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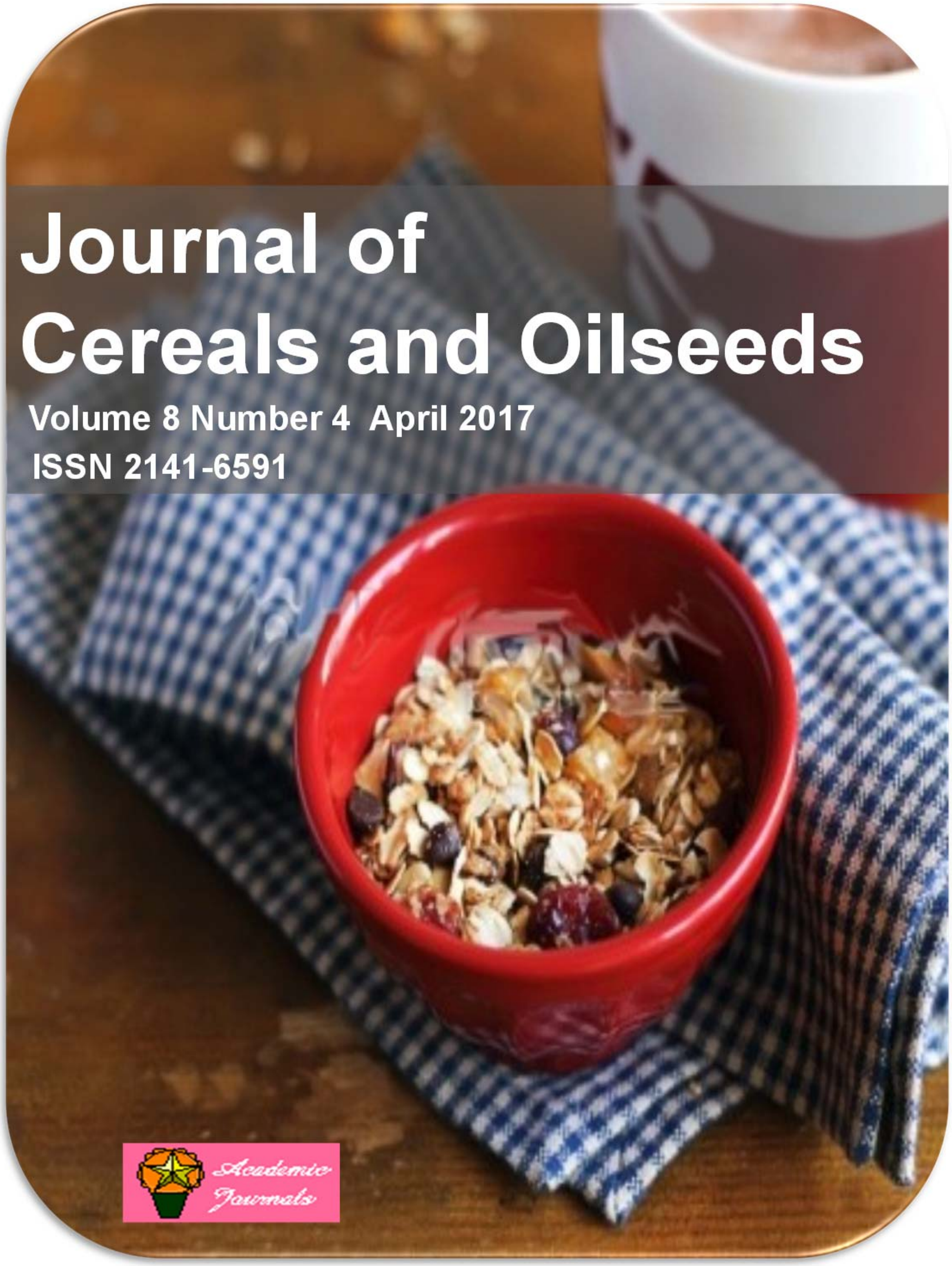

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Journal of Cereals and Oilseeds

*Full Length Research Paper*

# Determination of optimum seed rate for the production of sesame (*Sesamum indicum* L.) in the lowlands of North Shewa, Ethiopia

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**On-farm study was conducted in the lowland areas of Kewot district in the North Shewa Zone, Ethiopia on two sites during 2011 crop season to determine optimum seed rate of sesame. Four seed rates (2, 4, 6 and 8 kg ha$^{-1}$) of sesame cultivar Adi, were arranged in a randomized complete block design (RCBD) with four replications at each experimental site. The results of analysis of variance showed that location and seed rate had no significant effect on grain yield and plant height. Similarly, interaction of seed rate and location had no significant effect on grain yield, plant height and number of branches plant$^{-1}$. On the other hand, location and seed rate had significant ($p \leq 0.05$) effect in the number of branches plant$^{-1}$. The maximum number of primary branches plant$^{-1}$ (3.3) was obtained from the seed rate of 2 kg ha$^{-1}$ and the minimum number of primary branches plant$^{-1}$ (2.3) was obtained from the seed rate of 8 kg ha$^{-1}$. Since the statistical analysis revealed non-significant difference among treatment yields, comparison was made by using total costs that vary. Accordingly, 2- 4 kg ha$^{-1}$ seed rate found to be optimum for the production of sesame under rain-fed condition around Kewot district and similar areas.**

**Key words:** Adi, broadcast, Kewot, Medina, under rain-fed, Yelen crossing.

## INTRODUCTION

Sesame (*Sesamum indicum* L.) is considered one of the most important oil crop in the world because its seeds have high contents of oil (50 - 60%) and protein (Noorka et al., 2011; Islam et al., 2014; Toan et al., 2010; cited in Nadeem et al., 2015). In Ethiopia, sesame is mainly produced for the market and it is wanted for its seed and for the oil in the seed. Seed oil content is the most important parameter for determining its suitability for oil extraction, while sesame coat color determines the quality for the confectionery market and other purposes. Study reports indicate that Ethiopia is among the top-five producers of sesame seed, linseed and Niger seed (Wijnands et al., 2008; cited in Sorsa, 2009). Sesame has high agronomic importance as it has the ability to adapt to harsh environments in which other crops cannot be cultivated. Hence, in many sesame-growing regions the crop is indispensable not only for its economic importance but also for its suitability in such harsh areas. Therefore, developing improved cultivars and production technology is required to increase sesame yields and

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establish stability in different growing areas (Sorsa, 2009). Islam et al*.* (2011) stated that plant population or seed rate is influenced by row width, crop species, soil and climatic variables and, crop use. Genetic and environmental factors affect plant density (Shirtliffe, 2007). Loss et al. (1998) indicated that plant density can affect canopy architecture, light conversion efficiency, duration of vegetative growth, dry matter production, seed yield and ultimately, the economic productivity of the crop.

