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Berhanu Fentie Belay¹* and Mesfin Fenta Wale¹

Abstract: Participatory varietal selection (PVS) were conducted at Dembia, Gondarzuria and Takusa midland districts of North Gondar during 2015–2016 main cropping seasons to evaluate and select improved sorghum varieties for high yield and other agronomic traits. The experimental design was a randomized complete block design with three replications. The analysis of variance showed highly significant among treatments of all traits. Environment and Genotype by Environment Interaction also contributed significant effect on performance of some yield components. The highest average grain yield was recorded from the variety IS9302 (2635 kg/ha) followed by Birmash (2537 kg/ha) across locations. Four parametric stability methods including: Lin and Binns’s Cultivar Performance Measure (P), Wricke’s Ecovalence (Wₑ), Static stability and GGbiplot methods that consider both yield and stability were conducted. Based on those parameters genotype IS9302 showed high mean yield and stability across locations. Participant farmers’ prioritized seven traits: head size, panicle length, earliness, grain color, disease and pest tolerance, stalk vigor and plant height. Hence, farmer’s preferences in a variety selection process more prioritized yield-related traits. The best varieties ranked by traits of interest were IS9302, Dagem and Birmash that performed well under their circumstances. Hence, the results showed that farmers’ preferred varieties matches with researchers’. Therefore, based on objectively measured traits, farmers preferences and the agro ecologies of the site varieties IS9302, Dagem and Birmash were found promising for production in the mid altitude of North Gondar and similar agro ecologies.

ABOUT THE AUTHOR

Mr. Berhanu Fentie is an associate researcher in crops research directorate at Gondar Agricultural Research Center. He has been conducted many research activity related to plant breeding in cereal case team. He has an interest to do more researches on improvement of sorghum breeding program. Both cereal crop breeder and socioeconomic researcher were actively participated in this research. Mr. Mesfin Fenta is Researcher at Gondar Agricultural Research Center and currently, he is working as coordinating of the socioeconomic researcher directorate Program in the Center.

PUBLIC INTEREST STATEMENT

In Amhara region, North Gondar areas is one of the major high potential agro-ecologies for sorghum production. Even if, in Ethiopia, there have been many sorghum technologies with various desirable characteristics for the major agro ecologies, farmers predominant cultivate low yielding and late maturing local varieties. However, improved varieties may not be adaptable to different agro-ecologies without the smallholder farmers’ participation and involvement of their indigenous knowledge. Therefore, Farmers’ participation in variety evaluation and development is demanded to overcome adoption and dissemination of sorghum technologies.
**Subjects: Bioscience; General Science**

**Keywords: participatory evaluation; selection; high yielder; stable; sorghum; varieties**

1. **Introduction**

Sorghum (*Sorghum bicolor* L. Moench) in Ethiopia is the main staple food crop, ranking third after tef, and maize in total production and it ranks second after maize in productivity per hectare (CSA (Central Statistical Agency), 2014). It has tremendous uses for Ethiopian farmers, and no part of this plant ignored. The grains used for human foods such as local bread (injera) porridge, Nefiro, infant food, syrup, and local beverages known as “Tella” and “Arekie”. The leaf and stalks used for animal feed, fuel, and construction of houses and fences (Amelework Beyene et al., 2016).

North Gondar has one of the major high potential agro-ecologies for sorghum production in Amhara region and contributes the highest share (43.74%) as compared to other crops grown in the area and have three major agro ecological areas for crop production, sorghum grows in low land and intermediate agro ecologies (CSA (Central Statistical Agency), 2014). Despite the area under sorghum cultivation in these areas has steadily increased, the average yield trends downwards compared to the achievable yield potential of improved high yielder varieties released in the country (Abate, 2016). Main constraints of sorghum production in the region are predominant cultivation of low yielding local varieties, inaccessibility to improved varieties, and poor adoption of improved technologies, poor soil fertility, drought, pests, weed and diseases (Geremew Gemechu et al., 2004). Majority of the farmers in the study areas growing sorghum landraces which takes 7–8 months to mature and practice mono cropping in sorghum, finger millet and fenugreek; double cropping of maize, wheat, barely, teff with chickpea, pigeon pea, white cumin and black cumin and inter cropping of maize with faba bean.

Currently, variety of improvement and technology generation is selected as main national strategic as food security and agricultural growth. Over the last decades, more than 40 improved multipurpose sorghum varieties with various desirable characteristics that give high grain yield, feed and fuel wood were released by using conventional breeding approach for the major agro ecologies of the country (McGuire, 2005). The existing registered sorghum varieties in Ethiopia were released based on adaptability of their suitable agro ecology. The varieties used in this research released for the intermediate areas, which have similar agro ecological features of the experimental locations. However, how much of the improved varieties adopted at farmers field and their adoption intensity and impact is not quantified, majority of the farmers are growing farmers varieties in the three sorghum ecologies (FC Mekbib, 2000). Farmers preferred to grow the local varieties because of good adaptability to the environment and their local farming system. Even if varieties released for the intermediate areas are multipurpose sorghum varieties (high grain yield, feed, construction, and fuel wood), still not familiarized and adopted with farmers (I). Generally, in the past Ethiopian sorghum improvement program had a research gap on developing improved varieties that combine high grain yield, grain quality and biomass multiline, tolerance/resistance farmers preferred traits adapted to different agro ecologies (Chemeda Birhanu, 2018). The staple crops of many other developing countries reveal a similar resistance to the introduction of new or improved varieties (Grando & Grando, 2007; Virk & Witcombe, 2007).

