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Sorghum [*Sorghum bicolor* (L.) Moench] Varieties response to nitrogen fertilizer rates on growth yield and yield components in Omonada Jimma zone, South Western Ethiopia

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Abstract
Field experiments were conducted at Omonada woreda for two consecutive years 2019 and 2020 main growing seasons at farmer's fields. Three sorghum varieties (Bonsa, Abamelko and Dagem) and Five nitrogen treatments at four levels (0, 23, 46, 69 and 92 kg N ha^{-1}) were applied. Fifteen treatments were arranged in a randomized complete block design (RCBD) with three replications. Across season data analysis most parameters were not significantly affected by sorghum varieties. The number of spikelets per head was significantly affected by nitrogen rates and stem diameter was affected by both nitrogen fertilizer application and sorghum varieties. The highest and statistically significant (16.87 t ha-1) above-ground biomass yield was recorded from Abamelko. The tallest plant height 216.14 cm was recorded from the variety Abamelko and in contrast, the shortest 126.30 plant height was recorded from the variety Dagem. The highest grain yield was 2.61 t/ha obtained from Ababmelko and 2.53 t/ha from no application of nitrogen fertilizer. While the lowest from 2. 18 t/ha was obtained from Bonsa and it was statistically non-significant. The total nitrogen in the soil before planting analysis showed medium for crop growth and development. Based on the current results, those sorghum varieties were not responded to nitrogen fertilizer, unless the soil is degraded or if the preceding crop nitrogen residue was not available. So, applying 23 kg/ha nitrogen fertilizer for sorghum in the Omonada area was recommended when no nutrient residual effect and the crop was deficiency was observed during growth and development.

Keywords: Bonsa, abamelko, dagem grain yield, and dry above ground-biomass

Introduction
Ethiopia, according to Vavilov (Vavilov NI. 1951) [24], is the center of sorghum origin and diversification. Following the United States, Mexico, Nigeria, Sudan, and India, the country is the sixth greatest sorghum producer in the world. Sorghum is grown in 13 of Ethiopia's 18 major agroecological zones and 41 of the 49 sub-agroecological zones (Alemu TW. 2018) [3]. Because Ethiopia is one of the sorghum's founding countries, it is endowed with a richness of genetic variation, as evidenced by the variety of morphological kinds grown in the country and the crop's extensive agroecological coverage (Doggett H. 1988) [9]. It is grown in Ethiopia at a variety of elevations and rainfall conditions. Sorghum is grown in many of the hot, arid lowlands, and certain varieties are even grown in the cooler, wetter highlands up to 2,700 meters in height (Yali W, Begna T. 2022) [25].
Out of the total grain crop area, 81.19% was under cereals. Sorghum covers 12.94% of the grain crop area. As to production, the tables paint a similar picture as that of the cropland area. sorghum 13.22% of the grain production (CSA, 2021) [8]. Sorghum is one of the most important cereal crops worldwide after wheat, rice, maize and barley (Amal G. *et al*., 2007) [5] but its production and productivity in this area were low due to Nutrients depletion especially nitrogen by increased cropping intensity, use of smaller amounts of inputs, high rainfall, soil erosion, and leaching and other management practices in these areas. Low soil fertility and inadequate nutrient management are among the major factors determining its yield level.

The use of nutrients in agricultural production has important global consequences both on the availability of food, feed, and fuels, and on the environment. (Francisco R. 2012) [12]. Nitrogen and phosphorus fertilizers are major essential plant nutrients and key inputs for increasing crop yield (Alam *et al*., 2009) [26]. (Shrotriya. 1998) [23] reported that the balanced application of NPK caused an increase in sorghum yields by up to 122% in India. Nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle. The presence of N in excess promotes the development of the above-ground organs with abundant dark green (high chlorophyll) tissues of soft consistency and relatively poor root growth. This increases the risk of lodging and reduces the plant's resistance to brash climatic conditions and foliar diseases (Mohammadian Rushan *et al*., 2011).