Therefore, optimizing plant density, which may be defined by both the number of plants per unit area and the arrangement of plants on the ground, is a pre-requisite for obtaining higher yield (Naser et al., 2013). Several research results indicated that sesame seed rates vary from place to place depending on the specific situation of the localities. El Naim et al. (2012) reported that 1.5 and 2.0 kg $ha^{-1}$ were optimum for sesame cultivation under rain-fed conditions in sandy dunes of North Kordofan state, Sudan. Islam et al. (2014) indicated that seed yield increased while increasing the seed rate from 6 to 9 kg $ha^{-1}$. Similarly, Noorka et al., (2011) showed that decreasing planting distance from 20 to 15 and 10 cm increased plant height, height of the first fruiting branch, seed, and oil yields $ha^{-1}$. On the other hand, Roy et al., (2009) sowed sesame at 15, 30 and 45 cm between plants and observed that seed yield $ha^{-1}$ and yield components were increased by raising planting space from 15 to 30 cm.

In the lowland areas of Kewot and other similar districts sesame is predominantly grown in mixed cropping with tef as it has good drought and heat tolerance capacity and can access and utilize nutrients and moisture from below the root zone of cereal crops (Langham, 2007). Therefore, to introduce sole cropping and high yielding new cultivars of sesame, determination of the seed rate is essential. According to observation trial made, national recommendation of 7 - 10 kg $ha^{-1}$ is very high for the rain-fed production of sesame around Kewot district. Hence, this experiment was done with the objective of determining optimum broadcast seed rate under rain-fed condition in the lowlands of North Shewa, Ethiopia.

## MATERIALS AND METHODS

### Description of experimental site and materials

The experiment was conducted on farmers' field in Kewot district on two localities viz., Medina and Yelen crossing, on fertile black soil types as determined by farmers' experience for one year (2011) in the central lowland of Ethiopia. Medina is located at an altitude of 1480 m above sea level and Yelen crossing is located at an altitude of 1340 meters above sea level (Adamu and Kemelew, 2010). One improved sesame cultivar (Adi) which is early and white in color was used.

### Treatments and experimental design

The treatment included four broadcast seed rates (2, 4, 6 and 8 kg $ha^{-1}$) of sesame cultivar Adi. Randomized complete block design (RCBD) with four replications was employed at each location. The gross plot size of 5 m × 5 m (25 $m^2$) with alley space of 1 m between plots and replications was employed.

### Experimental procedures

The experiment was conducted under rain-fed condition during main cropping season of 2011. Seeds were sown by manual broadcast seeding method on each plot by mixing the seeds with sand. No fertilizer was applied. Weeding and other cultural practices were done based on the agronomic recommendations and/or farmers' practices. Planting was done on July 25 – July 28, 2011.

### Crop data collection and measurement

Plant height was measured in cm from the ground to the tip of the main stem as average of ten plants randomly taken at 90% physiological maturity in each plot (from the central part) by using measuring tape. Number of branches was recorded by counting the number of branches produced on the main stem as average of ten plants randomly taken from each plot from the central part. Grain yield was measured from plants harvested from the whole plot after sun drying and threshing manually. It was measured in grams and converted to kilograms per hectare basis.

### Statistical data analysis

Data collected were subjected to the analysis of variance (ANOVA) following the statistical procedure stated by Gomez and Gomez (1984) by using General Analysis of Variance procedure of GenStat *for Windows* Version 16 (VSN International, 2013). Mean comparison was performed by using Least Significant Difference (LSD) at 5% level of significance upon obtaining significant F-values of the factor and interaction.

## RESULTS AND DISCUSSION

The results of the combined analysis of variance (ANOVA) showed that location and seed rate had no significant influence on grain yield and plant height. On the other hand, there was significant ($p \leq 0.05$) difference among treatments for number of primary branches $plant^{-1}$. Interaction of seed rate and location had no significant effect on grain yield, plant height and number of primary branches $plant^{-1}$ (Table 1).

### Grain yield

Although the seed rate, location and the interaction of seed rate and location had no significant effect on grain yield, the highest grain yield was obtained from the lowest seed rates (Table 2). It was probably related to the increased number of branches while decreasing the seed rate which may compensated for higher seed rates. In other words, the decrease in branch number by increasing plant density could be attributed to high competition between plants in the same unit area. This

**Table 1.** Summary of combined analysis of variance of grain yield, plant height and number of primary branches plant$^{-1}$ on black fertile soil in Kewot district, Ethiopia, 2011.

| Source of variation | df | GY | PH | NPBPP |
|---|---|---|---|---|
| Location | 1 | 903.1$^{ns}$ | 178.13$^{ns}$ | 4.21** |
| Seed rate | 3 | 844.8$^{ns}$ | 6.13$^{ns}$ | 1.52** |
| Location x seed rate | 3 | 5561.5$^{ns}$ | 33.79$^{ns}$ | 0.18$^{ns}$ |
| Residual | 18 | 8208.68 | 27.16 | 0.17 |

*, **, *** Significant at 5, 1 and 0.1%, respectively. df= degree of freedom, GY = Grain yield, PH = Plant height, NPBPP = Number of primary branches plant$^{-1}$.

**Table 2.** Effect of seed rate on grain yield and some agronomic traits of sesame in Kewot district, Ethiopia, 2011.

| Seed rate (kg ha$^{-1}$) | GY (kg ha$^{-1}$) | PH (cm) | NPBPP |
|---|---|---|---|
| 2 | 516.2 | 104.7 | 3.3$^{a}$ |
| 4 | 526.2 | 104.8 | 2.8$^{ab}$ |
| 6 | 501.2 | 103.0 | 2.5$^{bc}$ |
| 8 | 515.0 | 104.8 | 2.3$^{c}$ |
| Mean | 514.7 | 104.3 | 2.7 |
| LSD (5%) | ns | ns | 0.438 |
| CV (%) | 17.6 | 5.0 | 15.4 |

GY = Grain yield, PH = Plant height, NPBPP = Number of primary branches plant$^{-1}$, CV = Coefficient of variation

indicates that lowering the seed rates may had advantage over higher seed rates. Therefore, a seed rate of 2 – 4 kg ha$^{-1}$ seemed optimum for the study area. El Naim et al. (2012) also reported that 1.5 and 2.0 kg ha$^{-1}$ were optimum for sesame cultivation under rain-fed conditions in sandy dunes of North Kordofan state, Sudan. In contrast, this result was in disagreement with the results obtained by Islam et al. (2014) in which seed yield increased while increasing the seed rate from 6 to 9 kg ha$^{-1}$. However, according to Baloch et al. (2002), under increased plant density, intra-specific competition for light and nutrient leads to a reduction in grain yield. Bond et al. (2005) revealed that intra-specific competition due to different seeding densities may vary in their intensity and compensatory growth of individual plants, when grown at lower densities, results in similar grain yield over a broad range of densities. Based on the fact that marginal response in yield is very small at high population and when the marginal cost of an increase in plant density approaches the marginal return from the increase in yield, further increases in seed rate are not warranted (Graf and Rowland, 1987, cited in Naser et al., 2013). Hence, the optimum population is highly dependent up on seed cost.