Joshi and witcombe (1996) indicated that the conventional breeding system restricts farmers’ participation in technology development despite their wealth of knowledge and skills in selecting varieties that can suit their needs, fit in local environments, and fulfill consumer satisfaction. However, improved varieties may not be adaptable to different agro-ecologies without the small-holder farmers’ participation and involvement of their indigenous knowledge in variety development due to climate variability (Chiara et al., 2017). Studies focused on participatory variety selection (PVS) show that breeders’ selection criteria and their way of assessing cultivar performance mainly quantitative and statistically based often differs widely from the methods traditionally implemented by farmers (Ceccarelli et al., 2000; F. Mekbib, 2006; Sperling et al., 1993). To
date, the existing breeding system in Ethiopia is still continuing with the same objectives and strategy (Tafere Mulualem, 2012). The role of beneficiaries in the technology development process were very limited and they were not sufficiently oriented towards the farmers’ needs and preferences (Mekonnen et al., 2004). Farmers’ participation in variety evaluation and development in North Gondar also is not emphasized as much as demanded in the research system.

Hence, participatory variety selection is seen by several scientists as a way to overcome the limitations of conventional breeding by including the farmers knowledge, and their selection criteria, into a plant improvement program (Grando & Grando, 2007; Mulatu & Zelleke, 2002; Thapa et al., 2009). It has shown success in identifying more number of preferred varieties by farmers in shorter time, in accelerating their dissemination and increasing cultivar diversity. Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Witcombe et al., 2003). Participatory plant breeding/selection also exploits the potential gains of breeding for specific adaptation through decentralized selection in the target environment (Ceccarelli et al., 1996). Selection for specific adaptation to each target environment is particularly important in crops that are grown predominantly in unfavourable conditions, because unfavourable environments can be very different from each other that helps to gains the larger heritability’s within each specific target environment (Annicchiarico et al., 2005). While favourable environments tend to be somewhat similar and considered as samples of the same macro-environment, hence selection could to be done for wide adaptation (Ceccarelli & Grando, 1997). The study areas were found at similar intermediate agro ecological regions, the weather patterns or management practices were similar and generally the target areas were considered as one mega environment. Hence, participatory varietal selection of sorghum varieties in these specific areas helps to solve the problem of fitting to different target environments.

“Like your suggestion, this can be understood as a strategy to take advantages from specific adaptation of varieties to different target environments.”

Globally, various studies have been conducted on participatory plant breeding-selection of sorghum. Some of sorghum participatory studies in West Africa: Farmer choice of sorghum varieties in southern Mali (Lacy et al., 2006); Participatory identification of superior sorghum varieties using multi-locational trials in two zones in Mali (Weltzien et al., 2008); Giving new sorghum variety options to resource-poor farmers in Nicaragua through participatory variety selection (Trouche et al., 2009); Participatory variety development for sorghum in Burkina Faso: Farmers’ selection and farmers’ criteria (Kirsten vom Brocke et al., 2010). Those studies approved that, farmers’ participation in sorghum breeding program helps to maintain crop diversity, improve crop yield, stability, adoption rate and strengthening the collaboration between farmers and researchers.

Therefore, the study was conducted with the objectives to identify farmer preferred plant traits, high yielding and well adaptable improved sorghum varieties through farmer’s participation in decision making during the selection process.

2. Materials and methods

2.1. Plant materials and test environments
The experimental materials were seven midland improved sorghum varieties released from Ethiopian sorghum improvement project including the local check (Table 1). The criteria for selecting the genotypes were based on best yield performance, release of year and suitability of adaptation for the testing sites. Accordingly, the seven sorghum genotypes were tested across six environments (year and location combinations) during 2015–2016 under rain fed condition (Table 2). From diversified local landraces varieties, majority farmers in the study areas grow local variety (Bulle) and this landrace was used as the local check variety. North Gondar have
three major agro ecological areas for crop production, sorghum grows in the two agro ecologies (low land and intermediate). The experimental locations were found at similar agro ecological regions (Intermediate Areas of North Gondar Agro-ecology) and considered as one mega environment. Researches testing and selection were conducted at farmers’ fields. Farmers’ field helps offering farmers the possibility to choose, in their own environment, which varieties suit better their needs and conditions. The experimental sites were selected based on sites data (Elevation, Longitude, and Latitude, soil type, soil texture, soil pH) that represents well the agro-ecological environments of the study areas. In all environments, the trial was planted between the mid of June up to the end of June, which almost similar sowing dates.

5. Mean performance and stability of varieties

Table 4–8 shows the mean values of the different agronomic traits for individual locations. The mean data indicated that sorghum varieties IS9302 and Birmash had higher grain yield in all individual locations (Table 4–8). Table 9 shows combined mean yield and different agronomic trait performance of varieties. The result indicated that varieties were highly significant for all grain yield and components. The responses of varieties in terms of mean grain yield across locations, the highest were achieved from variety IS9302 followed by Birmash and the least was achieved from Local check (Table 9). In terms of yield components, the variety Charie was the earliest to head and mature and local check scored long days to head and mature. Among the tested varieties, the tallest plant was observed Local followed by Birmash and shortest was observed Germew. Among the tested varieties, varieties IS9302 and Birmash had maximum panicle length and the minimum has been scored variety Charie. Anthracnose was the major sorghum disease observed and genotypes had shown highly significant difference for Anthracnose infestation. According to disease responses, minimum anthracnose score were observed from varieties Germew, Birmash and IS9302 and maximum were observed from Local (Table 9). According to parametric stability methods that compute both yield and stability and GGE biplot genotypes IS9302, Baje and Birmash considered as good genotypes based on their grain yield and stability performance (Table 10).