To increase the efficiency and profitability of chemical fertilizer, sound soil test calibration is essential for crop production and productivity. Because of soil, test calibration or correlation against cop response from the application of plant nutrient in a question is the ultimate measure of fertilization program. However, an accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the number of plant nutrients that should be added to achieve optimum crop yield. This implies that calibrations are specific for crop species and varieties, soil types and climates. It was similar to the study areas situated at different agroecology, resulting in the occurrence of various soil types and such variation in soil types and characteristics results from differences in fertilizer application rate and crop response.

Proper nitrogen application rates are critical to meet crop needs and indicate considerable opportunities for improving nitrogen use efficiency (Efriem T. *et al*., 2016) [11]. Nitrogen is the most nutrient required for high grain sorghum productivity. Exposing sorghum plants to the stress of nitrogen at any phase of its life cycle might lead to detrimental effects on growth, yield and its components (Amal G. A, 2007) [5]. And also, the response of different varieties to nitrogen was varied. There For, Great efforts have to be made to improve sorghum productivity by varieties and increase the efficiency of added fertilizers by minimizing the loss of nutrients. Therefore, this research proposal is initiated.

2. Materials and Methods

2.1 Description of the Study Area

Field experiments were for two consecutive main growing seasons at Omonada woreda, Jimma Zone Southwestern Ethiopia at farmers' fields. The sites were located at 7º46' N and 36º 00'E and laid at an altitude of 1753 m.a.s.l. with the soil type of the area being Upland: Chromic Nitosol and Combisol. The average maximum and minimum temperatures are 9 ºC and 28 ºC respectively and reliably receive good rains of 1561 mm per annum cropping season (fig 1) below.