## Effect of seed rate on plant height

Increasing seed rate from 2 to 8 kg ha$^{-1}$ had no significant effect on plant height probably due to vigorous and taller growth of lower seed rates. Similar results were reported by El Naim et al. (2012), which showed that plant density had no significant effect on plant height of sesame. On the other hand, contrasting results were obtained by Islam et al., 2014 who reported that significantly tallest plants were obtained from 10 kg ha$^{-1}$ and the shortest plants were obtained from 6 kg ha$^{-1}$. Similarly, Noorka et al., (2011) stated that increasing plant population density from 200000 to 266666 and 400000 plants ha$^{-1}$ by decreasing planting distance between hills from 20 to 15 and 10 cm significantly increased plant height. According to the authors, this result might be due to the higher competition effect among plants for light in dense plant population, which may results elongation of internodes and in turn gave taller plants. Nadeem et al. (2015) obtained similar results indicating that when the number of plants m$^{-2}$ increases, the competition for light also increases and plant grows taller to intercept maximum light.

## Effect of seed rate on number of primary branches plant$^{-1}$

Decreasing seed rate from 8 to 2 kg ha$^{-1}$ had significant effect on number of primary branches plant$^{-1}$. The highest number of primary branches plant$^{-1}$ (3.3) was obtained from the seed rate of 2 kg ha$^{-1}$ and the lowest number of

**Table 3.** Comparison of seed rates in Kewot district, Ethiopia, 2011.

| Seed rate (kg ha$^{-1}$) | Mean grain yield (kg ha$^{-1}$) | Yield advantage over 2 kg ha$^{-1}$ in % | Seed cost (Birr ha$^{-1}$) | Seed cost difference with 2 kg ha$^{-1}$ in % |
|---|---|---|---|---|
| 2 | 516.2 | | 40 | |
| 4 | 526.2 | 1.9 | 80 | 100 |
| 6 | 501.2 | -2.9 | 120 | 200 |
| 8 | 515.0 | -0.2 | 160 | 300 |
| Mean | 514.7 | | | |

primary branches plant$^{-1}$ (2.3) was obtained from the seed rate of 8 kg ha$^{-1}$. As expected lower seed rate produced significantly highest number of primary branches plant$^{-1}$. These results are in agreement with Islam et al. (2014) who reported that the number of primary branches plant$^{-1}$ decreased with the increase of seed rate from 6 kg ha$^{-1}$ to 10 kg ha$^{-1}$. He also indicated that the production of higher number of primary branches per plant$^{-1}$ at a lower seed rate was probably due to numerous factors such as availability of more space and water available to the plants. Other similar evidences were also reported by Noorka et al. (2011), El Naim et al. (2012) and Nadeem et al. (2015).

## Economic analysis

Because there was no significant difference among treatment yields, developing partial budget and/or performing economic analysis was found irrelevant (CIMMYT, 1988). Hence, the treatments were compared by using total costs that vary. The lowest seed rate of 2 kg ha$^{-1}$ was out yielded only by the seed rate of 4 kg ha$^{-1}$ with yield advantage of 1.9% and with extra cost of 100%. The other two seed rates (6 and 8 kg ha$^{-1}$) produced lower yields of -2.9 and -0.2% respectively than the lowest seed rate of 2 kg ha$^{-1}$ yet with extra cost of 200 and 300% respectively. As can be seen from this result, increasing seed rate above the optimum incurred extra seed cost without any significant yield increment. Hence, the optimum seed rate of sesame for the above locations seems 2 – 4 kg ha$^{-1}$ under rain-fed condition (Table 3).

## Conclusion

This result revealed that nationally recommended seed rate of sesame could be changed depending on the situations of specific localities. Accordingly, 2- 4 kg ha$^{-1}$ seed rate found to be optimum for the production of sesame under rain-fed condition around Kewot district and similar areas. This result could be used for sole cropping of sesame and/or could be used for determination of optimum proportions for tef-sesame intercropping.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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*Full Length Research Paper*

# Performance evaluation of sorghum [*Sorghum bicolor* (L.) Moench] hybrids in the moisture stress conditions of Abergelle District, Northern Ethiopia

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**Sorghum [*Sorghum bicolor* (L.) Moench] grown under rain-fed conditions is usually affected by moisture stress at different stages, resulting in reduced yield. The assessment of variation in agronomic traits contributing towards drought escaping at these stages is of vital importance. This study was conducted during 2014 and 2015 cropping seasons using a randomized complete block design with three replications to evaluate 12 sorghum hybrids (one standard check) for their better performance under moisture stress conditions at Abergelle Agricultural Research Center on station. The data of 9 different agronomic traits were subjected to combined analysis of variance, estimation of genetic variability and heritability. Data was analyzed for variance for number of seeds per panicle, panicle length, plant height, days to flowering and maturity, 1000 seed weight, grain yield, biomass yield and harvest index under moisture stress conditions. The combined analysis of variance result for grain yield of the hybrids evaluated over seasons was highly significant at p< 0.001. Relatively high magnitude of phenotypic and genotypic coefficient of variations (>20%) for grain yield, biomass yield and harvest index as well as high heritability (>80%) for biomass yield were recorded. Generally, the present study entails the presence of significant variations among sorghum hybrids. Therefore, the hybrid sorghum genotypes Enforce (3263 kg ha$^{-1}$), NGC22319 (3113 kg ha$^{-1}$) and NGC76319 (3068 NGC76319 kg ha$^{-1}$) were identified as superior for grain yield under moisture stress conditions of Abergelle district.**

**Key words:** Agronomic traits, grain yield, heritability, hybrid, moisture stress.

## INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] belongs to the grass family, *Poaceae* which is among the dominant staple cereals for the majority of Ethiopians. It forms the most important dry land cereal crop for the semi-arid tropics together with maize and pearl millet (*Pennisetum glaucum* (L.). It requires less water than most cereals; hence it offers great potential for supplementing food and feed resources (KARI Proceedings, 2000) especially in dry lands where rainfall is limited. Sorghum (*S. bicolar)* grows over a wide range of latitudes from 0 to 45° North and South of the equator (ICRISAT, 1991).