*Some studies in the Ethiopian germplasm showed, there was no obvious effect of photoperiode on rate of development from emergence to flowering over the photoperiode range included (Alemu Tirfessa, 2010). In Ethiopia, there is a long rainy season, although it is often bimodal, and the timing of the end of the rainy season is not as critical for adaptation. Consequently, PP regulation confers little advantage for sorghum adaptation in Ethiopian germplasm (Alemu Tirfessa, 2018). In the study, areas were also not a concern about adaptation. *

2.2. Experimental design and crop management

The trial was laid out in randomized complete block design (RCBD) with three replications. The experimental plots consisted of 6 rows, each 5 m in length with 0.75 m row to row and 0.15 m
Table 2. Agro-ecological features of the experimental locations

| Locations               | Year | Coordinate          | Altitude (M. asl) | Mean rainfall (mm) | Temperature(°C) | Soil type |
|-------------------------|------|---------------------|-------------------|--------------------|-----------------|-----------|
|                         |      | Latitude (N)        | Longitude (E)     |                    | Min   | Max   |          |
| Dembia (NW Amhara)      | 2015 | 12°30'49"          | 37°33'39"         | 1920               | 1000  | 18    | 27       | Vertisol |
|                         | 2016 |                    |                   |                    |                  |          |          |          |          |
| Gizuria (NW Amhara)     | 2015 | 10°57'06"          | 39°47'03"         | 1400               | 850   | 21    | 36       | Vertisol |
|                         | 2016 |                    |                   |                    |                  |          |          |          |          |
| Takusa (NW Amhara)      | 2015 | 12°10’11”          | 37°01'05”         | 1840               | 870   | 15    | 28       | Vertisol |
|                         | 2016 |                    |                   |                    |                  |          |          |          |          |

Where: m.a.s.l., meters above sea level; E, east; N, north; Min, minimum; Max, maximum; T, temperature.
plant-to-plant spacing. The total area of each plot was evaluated on 22.5 m² plots (0.75 m x 6 rows x 5 m). Sowing was done by hand drilling. The seed rate for each plot was calculated as per the recommendation for row planting 10 kg ha⁻¹. Then, thinning was done 2 weeks after emergence to adjust plant to plant spacing. Nitrogen and phosphorus fertilizer applications were practiced in the form of urea (46% N) and DAP (18% N and 46% P₂O₅) as per the recommendation of the national sorghum improvement program. The 100 kg/ha of DAP was applied during planting in the seed furrow. Urea was applied as top dressing at the rate of 50 kg/ha at knee height stage. The field was kept free of weeds during the period of the experiment. All other agronomic management practices such as land preparation and insect pest control were applied as per recommended and the required data were also collected on time. Plot and plant-based data were collected from the central four rows and five randomly sampled plants based on the descriptors for sorghum (IBPGR and ICRISAT (International Board of Plant Genetic Resources and International Crop Research Institute for Semi-Arid Tropics), 1993), respectively. Both quantitative and qualitative data were collected. The quantitative data: Phenological data (Days to 50 % heading date and maturity date), Growth Parameters (plant height (cm), panicle length (cm)), data on yield (kg ha⁻¹) and stand count at harvest (no) and Anthracnose disease data were collected. Anthracnose was recorded on a susceptibility scale from 1 to 9 to score disease incidence, where: 1 = Very low; 2 = Very low to low; 3 = Low; 4 = Low to intermediate; 5 = Intermediate; 6 = Intermediate to high; 7 = High; 8 = High to very high; 9 = Very high (IBPGR and ICRISAT (International Board of Plant Genetic Resources and International Crop Research Institute for Semi-Arid Tropics), 1993). The qualitative data like socioeconomic parameters were also collected. Collected quantitative data were subjected to analysis using (SAS Institute, 2001) and Genstat (2007) while qualitative data collected using group discussion and key informant interviews and field observation were analyzed using pair wise metrics and simple ranking method in accordance with the given value (De Boef & Thijssen, 2006).

*The researcher did not measured anthracnose as a qualitative variable. However during anthracnose data scoring, the researcher scored values zero for many plots that had not shown any symptoms of anthracnose and also did not give greater than score value 2, because of no sever incidence occurred across year and location.*

2.3. Statistical analysis

Analysis of variance (ANOVA): Grain yield and other traits data were subjected to analysis of variance separately for each environment and combined over environments’ using the Statistical Analysis System computer program (SAS Institute, 2001). Mean separation was conducted using Least Significant Difference (LSD) test to discriminate and select superior genotypes based on trait of interest at significant P 1% and 5% level. ANOVA is important to detect the presence of Genotype by Environment Interaction (GEI) but it doesn't indicate which genotypes hold more contribution for the interaction and which genotypes are more specific or wide stable across environments.