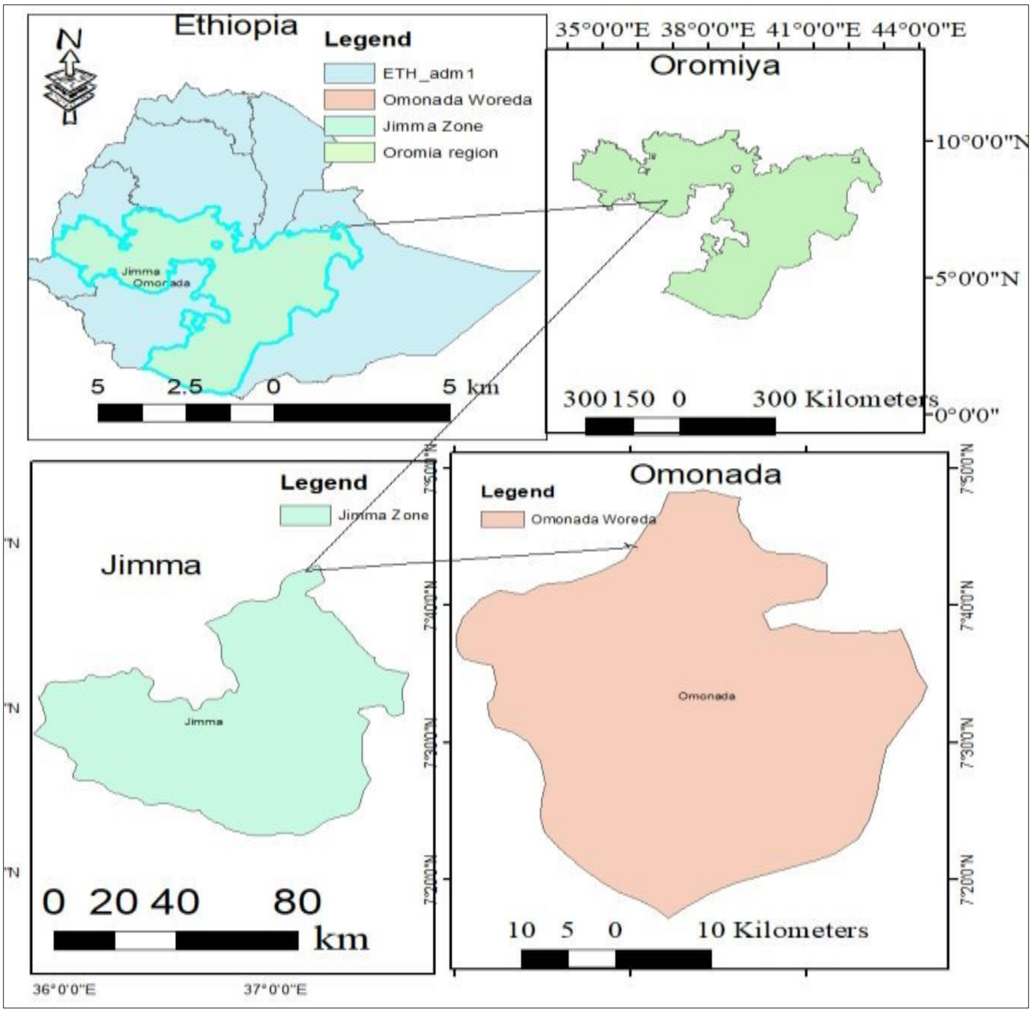

Fig.1. Location map of the study area, Omonada, Jimma Zone in Ethiopia.

2.2 Description of the experimental materials

Table 1. Descriptions of released sorghum varieties.

S.N	Variety	Year released	Altitude	Center released	Flowering date	Height (cm)	Yield (Q/Ha) Station	Yield (Q/Ha) farm	Seed color
1	Bonsa	2017	Intermediate	MARC/EIAR	111.7	168.1	50	43	Brown
2	Abamelko	2001	Intermediate	JARC/EIAR	90-100	250	75	50	Brown
3	Dagem	2011	Intermediate	MARC/EIAR	87	156	27-54	42	Brown

Source: Kinfe and Tesfaye [21] and some unpublished personal communication

2.3 Experimental treatment and procedures

The experimental field was ploughed and prepared with conventional tillage practice before planting at all experimental sites. The land was levelled using manual power before the field layout was made. Three released sorghum varieties: Bonsa, Abamalko and Dagim (table 1) above and Five levels of N fertilizers: 0, 23, 46, 69 and 92 kg N ha-1 used. The recommended 23 kg/ha phosphorous was uniformly applied. The proximate plot size of 4.50m x3.60 =16.20 m2 was used.

The seeds were drilled in furrows and thinning was at the seedling's good establishment to achieve the target population. Later N (Urea) was applied in split half during planting and at knee height growth stage to increase the nitrogen use efficiency. All other crop management practices will be applied as per the recommendation for sorghum uniformly to all experimental plots as per their respective recommendations for sorghum like three times hand weeding was done. The season rainfall pattern and other weather variables were suitable for sorghum growth and development.

Soil Analysis: The experimental field was blocked into three parts depending on land uniformity. Plant residues on the sampling soil surface were removed. A representative composite sample was taken from a root depth of (0 to 30 cm) depth using a gauge auger before planting for Physico-chemical analysis like soil pH, OM, TN, OC, and Available P.

The investigated soil properties are shown in (Table 1.) below. The soil of the experimental field was characterized by selected Physico-chemical properties before the application of the treatments. The average soil pH of the trial site was 5.01, which was strongly acidic (Batjes, 1995) [27] and ideal for the production of most field crops. The pH of the soil affects sorghum growth by suppressing root development and reducing the availability of macronutrients to plants, especially phosphorus (Brady and Weil, 2008) [28]. The others 3.50, 0.19 and 2.11 were OM, soil total N and OC respectively were found medium rates for crop growth and development those three nutrients (Berhanu, 1980). The Bray II extractable available P 10.89 mg kg-1 which is medium to high in content as described by Tekalign and Haque (1991) [29].

Table 1. Physiochemical properties of the experimental soil (0-30 cm depth) before sowing.

	Omonada	Rating
pH 1:2.5 (H_2O)	5.01	Strongly acid
Organic matter (%)	3.50	Medium
Total N (%)	0.19	Medium
Organic carbon	2.11	medium
Available P (mg kg^{-1})	10.89	Low

2.4 Data Collection and Measurement

2.4.1 Plant height: Plant height (cm): Was recorded on ten random plants at maturity by measuring the height from the ground to the tip of the panicle.