Plant moisture conditions are crucial to growth and

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development of plants. Under these stress conditions, the uptake of water by roots may be insufficient to meet the transpiration in such dry air and soil environments. rain fall (Geremew et al., 2004). It is a staple food in the drier parts of tropical Africa, India and China. Sorghum is grown in Ethiopia in 12 of the 18 major agro-ecological zones. It is one of the important indigenous food crops and is only second to *tef* as *injera* (leavened local flat bread) making cereal. The low land areas of Ethiopia are climatically characterized by high temperature and insufficient amount of rainfall during the crop-growing season. In these areas, crop production is mainly rain-fed. Because of the low amount, uneven distribution and erratic nature of the rainfall, crop production is seriously affected in these areas. A number of constraints have been standing on the way of sorghum production.

The major problems that check sorghum production in the dry land areas of the country include: lack of early maturing varieties that can escape drought, poor soil fertility, poor stand establishment due to reduced emergence in characteristically crusty soils, insect pests like the spotted stalk borers (*Chilo partellus*) and birds (Geremew et al., 2004). Sorghum grows in a wide range of agro ecologies most importantly in the moisture stressed parts of Ethiopia, where other crops can least survive and food insecurity is rampant (Asfaw, 2007).

Sorghum is one of the leading traditional stable food crops in Abergelle that acreage about 14335 hectares of land and this accounted for about 45.63%. It ranks first in its coverage in the district, but the area is often limited by moisture stress (Fantaye and Atsbha, 2016). Moisture stress is one of the most important abiotic problems/drought factors contributing significantly to yield loss in arid and semi-arid environments. This problem is alleviated by developing crops that are well adapted to moisture constraint areas. Sorghum is an important drought tolerant crop in such areas and is a good crop model for evaluating mechanisms of moisture stress. Over 80% of sorghum in Ethiopia, including Abergelle is produced under severe to moderate drought stress conditions. Most farmers grow long maturing local landraces, some of which take 7-8 months to mature further, complicating the drought problem. Although, the extent of yield loss due to drought was not studied in Ethiopia, complete yield loss was observed in some parts of the country, such as Mehoni area (EIAR, 2014).

In most of these areas, rainfall distribution is erratic and unreliable. Very short growing seasons are available for the crops grown in this part of the country. Consequently, only crop species which adapt to such short growing seasons are essential. The crops which are early maturing, drought tolerant and resistant to higher temperatures are of great interest to the farmers (Dereje et al., 1995). The national and regional sorghum improvement programs have released a number of open pollinated sorghum varieties for the moisture deficit lowland areas of Ethiopia. However, hybrids have been found to be better suited than varieties to such stress environments as a result of earliness, better adaptation and stability (Yilma and Abebe, 1986).

Therefore, there is still need for development of more acceptable varieties/hybrids, which are high yielding, drought escaping, and are able to tolerate low soil fertility, pests and diseases in the moisture stress areas. Hence, this study was performed to evaluate sorghum hybrids for their yielding ability and estimate genetic variability and heritability under random moisture stress conditions of Abergelle district.

## MATERIALS AND METHODS

### Description of the study area

The field experiment was carried out under rain-fed conditions at Abergelle Agricultural Research Center (AbARC) testing site, during 2014 and 2015 cropping seasons, respectively. Abergelle is located in the central zone of Tigray National Regional State, Ethiopia (Figure 1). It is 903 km away from north of Addis Ababa and 120 km south west of Mekelle and situated at 13°14’06” N latitude and 38°58’50” E longitudes. The study area is identified as the most droughts prone in the region, where sorghum varieties released for drought tolerance by research institutions are tested and optimized (Georgis et al., 2010). The area is agro-ecologically characterized as hot warm sub-moist lowland (SMl-4b) located at an elevation of 1450 m above sea level. Plains, hills and river valley, characterize the topography of the district and it is highly exposed to soil erosion. Most soils of the district are dominated by sandy textured with poor water holding capacity and less fertile; in turn most of the crops failed to produce good yield (CSA, 2015).

The dominant soil types of the study area are small seedily called walka, bahkel, hutsa and mekayih. The rainfall status of the study area is unpredictable and erratic from season to season. The average annual rainfall varies from 350-650 mm and the temperature of the study area ranges from 18-42°C. The distribution of rainfall is erratic and variable, which results in strong variation in crop yields. The rain may start late and/or ends early. It is obvious that this kind of rainfall has a negative impact on the agricultural activities of the community causing uncertainty. The rainfall distribution from the agricultural point of view is mono-modal, concentrated during the summer (July to August). The farmers grow only one crop per season (Dereje et al., 2007).

### Experimental design and crop management

The trial was laid out in randomized complete block design (RCBD) with three replications in a plot size of 11.5 $m^2$ (2.25 x 5 m). Experimental unit comprised of three-rows of 5 m length with row-to-row distance of 75 cm and plant-to-plant distance of 20 cm. Spacing between blocks and plots were 1 and 0.5 m, respectively. All plots were fertilized uniformly with 100 kg/ha diammonium phosphate (DAP) and 50 kg/ha urea. Full dose of P and half of N were applied at the time of planting and the remaining half was side dressed at knee height stage of the crop. Other management practices were applied as per recommendation.

