen fertilizer rates on leaf area at 90 and 120 DAS. The highest total leaf area per plant of 3193.3 cm^2 was obtained from Lalo variety with 46 kg N ha^{-1} which was at par with (2805cm) Chemada variety receiving 92kgN/ha at 90 DAS (Table 9). The highest total leaf area per plant (3694 cm$^{2)}$ was recorded in variety Lalo fertilized with 132kgN/ha, and the lowest leaf area per plant of 2631.9cm^2 was recorded in variety Lalo at 120DAS (Table 10). Increasing nitrogen fertilizer rates did not result in increment of leaf area at all stages in this study. Demir *et al*., (1996) reported that leaf area increased with increasing N levels.

Leaf Area Index (LAI)

The results revealed that there was no discernible effect of nitrogen fertilizer rates and sorghum genotypes on leaf area index. However, nitrogen rates and sorghum genotypes significantly interacted to influence this parameter ($P<0.05$). The highest LAI in Lalo genotype (3.28 cm^2) was recorded with the application of 138 kg N ha^{-1}, while the lowest (2.15cm^2) was recorded from variety Chemada under no N application. Generally, an increasing trend in LAI was observed with increased N application rates (Table 11). The increase in LAI was possibly due to the improved assimilation in plants receiving optimum nitrogenous fertilizers. Similar to this finding, Haghighi et al. (2010) also reported an increasing trend in LAI in maize due to an increase in N fertilizer application rates.

Table 6: Interaction effect of nitrogen rates and sorghum genotypes- on number of green leaves plant.

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	11.67bdc	14.00a	13.67a	13.11
46 kg N ha $^{-1}$	11.33dc	14.00a	12.67bac	12.67
92 kg N ha $^{-1}$	10.67d	13.67a	14.00a	12.78
138 kg N ha $^{-1}$	12.00bdc	13.00ba	11.33dc	12.11
Mean	11.42	13.67	12.92	12.67
CV%		7.33		

Table 7: Effect of nitrogen rates on number of effective tillers plant^{-1} of sorghum genotypes

Treatment	**Number of effective tillers per plant**
Nitrogen(N) rates	
0 kg N ha $^{-1}$	1.36a
46 kg N ha $^{-1}$	1.47a
92 kg N ha $^{-1}$	1.54a
138 kg N ha $^{-1}$	1.51a
Sorghum varieties	
Lalo	1.20b
Local	2.18a
Chamada	1.03b
CV%	22.46

Table 8: Effect of nitrogen rates on leaf area (cm) of sorghum genotypes at 60 DAS

Treatment	Leaf area
Nitrogen(N) rates	60DAS
0 kg N ha $^{-1}$	884.8a
46 kg N ha $^{-1}$	1028.5a
92 kg N ha $^{-1}$	1092.5a
138 kg N ha $^{-1}$	1054.5a
Sorghum varieties	
Lalo	1192.8a
Local	1005.4ba
Chamada	847.0b
CV%	25.31

Table 9: Interaction effect of nitrogen rates on Leaf area (cm) of sorghum genotypes at 90 DAS.

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	2869.4ba	2485.1bc	2376.1dc	2576.89
46 kg N ha $^{-1}$	3193.8a	2715.3bac	2361.5dc	2756.87
92 kg N ha $^{-1}$	2521.0bc	2728.3bac	2805.0bac	2684.77
138 kg N ha $^{-1}$	2799.0bac	2338.9dc	1955.9d	2364.6
Mean	2845.8	2566.9	2374.63	2595.78
CV%		11.27		

Table 10: Interaction effect of nitrogen rates on Leaf area (cm) of sorghum genotypes at 120DAS.

Nitrogen rates	Sorghum varieties			*Mean*
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	3229.8ba	3169.2bac	3204.5ba	3201.17
46 kg N ha $^{-1}$	3092.7bc	2813.6bc	2814.2bc	2906.83
92 kg N ha $^{-1}$	2631.9c	2859.3bc	3229.0ba	2906.73
138 kg N ha $^{-1}$	3694.9a	2950.8bc	2638.2c	3094.63
Mean	3162.33	2948.23	2971.48	3027.34
CV%		10.89		

Table 11: Interaction effect nitrogen rates and sorghum genotypes on Leaf area index

Nitrogen rates	Sorghum varieties			*Mean*
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	2.87ba	2.82bac	2.15ba	2.85
46 kg N ha $^{-1}$	2.75bc	2.50bc	2.50bc	2.58
92 kg N ha $^{-1}$	2.34c	2.54bc	2.87ba	2.58
138 kg N ha $^{-1}$	3.28a	2.62bc	2.38bc	2.76
Mean	2.81	2.62	2.65	2.69
CV%		10.88		

Table12: Interaction effect of nitrogen rates and sorghum genotypes on biological yield plot-1 (grams)

Nitrogen rates	Sorghum varieties			*Mean*
	Lalo	Local	Chamada	
0 kg N ha $^{-1}$	20459a	20131ba	22123a	20904.33
46 kg N ha $^{-1}$	21046a	20529a	20100ba	20558.33
92 kg N ha $^{-1}$	23443a	21784ba	21087a	22104.67
138 kg N ha $^{-1}$	21099ba	20237a	17934b	19756.67
Mean	21511.75	20670.25	20311	20831
CV%		10.01		

Effects of nitrogen rates on yield and yield components of sorghum genotypes

Biological yield

Biological yield of sorghum genotypes was not significantly influenced by nitrogen rates. However, there was significant interaction effect ($P<0.05$) of nitrogen rates and sorghum genotypes on this parameter (Table 12). Biological yield is a function of photosynthetic rate and proportion of the assimilatory surface area. The increase in biological yield with increase in rate of N might be due to better crop growth rate, LAI and accumulation of photo assimilates due to maximum days to maturity of the crop, which ultimately resulted in more biological yield. Biomass yield generally increased with the increase in the rate of nitrogen across the increasing frequency of application. The variety Lalo recorded the highest biomass yield (23443 g plot^{-1}) with the application of 92 kg N ha^{-1} and the lowest biomass yield was obtained from variety chemada (1793 g plot^{-1}) with the application of 138 kg ha^{-1}. This result is, however, in variance with the report of Haftom *et al*. (2009).