2.4.2 Stem Diameter (girth): Stem Diameter was measured and the average value of ten was randomly taken from a plant stem 50 cm above the ground.

2.4.3 Panicle Length: Was measured from ten random plant head panicles at harvest.

2.4.4 Number of Spikelets: Was recorded from ten random plants' head spikelets at maturity.

2.4.5 Dry Above ground Biomass yield: Dry above-ground Biomass: Harvestable row plants were considered for the determination of above-ground dry biomass weight by drying in sunlight till a constant dry weight was attained.

2.4.6 Grain yield: Grain yield (q/ha) was recorded after harvesting from the harvestable rows. Seed yield was adjusted to 12.5% moisture using a moisture tester (Dickey-john) and converted to quintal ha-1 for statistical analysis. Adjusted yield=Actual yield × 100-M/100-D; where M is the measured moisture content in grain and D is the designated moisture content (12.5%). where D is the designated moisture

2.4.7 Harvest index: It was calculated as the ratio of grain yield to total above-ground dry biomass yield multiplied by 100 at harvest from the respective treatments [21]. Harvest Index = Grain yield/above-ground dry biomass yield × 100.

2.5 Statistical analysis

The analysis of variance (ANOVA) for collected data was computed using R software version 3.5.3 statistical software R Core Team (2019-03- 11). Whenever the ANOVA results showed significant differences between sources of variation, the means were separated using Fisher's least significant difference (LSD).

Table 2. Across-season effect of sorghum varieties and Nitrogen fertilizer rates on logging, plant height and stem diameter (girth) of Sorghum at Omonada

Sorghum Varieties	Logging Percentage	Plant Height (cm)	Stem Diameter/ Girth (cm)
Bonsa	21.64	150.10	1.77
Abamelko	26.06	216.14	1.83
Dagim	17.66	126.30	2.28
LSD (0.05)	11.86	16.06	0.16
Nitrogen rates (kg ha^{-1})			
0	21.64	174.22	1.92
23	26.66	161.74	2.09
46	17.66	166.48	1.97
69	15.38	155.61	1.82
92	17.41	162.84	2.02
Mean	19.57	164.18	1.96
LSD (0.05)	Ns	Ns	0.20
CV %	16.99	18.96	15.19

3. Results and Discussions

3.1 Plant height

The result of plant height was shown a significant effect (P <0.01) on the varieties and not on nitrogen fertilizer rates. The tallest plant height 216.14 cm was recorded from the variety Abamelko and in contrast, the shortest 126.30 plant height was recorded from the Dagem variety. It's due to in variety difference morphology and responsible for the difference in plant height (Table 2). The result was supported by (Augng *et al*., 2013) [2] who observed significant variation in plant height among the four sweet sorghum varieties considered in their study. Also, the tallest plant height 174.22 cm was recorded from the no nitrogen application. Application of nitrogen fertilizer was shown to inconstantly decrease stem diameter starting from negative control (0 kg ha-1) nitrogen application. But the result was statistically non-significantly. It may be due to the total nitrogen in the soil before planting analysis showing medium and enough for the variety's response to nitrogen. Similarly, (O.lgugbemi *et al*., 2018) [19] reported that, Although the total soil nitrogen as observed in the pre-planting analysis of the soil of the experimental site was within the moderately low and medium range in the 2014 and 2015, respectively, the native soil nitrogen was possibly high enough to sustain the seedling through to 6WAS when marked, differences were observed among the plants in the control plots (0 kg N ha-1) and application. Further, (Sadeghi and Bahrani. 2002) [21] reported that an 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.