### Data collection and sampling techniques

Data were collected on some phenological (days to 50% flowering and 75% maturity), growth (plant height and panicle length), yield

**Table 1.** Mean values of morphological traits of sorghum hybrids tested at Abergelle on station.

| Genotypes | Code | DM | | | PH | | | PL | | | NSPP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | Mean | E1 | E2 | Mean | E1 | E2 | Mean | E1 | E2 | Mean |
| Liberty | H1 | 113 | 95 | 104$^{abcd}$ | 112.23 | 158.33 | 135.3$^{b}$ | 29.6 | 29.9 | 29.73$^{ab}$ | 2378 | 2130 | 2254$^{abcd}$ |
| Dominator | H2 | 115 | 93 | 104$^{abcd}$ | 110.27 | 131.67 | 121.0$^{cd}$ | 27.42 | 23.9 | 25.64$^{c}$ | 2308 | 2224 | 2266$^{abc}$ |
| Enforces | H3 | 109 | 94 | 102$^{cde}$ | 118.8 | 150.0 | 134.4$^{b}$ | 29.8 | 27.8 | 28.8$^{bc}$ | 2401 | 2258 | 2330$^{ab}$ |
| NGC10341 | H4 | 112 | 94 | 103$^{bcd}$ | 97.57 | 113.33 | 105.4$^{f}$ | 27.1 | 27.5 | 27.3$^{cd}$ | 2349 | 2423 | 2386$^{a}$ |
| NGC58366 | H5 | 119 | 96 | 108$^{ab}$ | 111.3 | 193.33 | 152.3$^{a}$ | 29.1 | 30.9 | 30.0$^{ab}$ | 2033 | 1984 | 1994$^{d}$ |
| NGC05304 | H6 | 112 | 95 | 104$^{bcd}$ | 132.07 | 178.33 | 155.2$^{a}$ | 30.73 | 30.7 | 30.73$^{a}$ | 2343 | 1919 | 2131$^{abcd}$ |
| NGC10315 | H7 | 124 | 94 | 109$^{a}$ | 99.63 | 123.33 | 111.5$^{ef}$ | 25.8 | 25.8 | 25.8$^{de}$ | 2258 | 2286 | 2272$^{abc}$ |
| NGC22319 | H8 | 104 | 94 | 99$^{def}$ | 114.42 | 133.33 | 123.9$^{c}$ | 28.62 | 27.4 | 28.01$^{c}$ | 1935 | 2217 | 2076$^{bcd}$ |
| NGC76319 | H9 | 111 | 93 | 102$^{bcde}$ | 111.93 | 135.0 | 123.5$^{c}$ | 29.13 | 26.3 | 27.73$^{c}$ | 2165 | 2230 | 2197$^{abcd}$ |
| NGC41301 | H10 | 104 | 91 | 98$^{ef}$ | 112.6 | 135.0 | 123.8$^{c}$ | 26.37 | 24.8 | 25.58$^{e}$ | 2072 | 2186 | 2129$^{abcd}$ |
| NGC77344 | H11 | 99 | 91 | 95$^{f}$ | 118.67 | 110.0 | 114.3$^{de}$ | 24.67 | 23 | 23.83$^{f}$ | 1953 | 2125 | 2039$^{cd}$ |
| ESH-1 (check) | H12 | 117 | 97 | 107$^{abc}$ | 144.73 | 166.67 | 155.7$^{a}$ | 27.87 | 22.2 | 25.03$^{ef}$ | 2151 | 2395 | 2273$^{abc}$ |
| LSD (5%) | | | | 7.56 | | | 11.97 | | | 2.21 | | | 383 |
| CV (%) | | | | 4.5 | | | 5.6 | | | 4.9 | | | 10.6 |

Where, H=hybrid, E1= 2014 and E2= 2015 cropping seasons respectively; PH = plant height (cm), PL=panicle length (cm), DM = days to physiological maturity, NSPP=number of seeds per panicle, LSD = least significant differences, CV (%) = coefficient of variance.

and yield related traits of sorghum such as number of seeds per panicle thousand seed weight, grain yield, biomass yield and harvest index. Description of the traits investigated in this study includes: Days to 50% flowering, the date when 50% of the plants produced flowers was recorded and converted in number of days from date of emergence up to date of flowering; Days to 75% maturity, the date when 75% of the plants were physiologically matured; Plant height, plant height of tagged plants were measured from the ground level to the tip of the panicle at maturity and expressed in centimeter (cm); Panicle length, panicle length measurement (cm) from the base of the panicle to the tip from randomly selected plants per plot at maturity; Grain yield, total grain weight per plot (kg) after threshing then converted to kg per hectare. Biomass yield, the total sun-dry weight of the above ground biomass of the plants in the two middle rows (kg), then converted to kg per hectare; Number of seeds per panicle: Average number of seeds counted from 5 randomly selected plants' panicle in the plot; Thousand seed weight, the weight of one thousand seeds counted manually sampled from a plot and weighed at 12.5% moisture content. Harvest index, the ratio of grain weight to the total above ground biomass yield computed from the two middle rows.

#### Data analysis

The collected data were subjected to combine the analysis of variance (ANOVA) using the Statistical Analysis System (SAS) software version 9.1 program (SAS Institute, 2004). Means were separated using Fisher's Least significant difference (LSD) test at 5% level of probability as stated in Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

### Variation in grain yield and other agronomic traits

The combined analysis of variance revealed that the studied hybrids were significantly different in most traits measured. The tallest mean plant height (155.2 cm) was attained in H6 (NGC05304) and the difference in height with the other hybrids was significant at $p<0.001$. Moreover, H6 (NGC05304) had the tallest mean panicle length (30.73 cm) and the difference with the other hybrids was significant at $p<0.05$ (Table 1). However, the shortest plant height (105.4 cm) and panicle length (23.83 cm) were recorded from H4 (NGC10341) and H11 (NGC77344), respectively. The difference in days to 50% flowering was statistically significant between NGC77344 and the other studied hybrids (Figure 2). NGC77344 had shorter days to 75% maturity. This shows that NGC77344 is a candidate hybrid for terminal drought prone areas, where the longest mean number of days to maturity (109) was recorded for NGC10315.

The earliness traits (days to flowering, grain filling period and days to physiological maturity) enables them to flower, grain fill and mature early. NGC77344 matured earlier than the other hybrids thus making it more adaptable in the moisture stress conditions of Abergelle district and other districts having the same agro-ecologies, but low yielder as compared to the other sorghum hybrids.