Stability analysis: after testing the significance of GEI mean square with ANOVA, stability of genotypes for grain yield had computed using Genstat (2007). The proposed stability statistics that has been in frequent use by breeders were statistical model: Lin and Binns (1986) cultivar performance measure (Pₙ), (Wricke, 1962) Ecovalence (W) and Static stability. Thus, univariate types of stability models were used for estimating stability parameters of genotypes. The multivariate approach that used to describe and interpret multi-environment data structure in breeding programs that combines the two main effects, i.e. genotypes (G) plus the G x E interaction (GE) is (GGE) biplot model (Yan et al., 2000). In this study, environment comparison GGE plot method of analysis were used. This method is shown to be useful to determine which-won-where pattern of the Meta environmental data thereby identifying high-yielding and stable cultivars and the power to discriminate and identify representative test environments (Yan, 2002). The environment-focused scaling is the most frequently used method and is referred to as the principal component analysis scaling. Since the singular values are fully incorporated into environment scores, this type
of scaling is most informative of interrelationships among environments. This view of biplot was used to indicate the representativeness and discriminative ability of test environments (Yan & Tinker, 2006).

*I agree in the farmers participatory work breeders prediction about wider adapted genotypes before doing the analysis was not accepted. Farmers should be evaluating the number of varieties for performance-based criteria adapting to their agro-ecosystems without breeders interference. However, the study areas were considered as samples of the same macro-environment and across many environments must be relatively with across the study locations specific adaptation. Like your suggestion, wide adaptability can be understood as a strategy to take advantages from specific adaptation of varieties to different target environments.*

2.4. Farmer's participation

To improve production and productivity of sorghum in Dembi, Gondarzuria and Takusa districts participatory potential-based variety development is incomparable responsibilities for the research organizations. When the farmers select the variety by their own selection criteria the newly generated technology is familiar to their farming activity and increase technology utilization. Hence, participatory variety selection was used in this research to identify farmers' selection criteria and acceptable varieties to adopt and assimilate into the production system as expected in these areas. From all locations both male (38) and female (20) key informant farmers that are familiar about the crop were randomly selected and involved irrespective of wealth, religion to determine the adaptability and growth performance of all sorghum technologies. Three farmers research and extension group (FREG) were established and members’ got training about sorghum production and FREG concepts. Thus, at Dembi district a total of 17 farmers (7 females and 10 males), at Gondarzuria district a total of 16 (6 females and 10 males) and at Takusa district a total of 15 farmers (7 females and 8 males) were participated during 2015–2016 cropping season, respectively. Hence by making field observation and focus group discussion, members’ seat their own selection criteria then weight by its importance. Due to their homogeneous sociocultural entities, both male and female farmers across location identified seven preference parameters in common to select their best sorghum variety during 2015. Accordingly, head size, panicle length, earliness, grain color, disease and pest, stalk vigor and plant height were identified as the most important farmers’ selection criteria. The varieties were selected by direct ranking evaluation method and scoring was carried out in all repetitions and years at physiological maturity. During the evaluation and selection all farmers (men and women) were participated equally, being encouraged to explain their choices and select varieties that represent their conditions with their trait of interest. The farmers’ own selection criteria were analyzed using pair-wise ranking matrix (Table 11). Pair-wise ranking matrix method is one kind of structured participatory rural appraisal technique used to weight the selection criteria in priority order. The weight and rank assignments were determined from the number of times each selection criterion was preferred by the group (Lelo et al., 1995). The promising varieties were identified based on simple ranking score method (Table 12–15). Simple ranking is a tool often used to score and identify promising varieties based on farmers’ preferences (De Boef & Thijsen, 2006). The ranking procedure was explained for farmer participants and then each selection criterion was ranked and scored on a scale of 1–5 (1 = not preferred, 2 = less preferred, 3 = moderately preferred, 4 = highly preferred and 5 = excellent) for each variety. Ranking was done on consensus where differences are resolved through discussion (De Boef & Thijsen, 2006).

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3. Results

3.1. Researchers’ evaluation

In all environments, the trial was planted between the mid of June up to the end of June, which have almost similar sowing dates. The rainfall amount and distributions were also uniform throw out the growing season during the study period. Majority of the experimental trials were qualified the standard values of coefficient of variation (CV), showed the good quality of the trials and

| Traits       | Variety     | Environment | GEI            |
|--------------|-------------|-------------|----------------|
| GY (kg h⁻¹)  | 1,656,108.1** | 466,281.2*  | 468,593.4 *    |
| DH (No.)     | 296.9**     | 3.6 ns      | 5.7*           |
| DM (No.)     | 320.3**     | 19.2 ns     | 177.5**        |
| PH (cm)      | 445.8**     | 10.7 ns     | 102.8 ns       |
| PL (cm)      | 279.56**    | 83.35**     | 5.13**         |
| HHA (No.)    | 1159.8**    | 22.0 ns     | 750.1*         |
| Anth (No.)   | 1.48**      | 0.25 ns     | 0.42**         |

*and ** denote significant difference at P < 0.05 and P < 0.01, respectively. NS = Non significant difference.

GY, Grain yield (kg/ha); DH, Days to heading (days); DM, Days to maturity (days); PH, Plant height (Cm); PL, Panicle (inflorescence) length (Cm); HHA, Heads harvested (number); Anthracnose (Scale).
appropriate experimental design were applied in the study. The ranking of genotypes across locations and years showed very consistent, indicating repeatable G × L interactions.