3.2 Logging percentage

The result of plant height was shown a significant effect (P <0.01) on the varieties and not on nitrogen fertilizer rates. The higher and statistically significant plant logging percentage of 26.06 was recorded from the variety Abamelko and in contrast, the lowest 17.66 logging was recorded from the Dagem variety. It's related to varietal variation in plant height. The result due to the Abamelko variety was the highest and Diadem was the shortest in plant height. The current result was in agreement with (Sheleme *et al*., 2015) reported that the maximum lodging percentage was observed in Lalo, followed by Chemada and the lowest percentage was in the Local variety Also, the effect of nitrogen application shows an increase from negative control (0 kg ha-1) to 23 N kg ha^{-1} but statistically not significant the current result was in agreement with (Sheleme *et al*., 2015) Increasing the rates of nitrogen increased the lodging of sorghum genotypes across all nitrogen fertilizer rates.

3.3 Stem diameter (Stem girth)

The result of stem diameter (Girth) was a significant effect (P <0.05) on both varieties and nitrogen fertilizer rates. Among varieties, the highest stem diameter 2.28 cm was recorded from Dagem and the lowest 1.77 cm was from the Bonsa variety (Table 2). It's due to variety response and obviously, the Dagem variety was the shortest and thickest than the others varieties. Also, stem diameter was related to plant height as plant height division increased stem diameter decreased inconstantly due to differences and the low response of those varieties. Again, the higher stem diameter of 2.09 cm was recorded from the lowest 23 kg ha-1 nitrogen application. Again, the application of nitrogen fertilizer was shown inconstantly increase stem diameter from negative control 0-23 kg ha-1 nitrogen application and was statistically significant. The result was in agreement with (O.lgugbemi *et al*., 2018) [19] reported that it was observed on the effect of N fertilizer increased the girth to a certain extent. Similarly, (Almoderes *et al*., 2013) [4] reported a significant effect of N fertilizer on the stalk length and girth (or diameter) of sweet sorghum, which they attributed to the effect of cell and elongation.

3.4 Number of Spikelets per head

The result of the number of spikelets per head was significantly affected (p<0.05) nitrogen fertilizer rates and not for varieties. The highest 60.03 number of spikelets was recorded from the Dagim Variety and the lowest 55.46 was from the Abamelko variety (Table 3). It's due to the variety of sorghum differences in morphology resulting in differences in the number of spikelets. Also, the highest number of spikelets 61.44 was recorded from the higher 69 kg ha-1 nitrogen application. Application of nitrogen fertilizer was shown inconstantly increase the number of spikelets from negative control (0-96 kg ha^{-1}) significantly and decline with further application. Similarly, (Salam *et al*., 2010) [22] reported that yield-related traits increased with an increased rate of nitrogen. Thousand seed weight of sorghum increased with increased rates of N might be because the application of nitrogen to the sorghum plants maintained the greenness of leaves for a longer period which in turn helped in greater dry matter accumulation this might have contributed much as a major source for the development of sink and thereby improved the yield attributes (Asaduzzaman *et al*.,2014) [6].

3.5 Panicle Length

The longest 32.80 cm panicle length was recorded from the Bonsa variety. While the shortest 29.76 cm was from the Dagim variety and statistically, they were non-significant (Table 3). It's due to the various response and obviously that the Bonsa variety panicle was somewhat longer than others. The increments trend of panicle length concerning increased N application rate indicates maximum vegetative growth of the plants under higher N availability due to an increase in cell elongation as nitrogen is essential for plant growth. This result is consistent with (Geberemariam & Assefa. 2015), who reported that the application of nitrogen fertilizer on different sorghum varieties increases panicle length.