Highly significant ($p<0.001$) varietal difference was observed for most of yield and yield related traits (Table 2). The mean total grain yields of the hybrids showed high variation in grain yield which ranged from 1844 (NGC58366) to 3263 kg ha$^{-1}$ (enforces). This result revealed that when there were more mean plant height and panicle length, the yield increased (Table 1). Farooq et al. (2009) also reported that grain yield is the result of the expression and association of several plant growth components. The combined analysis of variance indicated that among the 12 hybrids, Enforce (3263 kg

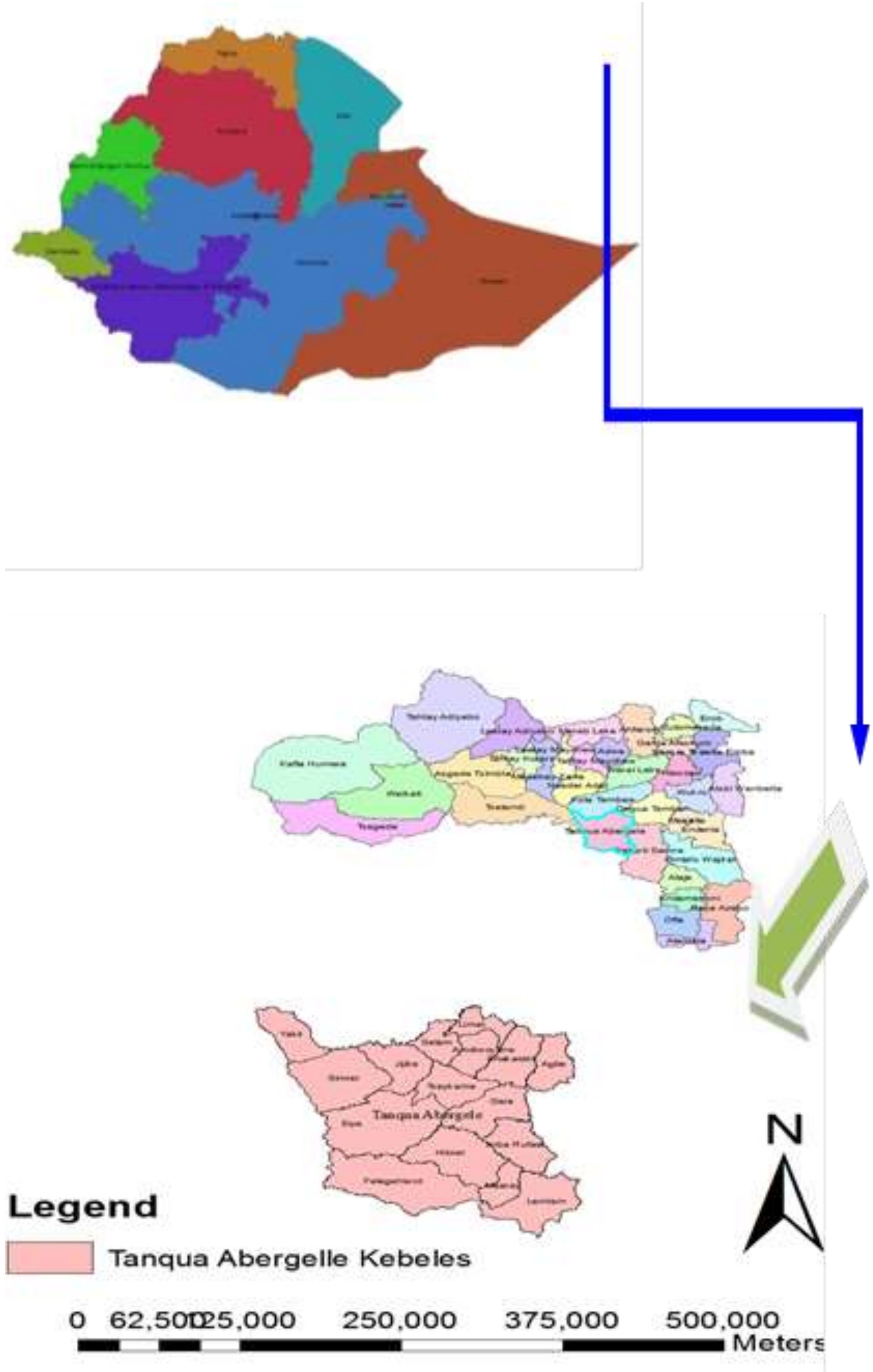


**Figure 1.** Map of the study area.

ha$^{-1}$), NGC22319 (3113 kg ha$^{-1}$) and NGC76319 (3068 kg ha$^{-1}$) had significantly ($p<0.001$) higher grain yield than the commercial hybrid ESH-1 used as a check in Ethiopia. Besides, the results of the present study (Table 2) showed that the 11 hybrids had significantly ($p<0.001$) higher biomass yield, thousand seed weight and harvest index than the check (ESH-1). The number of seeds per panicle ranged 1994 (NGC58366) to 2386 (NGC10341).