4. Analysis of variance
Before pooling the data over locations, Bartlett’s test of homogeneity of error variance was performed for each parameter to determine the validity of the combined analysis of variance of the data. Error variance revealed homogeneous and so a combined ANOVA could be done. Table 3 shows mean square of yield and yield components of main effect genotypes, environments and their interaction effects across five environments. One environment data (Dembia 2016) does not incorporate due to bird problem and poor management treatments respond extremely low yield data. The genotypes main effect showed highly significant difference (P < 0.01) for all grain yield and yield components (Table 3). Environment and Genotype by Environment Interaction also contributed significant effect on performance of yield and some yield components. Hence, these indicated in addition to genotypic effect sorghum grain yield could be affected by environment and GEI. Thus, creates opportunity to evaluate yield stability, adaptation and as well for a prediction of yield performance of sorghum genotypes across environments (Adugna Asfaw, 2007).

5.1. Farmer’s preference
Farmers’ involved in the participatory varietal evaluation selected seven preferred sorghum characteristics and ranked through pair-wise matrix system as shown in (Table 11). The farmers’ preference traits were similar across locations and focusing more on yield-related traits to select their best variety. Among those, head size was ranked first followed by panicle length. Because of sorghum productivity in the study areas is the major concern farmers need this type of traits. Large head size and panicle length are attractive to look at and produce more grains per head, thereby increase yield. Consistent result was also reported by (Rashid et al., 2004) who evaluated farmers’ selection criteria on wheat varieties were focusing more on yield-related traits. The next important character was maturity followed by color. Majority of the farmers in the study areas growing sorghum landraces which takes 7–8 months to mature. Hence, farmers preferred “earliness of a variety” as one of their most important traits. Importance of grain color was also considered as an important selection trait, especially women farmers were most interested in white color sorghum grains for making local bread (injera) porridge and local beverages known as “Tella”. Farmers were also selected varieties by direct simple ranking evaluation method across all

| Treats      | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg/ha) |
|-------------|----------|----------|---------|---------|------------|-------------|------------|
| Charie      | 87 c     | 132.6e   | 134.8 c | 12.2d   | 99         | 0.3         | 930.6bc    |
| Dagim       | 102ab    | 154.6d   | 133 c   | 28.4a   | 109        | 0.6         | 928.3bc    |
| Baje        | 101ab    | 161 c    | 138.7bc | 27.6a   | 105        | 0           | 1253.3bc   |
| Germew      | 109a     | 167b     | 121.5d  | 22.0 c  | 99.3       | 0           | 684.9 c    |
| Birmash     | 98.6ab   | 153.6d   | 148.4b  | 23.8bc  | 103        | 0           | 2008.5a    |
| 159302      | 98b      | 150d     | 149.7b  | 24.4b   | 111        | 0           | 1548.5ab   |
| Local       | 94bc     | 184a     | 204.2a  | 24.2b   | 108        | 0.6         | 1110.3bc   |
| Mean        | 98.5     | 157.7    | 147.2   | 23.3    | 104.5      | 0.2         | 1209       |
| CV%         | 6        | 2        | 4.2     | 7       | 5          | 155        | 28         |
| LSD         | 10.7     | 5.4      | 11      | 1.8     | 9.5        | 0.6         | 712        |
| Treats      | *        | **       | *       | Ns      | Ns         | **          |            |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (Cm); PL, Panicle (inflorescence) length (Cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).
Table 5. Mean yield and yield-related traits performance of improved sorghum varieties tested at G/zuria in 2015

| Treats  | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg/ha) |
|---------|----------|----------|---------|---------|-----------|------------|------------|
| Charie  | 86.3 c   | 128.3e   | 152.7 c | 10.6 c  | 120       | 1.0b       | 2008.4 cd  |
| Dagim   | 102b     | 144 c    | 168.8b  | 21.2b   | 130       | 0.3 c      | 2674.7b   |
| Baje    | 103b     | 141.67 cd| 162.4bc | 19.4bc  | 136       | 0.0 c      | 3085.8ab  |
| Germew  | 106.6a   | 160.3b   | 161.6bc | 20.2bc  | 133       | 0.0 c      | 1701.8d   |
| Birmash | 100.6b   | 142.6 c  | 174.1b  | 24.0a   | 137       | 0.0 c      | 2952.4ab  |
| IS9302  | 100.6b   | 139d     | 174.8b  | 23.0ab  | 140       | 0.0 c      | 3308.7a   |
| Local   | 102b     | 183a     | 204.1a  | 23.4a   | 135       | 1.6a       | 2610.1bc  |
| Mean    | 100      | 148.5    | 171     | 20.3    | 133       | 0.4        | 2620      |
| CV%     | 1.5      | 1.4      | 5       | 7       | 12        | 66.6       | 13        |
| LSD     | 2.7      | 3.6      | 15.5    | 1       | 31        | 0.6        | 618       |
| Treats  | **       | **       | **      | ns      | **        | ns         | **        |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (cm); PL, Panicle (inflorescence) length (cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).