3.6 Above-ground biomass yield

The results of the analysis of variance showed that the above-ground biomass of sorghum was significantly influenced by the main effect of sorghum varieties (Table 3). The highest 16.87 t ha^{-1}) above-ground biomass yield was recorded from Abamelko but the smallest 13.91 t ha-1 was recorded Bonsa variety (fig.2). It's was resulted due to morphological and genetic differentiation of the variety Abamelko highest in plant height than others, which results directly an increase in above-ground biomass yield. The result was supported by the (Mohammed *et al*. 2022) [18] report that the Girana 1 with any fertilizer level even with no fertilizer was better in stalky yield due to the clear morphological and genetic differences between the two improved sorghum varieties. The results of the analysis of variance showed that the above-ground biomass of sorghum varieties was not significantly influenced by nitrogen fertilizer rates (Table 3). The highest 16.20 t ha-1 above-ground biomass yield was recorded from no fertilizer applied or negative control and the smallest 14.79 t ha-1 was recorded at 23 kg/ha nitrogen rate (fig.3). Based on soil result before planting showed a medium/optimum for sorghum growth to produce more biomass. This result was further supported by (Mohammed *et al*., 2022) [18] report that the better availability of nitrogen to vegetative growth of sorghum which can contribute to higher biomass production was obtained from the optimum nitrogen fertilizer. It resulted due to the sorghum's low response to nitrogen fertilizer rate or the residual is enough for them if available but beyond the application of 23 kg/ha nitrogen rate the biomass yield was gradually increased with nitrogen increase but statistically non-significant. The result showed that with an increase in the application of nitrogen rate, there was a gradual increase in dry above-ground biomass.

Table 3. Across-season effect of sorghum varieties and nitrogen fertilizer rates on number of spikelets, panicle length, dry above ground biomass yield, grain and harvest index of Sorghum at Omonada

Sorghum Varieties	Number of Spikelets	Panicle Length	Dry Above Ground Biomass (t ha^{-1})	Grain yield (t ha^{-1})	Harvest Index (%)
Bonsa	56.43	32.80	13.91	2.18	16.45
Abamelko	55.46	30.80	16.87	2.61	15.56
Dagim	60.03	29.76	15.77	2.58	16.53
LSD (0.05)	Ns	Ns	1.90	Ns	Ns
Nitrogen rates (kg ha^{-1})					
0	53.33	29.77	16.20	2.53	16.00
23	58.00	31.83	14.79	2.49	17.18
46	55.33	31.83	15.19	2.37	16.65
69	61.44	32.88	15.57	2.43	15.70
92	58.00	29.39	15.83	2.46	15.38
Mean	57.31	31.12	15.01	2.45	16.18
LSD (0.05)	4.96	Ns	Ns	Ns	Ns
CV %	22.80	20.78	23.18	19.21	25.02

3.4 Grain yield

The highest grain yield was 2.61 t/ha obtained from Ababmelko and followed by 2.58 t/ha from the Dagim variety while the lowest from 21.8 t/ha obtained from Bonsa and they were non-significant (fig.2). This may be due to varieties varying in response to nitrogen fertilizer rates. Again, the highest grain yield was 2.53 t/ha obtained from no application of nitrogen and followed by 2.49 t/ha from the application of 23 kg/ha nitrogen. Also, beyond 23 kg/ha application of nitrogen showed inconsistent, gradual increase in grain yield and statistically non-significant response. This implies that those sorghum varieties were not responsive to nitrogen fertilizer applied because of the area's ample amount of rainfall during crop growth and development. A similar result was reported by (Asfaw., *et al*. 1997) [7] the observed grain yield decrease was not entirely due to treatments but due to sufficient rainfall in the area during the study period. It may be due to the total nitrogen in the soil before planting analysis showing medium for the crop development and applied nitrogen was remain in the soil as residual. In the case of N, up to 40% of the amount applied can be retained in the soil in different organic forms (Hauck, 1971; Kundler, 1970; Legg & Meisinger, 1980) [14, 16, 17]. The result was further supported by (Mohammed *et al*., 2022) [18] there was a gradual increase in grain yield and significant variations were observed in all treatments compared to the control.

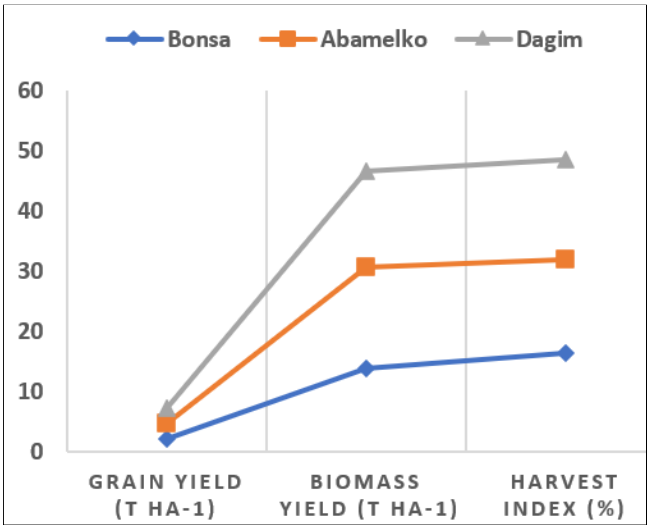

Fig 2: Effect of sorghum varieties on grain, above ground biomass yield and harvest index.