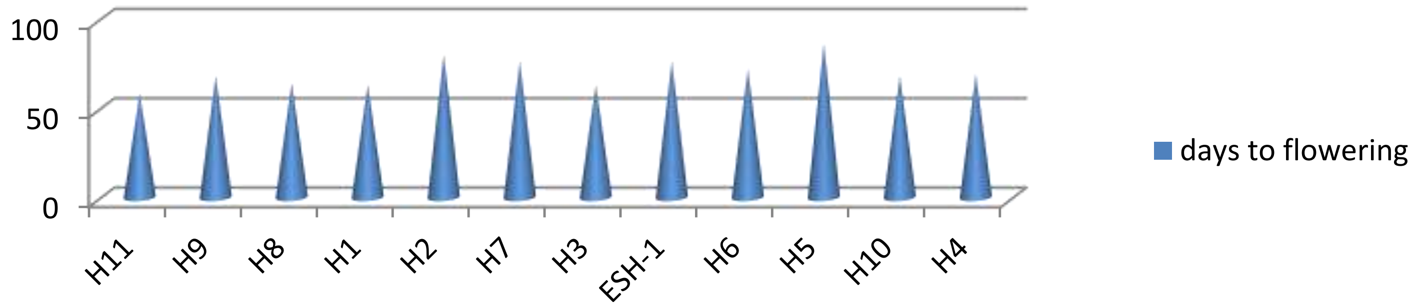


**Figure 2.** Days to 50% flowering of the studied sorghum hybrids during the main rainy season.

**Table 2.** Mean yield and yield related traits of sorghum hybrids tested at Abergelle on station.

| Genotypes | Code | TSW | | | GY | | | BM | | | HI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E1 | E2 | Mean | E1 | E2 | Mean | E1 | E2 | Mean | E1 | E2 | Mean |
| Liberty | H1 | 20 | 22 | 21.00[cd] | 2115 | 3075 | 2595[cd] | 2588 | 3469 | 3028[ef] | 0.81 | 0.89 | 0.850[ab] |
| Dominator | H2 | 19 | 23.7 | 21.33[bcd] | 2141 | 2277 | 2209[e] | 3439 | 3889 | 3134[de] | 0.66 | 0.81 | 0.733[cd] |
| Enforces | H3 | 20.3 | 21.7 | 21.00[cd] | 2955 | 3570 | 3263[a] | 3331 | 3889 | 3610[abc] | 0.88 | 0.92 | 0.899[a] |
| NGC10341 | H4 | 19 | 20.3 | 19.67[de] | 1733 | 2650 | 2192[e] | 2102 | 2949 | 2526[g] | 0.84 | 0.89 | 0.864[a] |
| NGC58366 | H5 | 18.67 | 25.3 | 22.00[bc] | 1807 | 1881 | 1844[f] | 3601 | 2346 | 2974[efg] | 0.50 | 0.80 | 0.653[d] |
| NGC05304 | H6 | 22.3 | 24 | 23.17[ab] | 2869 | 2783 | 2826[bc] | 3296 | 3113 | 3205[bcde] | 0.88 | 0.89 | 0.885[a] |
| NGC10315 | H7 | 17.3 | 18.7 | 18.00[e] | 1445 | 2853 | 2149[e] | 3067 | 3238 | 3152[cde] | 0.47 | 0.88 | 0.676[d] |
| NGC22319 | H8 | 23.3 | 20 | 21.67[bc] | 2304 | 3922 | 3113[a] | 2868 | 4412 | 3640[abc] | 0.81 | 0.89 | 0.848[ab] |
| NGC76319 | H9 | 20.3 | 22 | 21.17[cd] | 2747 | 3390 | 3068[ab] | 3683 | 3848 | 3766[a] | 0.76 | 0.88 | 0.819[abc] |
| NGC41301 | H10 | 22 | 21.7 | 21.83[bc] | 2283 | 2697 | 2490[d] | 2675 | 3073 | 2874[efg] | 0.86 | 0.88 | 0.868[a] |
| NGC77344 | H11 | 23.67 | 20.7 | 22.17[bc] | 2033 | 1995 | 2014[ef] | 2817 | 2480 | 2648[fg] | 0.74 | 0.81 | 0.773[bc] |
| ESH-1 (check) | H12 | 20 | 29 | 24.50[bc] | 2101 | 3324 | 2713[cd] | 3286 | 3871 | 3578[abcd] | 0.67 | 0.81 | 0.765[bc] |
| LSD (5%) | | | | 2.66 | | | 390.65 | | | 656.5 | | | 0.12 |
| CV (%) | | | | 7.5 | | | 9.4 | | | 12.6 | | | 9.3 |

Where, H=hybrid, E1= 2014 and E2= 2015 cropping seasons respectively; TSW= 1000 seed weight (g), GY = grain yield (kg·ha−1), BM = total biomass (kg·ha−1), HI (%) = harvest index, LSD = least significant differences, CV (%) = coefficient of variance.

1000 seed weight ranged from 18.00g (NGC10315) to 24.50 g (ESH-1).The highest biomass yield was observed in NGC76319 (37.66 kg ha$^{-1}$) followed by NGC22319 (3640 kg ha$^{-1}$), whereas the lowest biomass yield was recorded from NGC10341 (2526 kg ha$^{-1}$). However, the newly evaluated hybrids did not differ significantly from ESH-1 in number of seeds per panicle. Generally, from farmers' opinion during field day and results obtain from the experiment the hybrids, Enforces, NGC22319 and NGC76319 took the first, second and the third places orderly in Abergele district.

## Components of variability and heritability

The phenotypic and genotypic variance were estimated according to the methods suggested by Burton and de Vane (1953) and these components of variance ($\delta^2$p, $\delta^2$e and $\delta^2$g) were used for the estimation of coefficients of variation (PCV, GCV) as described by Singh and Chaudhary (1977). Heritability (K=2.06 at 5% selection intensity) were computed for each character based on the formula developed by Allard (1960).

1. Genotypic variance, $GV = (MSg - MSe)\ r$, where $MSg$ = mean square of genotypes, $MSe$ = mean square of error, and $r$ = number of replications;
2. Phenotypic variance, $PV = GV + MSe$, where $GV$ = genotypic variance and $MSe$ = mean square of error;
3. Phenotypic coefficient of variation, $PCV = (\sqrt{(PV)})/x \times 100$ , where $PV$ = phenotypic variance and $x$ =mean of the character;
4. Genotypic coefficient of variation, $GCV = (\sqrt{GV}) /x \times 100$, where $GV$ = genotypic variance and $x$ =mean of the character;
5. Heritability (broad sense heritability), $H = GV/PV \times 100$ where $GV$ and $PV$ are genotypic and phenotypic variances, respectively.

**Table 3.** Estimates of means, genotypic and phenotypic variation, genotypic and phenotypic coefficients of variation for yield and yield related traits of hybrid sorghum genotypes.

| Traits | Mean square | | | Mean | $\delta^2$g | $\delta^2$p | GCV (%) | PCV (%) |
|---|---|---|---|---|---|---|---|---|
| | Genotypes (df=11) | G*E (df=11) | Error (df=44) | | | | | |
| Days to flowering | 133.39 | 28.65 | 34.55 | 59.61 | 30.097 | 117.387 | 7.724 | 15.2543 |
| Days to maturity | 11.38 | 49.59* | 21.16 | 102.8 | 46.45 | 80.2977 | 6.05 | 7.955 |
| Plant height | 42.79 | 725.03*** | 53.03 | 129.7 | 207.37 | 428.143 | 12.15 | 17.458 |
| Panicle length | 4.169 | 6.104* | 1.813 | 27.4 | 2.084 | 4.8713 | 5.16 | 7.886 |
| Number of seeds per panicle | 8152 | 63663 | 54293 | 2196 | 12616.5 | 54429.7 | 5.135 | 10.665 |
| Thousand seed weight | 1.542 | 18.852*** | 2.614 | 21.5 | 14.315 | 17.955 | 17.63 | 19.745 |
| Grain yield | 345704 | 500763*** | 56497 | 2540 | 17.51 | 23.19 | 18.88 | 21.726 |
| Biomass yield | 1455729 | 845552*** | 159563 | 3178 | 107.36 | 122.36 | 33.07 | 35.307 |
| Harvest index | 0.0133 | 0.022*** | 0.0055 | 0.803 | 0.032 | 0.042 | 23.58 | 27.015 |

*Indicates significance at P< 0.05, **= p< 0.01, *** =p< 0.001. Where, G*E=genotype by environment interaction, $\delta^2$p = phenotypic variation, $\delta^2$g = genotypic variation, GCV (%) = genotypic coefficient variance, PCV (%) = phenotypic coefficient variance.