Table 6. Mean yield and yield-related trait performance of improved sorghum varieties tested at G/zuira in 2016

| Treats  | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg/ha) |
|---------|----------|----------|---------|---------|-----------|------------|------------|
| Charie  | 90.6 c   | 178.3b   | 149b    | 17.6 c  | 123       | 0.3        | 1510.1 c   |
| Dagim   | 108b     | 186b     | 172.9a  | 30.4a   | 137       | 0.0        | 2714.9 b   |
| Baje    | 106.6b   | 185b     | 166.7a  | 30.3a   | 128       | 0.3        | 3004.1b    |
| Germew  | 122a     | 200.6a   | 136.6c  | 22.0 b  | 122       | 0.0        | 1922.4 c   |
| Birmash | 107 b    | 185.3b   | 172.2a  | 30.2a   | 132       | 0.0        | 2989.1b    |
| IS9302  | 107b     | 185 b    | 177.1a  | 30.6a   | 133       | 0.3        | 3746.4a    |
| Local   | 112.3ab  | 202.6a   | 174.6a  | 22.1b   | 132       | 1.3        | 3131.4b    |
| Mean    | 107.6    | 189      | 164     | 26.1    | 129       | 0.3        | 2716      |
| CV%     | 6        | 3        | 3.6     | 6.5     | 5         | 167        | 9.9       |
| LSD     | 12       | 11       | 10.5    | 3       | 12        | 0.8        | 481       |
| Treats  | **       | **       | **      | ns      | **        | ns         | ***       |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (cm); PL, Panicle (inflorescence) length (cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).

environments (Table 12–14). Each variety received a rating for each trait, after a discussion among the group to agree on the score. The traits in all varieties with highest scores were listed (Table 16). Accordingly, head size and panicle length has got the highest score and ranked first followed by maturity and grain color. Ranking of varieties using individual traits could show clearly the relation between the farmer’s preferences and the researchers view across the varieties. Farmer’s varietal preference ranking result in 2015 at Dembia district showed, IS9302 was ranked first followed by Dagim and Birmash (Table 12). Similarly, farmer’s varietal mean preference ranking result at Gondarzuria and Takusa districts showed that, IS9302 was ranked first at both locations followed by Dagim and Birmash at Gondarzuria and Birmash and Dagim at Takusa, respectively (Tables 13 and 14). The farmers’ overall mean preference value of the studied varieties for the three district farmers indicated that the highest preference score was got by IS9302 followed by Dagim and Birmash and the least was scored by local check (Table 15). The reasons of the preference for these
Table 7. Mean yield and yield-related trait performance of improved sorghum varieties tested at Takessa in 2015

| Treats  | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg/ha) |
|---------|----------|----------|---------|---------|-----------|------------|------------|
| Charie  | 84.6 c   | 135.6 d  | 144.3 d | 11.4 c  | 75.3 bc   | 1.0 ab     | 1170.7 d   |
| Dagim   | 96.6 b   | 166.6 c  | 168.8 b | 20.4 ab | 156.0 a   | 0.3 b      | 1830.2 b   |
| Baje    | 94.0 b   | 173.3 c  | 160.2 c b | 20.0 ab | 138.6 a   | 0.0 c      | 1520.5 c   |
| Germew  | 118.6 a  | 181.3 b  | 145.2 cd | 24.3 a  | 127.3 a   | 0.0 c      | 1840.0 b   |
| Birmash | 96.3 b   | 167.6 c  | 169.2 b | 20.5 ab | 142.3 a   | 0.0 c      | 2341.5 a   |
| IS9302  | 94.3 b   | 170.6 c  | 171.6 b | 23.2 a  | 118.0 ba  | 0.0 c      | 2230.3 a   |
| Local   | 122.0 a  | 192.0 a  | 238.4 a | 21.2 ab | 51.0 c    | 1.3 a      | 1030.4 d   |
| Mean    | 100.9    | 169.6    | 171.2   | 27      | 115.5     | 0.3        | 1709       |
| CV%     | 2.0      | 2.4      | 4.9     | 7.5     | 23.6      | 98         | 9.2        |
| LSD     | 7.4      | 7.3      | 15.1    | 2       | 48.5      | 0.6        | 300        |
| Treats  | **       | **       | **      | **      | **        | ns         | **         |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (Cm); PL, Panicle (inflorescence) length (Cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).

Table 8. Mean yield and yield-related traits performance of improved sorghum varieties tested at Takessa in 2016

| Treats  | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg/ha) |
|---------|----------|----------|---------|---------|-----------|------------|------------|
| Charie  | 85.3 e   | 162.3 c  | 156.1 bc | 13.0 d  | 125       | 0.3        | 1135.3 d   |
| Dagim   | 106.3 c  | 188.6 b  | 165.7 b | 25.4 ab | 138       | 0.0        | 1969.4 bc  |
| Baje    | 105.3 c  | 189 b    | 155.4 bc | 23.0 bc | 128       | 0.6        | 1589.5 c   |
| Germew  | 125 b    | 191.3 b  | 145 c   | 21.8 c  | 130       | 0.3        | 1840 bc    |
| Birmash | 100d     | 183 b    | 167.8 b | 26.0 a  | 141       | 0.3        | 2431.6 a   |
| IS9302  | 104 c    | 185 b    | 169.2 b | 26.2 a  | 138       | 0.3        | 2110.3 ab  |
| Local   | 149 a    | 205 a    | 295.1 a | 24.1 b  | 120       | 1.6        | 1074.5 d   |
| Mean    | 10.7     | 186      | 179     | 22.8    | 131       | 0.6        | 1735       |
| CV%     | 1.8      | 2.8      | 5.3     | 5.0     | 2.5       | 145        | 10.6       |
| LSD     | 3.6      | 9.2      | 16.9    | 1.2     | ns        | 0.8        | 350        |
| Treats  | **       | **       | **      | **      | ns        | ns         | **         |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (Cm); PL, Panicle (inflorescence) length (Cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).

varieties were related to head size, head length, earliness and seed colour. During the evaluation, it was able to observe that farmers’ preference coincided with biological selection criteria for sorghum yield. Similar to farmers, researchers may use sorghum head-related traits to predict the yield potential of a specific type of sorghum variety (Bezabih et al., 2017).