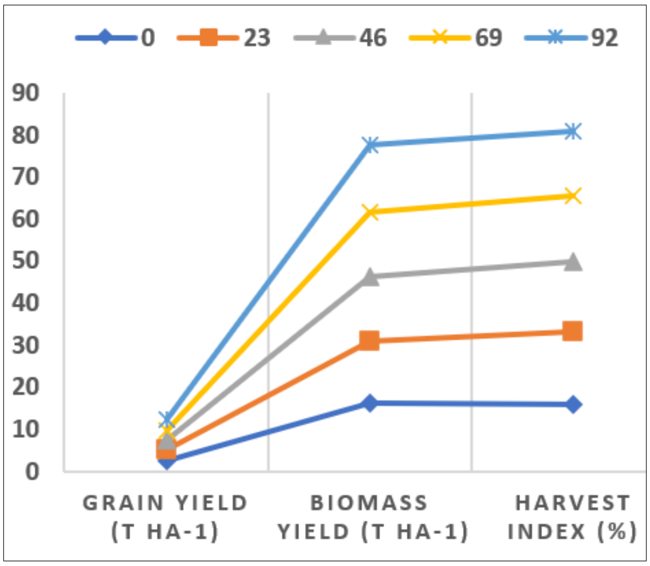

Fig 3: Effect of nitrogen fertilizer rates on grain, above ground biomass yield and harvest index

3.5 Harvest index

The highest 16.53% harvest index was recorded from Dagim and followed by 16.45% from the Bonsa variety (Table 3). It may be due to the variety difference in genetic variation in photo assimilate portioning than nitrogen fertilizer. The result was in agreement with (Mohammed *et al*., 2022) [18] report that the harvest index value increased with increasing N level in the Melkam variety. However, there were no significant variations in Girana 1 with any level of fertilizer, which indicates the genetic variation of the two sorghum varieties in partitioning assimilates. Also, the highest 17.18 harvest index was recorded from the application of 23 kg/ha of nitrogen fertilizer (fig.3). It may be due to the total nitrogen in the soil before planting being medium crop growth and development, and not sorghum's further response to applied nitrogen fertilizer. The result showed that beyond the application of 23 kg/ha nitrogen rate, there was a gradual decline in harvest index similar to dry above-ground biomass. The result was in agreement with the (Abdo. 2009) [1] reported highest harvest index from treatments with the lowest rate of nitrogen application.

4. Summary and Conclusion

Sorghum was an important crop in the area and was produced for grain consumption, it's stalk for fuel and fence making. An experiment was conducted to evaluate recently released different sorghum varieties' response to nitrogen fertilizer rates. Across-season data analysis showed that parameters like Logging percentage, plant height and dry above-ground biomass were significantly affected by sorghum varieties. The number of spikelets per head was significantly affected by nitrogen rates and stem diameter was affected by both nitrogen fertilizer application and sorghum varieties. Based on the current result, grain yield was not increased with an increase in nitrogen fertilizer application significantly. Due to residual effect of the preceding crop fertilizer applied like OM, soil total N and OC respectively were found medium rates for crop growth and development. Also, the area receiving a sufficient amount of rainfall during crop growing season. Therefore, unless the soil is not degraded or if there is the presence of preceding crop nitrogen residue was available and deficiency was not observed during growth and development application of nitrogen fertilizer for sorghum was not economical. Otherwise, the application of 23 kg/ha nitrogen fertilizer was recommended for the study area when the above conditions were observed.

5. Acknowledgements

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6. Conflicts of interest

There is no conflict of interest for this article.

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