Thousand Seed weight

Thousand seed weight is an important yield determining component and reported to be a genetic character that is influenced least by environmental factors (Ashraf *et al*, 1999).

Significantly higher 1000 seed weight (32.25 g) was obtained from variety Lalo than Local variety (22.52 g),while the lowest weight (21.24 g) was obtained from Chemada. Regarding Nitrogen , the highest 1000seed weight was observed with 92 kg N ha^{-1} and lowest with 46kgNha^{-1} and 138kgNha^{-1} (Table13). Melesse (2007) reported no significant effect of the application of different rates of nitrogen fertilizer on 1000 kernel weight of bread wheat.

Panicle number plant^{-1}

Panicle number per plant is one of the yield attributes of sorghum that contribute to grain yield. Crops with higher panicle number could have higher grain yield. Panicle number was significantly ($P< 0.01$) influenced by the sorghum genotypes, but not by nitrogen rates (Table13). The genotype Lalo produced substantially higher number of panicles /plant (72.6) than local(59) and chamada(50).

Table 13: Effect of nitrogen rates on thousand seed weight and panicle number plant^{-1} of sorghum genotypes

Treatment	**Thousand seed weight(g)**	**Panicle number per plant**
Nitrogen(N) rates		
0 kg N ha^{-1}	26.07ba	59.67a
46 kg N ha^{-1}	24.17c	61.11a
92 kg N ha^{-1}	26.57a	62.89a
138 kg N ha^{-1}	24.53bc	59.00a
Sorghum varieties		
Lalo	32.25a	72.67a
Local	22.52b	59.25b
Chamada	21.24b	50.08c
CV%	3.41	9.4

Table 14: Interaction effect of nitrogen rates on grain yield hectare^{-1} (quintal) of sorghum genotypes

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha^{-1}	41.63	40.16	24.27	35.35
46 kg N ha^{-1}	45.97	41.10	31.54	39.54
92 kg N ha^{-1}	47.72	45.27	30.83	41.27
138 kg N ha^{-1}	41.87	41.08	28.93	37.29
Mean	44.3	41.9	28.89	38.36
LSD(0.05)		2.82		
CV%		4.13		

Table 15: Interaction effect nitrogen rates on harvest index of sorghum genotypes

Nitrogen rates	**Sorghum varieties**			***Mean***
	Lalo	Local	Chamada	
0 kg N ha^{-1}	20.64a	17.11 cb	10.24f	15.99
46 kg N ha^{-1}	21.02a	18.12 cd	12.29ef	17.14
92 kg N ha^{-1}	22.0a	19.63ab	13.38f	18.34
138 kg N ha^{-1}	21.3a	18.97 ed	12.85e	17.71
Mean	21.24	18.46	12.19	17.3
CV%		8.54		

Grain yield

Sorghum grain yield was significantly affected by the nitrogen rates, sorghum varieties and their interaction ($p<0.01$) (Table 14). Significantly greater grain yield was obtained from the variety Lalo with the application of 92 kg N ha^{-1}(47.72quintal ha^{-1}) which was on par with 46kgN/ha(45.9q/ha), and with 92kgN/ha of Local variety (45.2q/ha),and the lowest grain yield was recorded in variety Chemada with no nitrogen application (24.27ql ha^{-1}) (Table14). Thus Lalo and Local varieties responded up to 92kg N/ha , while chamada responded upto 46N/ha. The results of this study are consistent with result of Sage and Pearcy (1987) who reported that a well-balanced supply of N results in higher net assimilation rate and increased grain yield as also observed by Al-Abdulsalam (1997). Corroborating the results of this study, Blankenau *et al*. (2002) reported that proper rate and time of N application are critical for meeting crop needs, and indicated considerable opportunities for improving yields.

***Harvest index* (HI)**

The physiological efficiency and ability of a crop for converting the total dry matter into economic yield is known as harvest index (HI). The interaction effect of nitrogen rates and sorghum cultivar on harvest index was highly significant (Table 15). In line with the result obtained by Lawrence (2008) who reported that harvest index in maize increases when nitrogen rates increases. With the increase in the rate of nitrogen application, harvest index increased. This indicates significantly lower biomass partitioning to grain production when N was increased. The lower mean HI values in this experiment for the higher N application might indicate the need for the enhancement of biomass partitioning through genetic improvement. In line with the results of this study, Abdo (2009) reported highest harvest index from treatments with the lower rates of nitrogen application.

CONCLUSIONS

From the foregoing account it could be inferred that among the test genotypes of sorghum , improved Lalo and traditional Local variety exhibited greater response up to 92kgN/ha, while Chamada responded to 46kg N/ha under rain fed conditions of Ethiopia, East Africa. Across genotypes, increased N rates delayed flowering, physiological maturity ,increased lodging ,enhanced plant height, tillers /plant, leaf area, panicles /plant, grain yield, harvest index; but showed no discernible influence on leaf number/plant, LAI, and test seed weight.

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