6. Discussion

*In the photoperiod issue I try to discuss, this may be the reason for late maturity and vegetative growth of local landraces. But I agree with your explanation that Photoperiod was not the cause of lateness. Even some studies in the Ethiopian germplasm showed, there was no obvious effect of PP on rate of development from emergence to flowering over the PP range included (Alemu Tiffessa, 2018). In Ethiopia, there is a long rainy season, although it is often bimodal, and the timing of the end of the rainy season is not as critical for adaptation. Consequently, PP regulation confers little
Table 9. Overall combined Mean yield and yield-related traits performance of improved sorghum varieties tested at G/zuria, Dembia and Takusa in 2015–2016

| Treats | DH (No.) | DM (No.) | PH (cm) | PL (cm) | HHA (No.) | Anth (No.) | GY (kg ha⁻¹) |
|--------|----------|----------|---------|---------|-----------|------------|-------------|
| Charie | 87.3d    | 150.4d   | 148.1d  | 13.6d   | 104.3bc   | 0.55b      | 1436.2d     |
| Dagim  | 104.6bc  | 166.2bc  | 160.1bc | 24.0ab  | 115.5ab   | 0.44bcd    | 2028.4c     |
| Baje   | 104.0bc  | 169.3ab  | 155.8c  | 23.7bc  | 114.8ab   | 0.22cde    | 2256.1bc    |
| Germew | 115.6ab  | 172.5a   | 141.1e  | 22.5c   | 94.3cd    | 0.11e      | 1547.3d     |
| Birmash| 101.5c   | 164.9bc  | 165.6ab | 25.9a   | 114.3ab   | 0.11e      | 2537.1ab    |
| IS9302 | 102.4c   | 164.8c   | 155.2c  | 26.4a   | 122.8a    | 0.16de     | 2635.1a     |
| Local  | 118.2a   | 173.1a   | 167.7a  | 23.1bc  | 90.8d     | 1.00a      | 1216.2e     |
| Mean   | 104.8    | 165.9    | 156.3   | 22.7    | 108.1     | 0.37       | 1951.0      |
| cv%    | 1.6      | 3.1      | 5.3     | 5.2     | 8.5       | 124.97     | 16.5        |
| Lsd    | 1.3      | 4.2      | 6.4     | 2       | 10.6      | 0.31       | 281         |

DE, Days to heading (days); DM, Days to maturity (days); PH, Plant height (Cm); PL, Panicle (Inflorescence) length (Cm); HHA, Heads harvested (number); Anthracnose (Scale); GY, Grain yield (kg/ha).

Table 10. Estimates of stability and yield performance simultaneously selection parameters

| Trt. No | GEN | Cultivar superiority (P) | Mean Rank | Wricke’s ecovariance (W) | Mean Rank | Static stability | Mean Rank |
|---------|-----|--------------------------|-----------|--------------------------|-----------|------------------|-----------|
| 1       | Charie | 730,997               | (6)       | 228,119                  | (4)       | 43,155           | (3)       |
| 2       | Dagim  | 230,499                | (4)       | 176,358                  | (3)       | 65,327           | (6)       |
| 3       | Baje   | 139,458                | (3)       | 78,440                   | (1)       | 35,437           | (2)       |
| 4       | Germew | 387,000                | (5)       | 405,674                  | (7)       | 84,098           | (5)       |
| 5       | Birmash| 36,146                 | (2)       | 302,257                  | (5)       | 109,667          | (6)       |
| 6       | IS9302 | 405,674                | (5)       | 302,257                  | (5)       | 109,667          | (6)       |
| 7       | Local  | 980,647                | (7)       | 384,374                  | (6)       | 112,656          | (7)       |

advantage for sorghum adaptation in Ethiopian germplasm (Alemu Tirfessa, 2018). The rainy season in the study areas have not variations in the onset of rainy season. So, farmers do not need flexibility in sowing date.*

The presence of highly significant differences (P < 0.01) among the tested genotypes for all grain yield and components indicated the presence of genetic variation among the genotypes (Table 3). Significant genetic effect of genotypes on grain yield and yield components of sorghum was also reported by different authors (Almeida et al., 2014; Adugna Asfaw, 2007; Fahri, 2012). Similarly, significant effect of environment and Genotype by Environment Interaction on performance of yield and some yield components showed genotypes respond differently to diverse environments (Abiy Legesse, 2015; Adugna Asfaw, 2007; Cossa et al., 1990).