## Mean, estimates of variance component coefficients of variation

A relatively high phenotypic coefficient of variation (PCV) values (>20%) were obtained for grain yield (21.73%), biomass yield (35.31) and harvest index (27.015%) (Table 3). Similarly, high genotypic coefficients of variation (GCV) values (> 20%) were also obtained for biomass yield (33.07%) and harvest index (23.57%). Bello et al. (2007) reported high value of PCV and GCV for panicle length per plant, 1000 seed weight, days to flowering and days to maturity (Kassahun et al., 2015), high PCV values (>20%) for leaf area index, plant height, panicle weight, panicle yield, grain yield and harvest index and relatively high GCV values (> 20%) for leaf area index, plant height, panicle yield, grain yield and harvest index. Tesfamichael et al. (2015) also reported high magnitude of phenotypic and genotypic coefficient of variations for plant height, harvest index and biomass. In contrast to the present study, low GCV and PVC (<20%) was observed in terms of panicle length, number of seeds per panicle, plant height, days to maturity, 1000 seed weight except grain yield, biomass and harvest index (Table 3). In another case, the study indicated that improvement of these traits through selection is less effective due to lack of genetic variation among the genotypes which is the basic
prerequisite in which positive response due to selection depends on.

According to Singh (2001), high heritability of a trait (≥ 80%) provides selection for such traits which could be fairly easy due to a close correspondence between the variety and the phenotype due to the relative small contribution of the environment to the phenotype. In other words, if environmental variability is small in relation to genotypic differences, selection will be efficient because the selected character will be transmitted to its progeny. Based on this idea, high broad sense heritability was estimated for only biomass yield (87.74).

## Conclusions

According to the combined analysis of variance, the studied hybrids were significantly different in most traits measured. The findings of this study showed that H3 Enforces (3263 kg ha-1), NGC22319 (3113 kg ha-1) and NGC76319 (3068 kg ha-1) had a good performance while yield of other hybrids reduced due to low yield potential, which were sensitive to stress conditions than the check (ESH-1). The earliness traits (days to flowering, grain filling period and days to physiological maturity) enables them to flower, grain fill and mature early. Relatively, high magnitude of phenotypic and genotypic coefficient of variations (>20%) for grain yield, biomass yield and harvest index as well as high heritability (>80%) for biomass yield were recorded.

Generally, from farmers' opinion, during field day and results obtain from the experiment, it was revealed that the present study entails the presence of significant variation in sorghum yield increment. Therefore, the sorghum hybrids Enforces, NGC22319 and NGC76319 were identified as superior for grain yield under random moisture stress conditions of Abergelle district.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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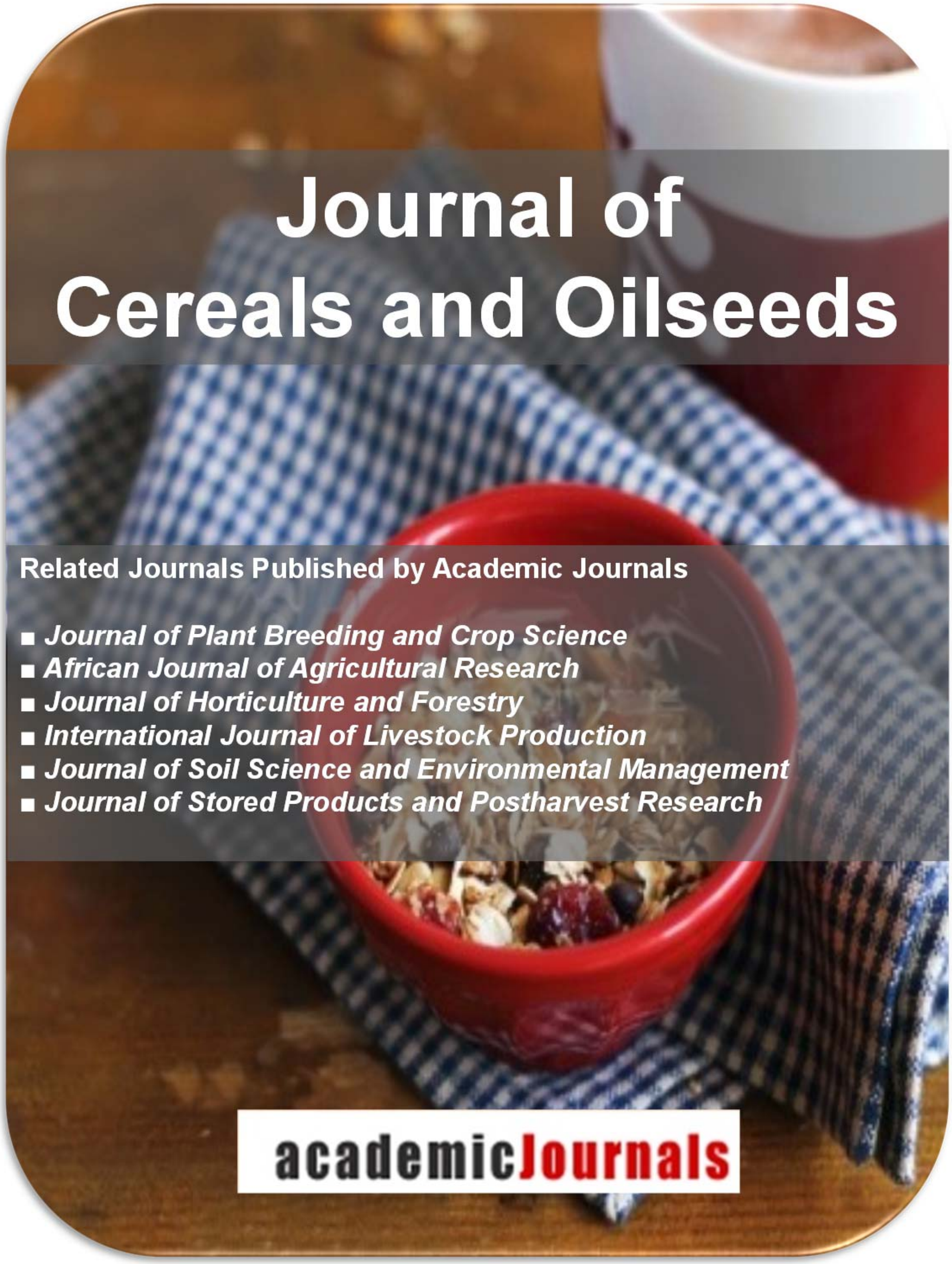
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