In case of grain yield, genotypes IS9302 and Birmash had the highest mean grain yield across locations while Local check had the least (Table 9). Gemenchu et al. (2004) also indicated that released intermediate varieties gave reasonable yield and significantly out yielded the farmers’ Local check. The best yielding genotypes tend to have longer panicle length than low yielder genotypes. In this regard, genotypes IS9302 and Birmash had maximum panicle length and Charie had the minimum (Table 9). Baumhardt et al. (2005) likewise reported that grain yield of sorghum had positive statistically significant association with panicle length. The presence of highly
Table 11. Pair-wise ranking of farmer’s selection criteria for sorghum variety at North Gondar districts in 2015

| Criteria          | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------|---|---|---|---|---|---|---|
| Grains color      | 2 | 1 | 3 | 1 | 1 | 6 | 7 |
| Head size         | 3 | 2 | 1 | 2 | 1 | 6 | 7 |
| Peduncle length   | 4 | 3 | 2 | 2 | 5 | 2 | 6 |
| Earliness         | 4 | 2 | 3 | 2 | 5 | 3 | 6 |
| Disease and pest  | 4 | 2 | 3 | 4 | 5 | 2 | 6 |
| Height            | 4 | 2 | 3 | 3 | 5 | 4 | 6 |
| Stalk vigor       | 4 | 2 | 3 | 3 | 5 | 4 | 6 |

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### Table 12. Farmers varietal assessment result in Dembia district of North Gondar (2015)

| Criteria                | Chare | Dagim | Baji | Germew | Birmash | IS9302 | Local |
|-------------------------|-------|-------|------|--------|---------|--------|-------|
| Grain color             | 4     | 4     | 4    | 3      | 4       | 5      | 1     |
| Head size               | 3     | 4     | 3    | 3      | 3       | 5      | 2     |
| Pedicel length          | 3     | 5     | 3    | 3      | 4       | 5      | 3     |
| Earliness               | 3     | 5     | 3    | 4      | 4       | 4      | 3     |
| Disease and pest        | 2     | 3     | 3    | 2      | 3       | 4      | 2     |
| Plant height            | 2     | 4     | 3    | 3      | 4       | 4      | 4     |
| Stalk vigor             | 3     | 5     | 5    | 4      | 4       | 5      | 4     |
| Overall score           | 20    | 30    | 24   | 22.5   | 26      | 32     | 19    |
| Average score           | 2.9   | 4.3   | 3.5  | 3.2    | 3.8     | 4.6    | 2.8   |
| Rank                    | 6     | 2     | 4    | 5      | 3       | 1      | 7     |

### Table 13. Farmers two years average varietal assessment result in Gondarzuria district of North Gondar

| Criteria                | Chare | Dagim | Baji | Germew | Birmash | IS9302 | Local |
|-------------------------|-------|-------|------|--------|---------|--------|-------|
| Grain color             | 4     | 3     | 4    | 4      | 5       | 5      | 1     |
| Head size               | 3     | 4     | 3    | 3      | 3       | 5      | 1     |
| Pedicel length          | 4     | 4     | 3    | 3      | 4       | 5      | 3     |
| Earliness               | 3     | 3     | 3    | 3      | 3       | 4      | 2     |
| Disease and pest        | 3     | 3     | 3    | 3      | 3       | 4      | 2     |
| Plant height            | 2     | 3     | 3    | 3      | 3       | 4      | 4     |
| Stalk vigor             | 3     | 5     | 5    | 4      | 4       | 5      | 4     |
| Overall score           | 22    | 27    | 24   | 22     | 25      | 33     | 17    |
| Average score           | 3.2   | 3.9   | 3.5  | 3.2    | 3.6     | 4.8    | 2.4   |
| Rank                    | 5     | 2     | 4    | 5      | 3       | 1      | 6     |

### Table 14. Farmers two years average varietal assessment result in Takusa district of North Gondar

| Criteria                | Chare | Dagim | Baji | Germew | Birmash | IS9302 | Local |
|-------------------------|-------|-------|------|--------|---------|--------|-------|
| Grain color             | 3     | 3     | 4    | 3      | 4       | 5      | 1     |
| Head size               | 3     | 3     | 3    | 3      | 5       | 5      | 1     |
| Pedicel length          | 3     | 4     | 3    | 3      | 4       | 5      | 3     |
| Earliness               | 3     | 3     | 3    | 3      | 4       | 4      | 3     |
| Disease and pest        | 2     | 2     | 2    | 2      | 4       | 3      | 2     |
| Plant height            | 2     | 3     | 3    | 3      | 3       | 4      | 4     |
| Stalk vigor             | 3     | 3     | 5    | 4      | 4       | 5      | 3     |
| Overall score           | 19    | 21    | 23   | 21     | 28.5    | 31     | 17    |
| Average score           | 2.8   | 3     | 3.3  | 4      | 4       | 4.4    | 2.5   |
| Rank                    | 5     | 4     | 3    | 4      | 2       | 1      | 6     |
Table 15. Overall combined two years farmers’ average varietal assessment result in North Gondar districts (2015 and 2016)

| Varieties | Dembia district | Gondarzuria district | Takusa district | Average | Rank |
|-----------|-----------------|----------------------|-----------------|---------|------|
| Chare     | 2.9             | 3.2                  | 2.8             | 2.9     | 6    |
| Dagim     | 4.3             | 3.9                  | 3               | 3.9     | 2    |
| Baji      | 3.5             | 3.5                  | 3.3             | 3.4     | 5    |
| Germew    | 3.2             | 3.2                  | 4               | 3.5     | 4    |
| Birmash   | 3.8             | 3.6                  | 4               | 3.8     | 3    |
| IS9302    | 4.6             | 4.8                  | 4.4             | 4.6     | 1    |
| Local     | 2.8             | 2.4                  | 2.5             | 2.5     | 7    |

Table 16. Overall combined direct ranking matrix evaluation of sorghum variety preference (Score x Weight)

| Criteria          | Weight | Chare | Dagim | Baji |
|-------------------|--------|-------|-------|------|
| Germew            |        |       |       |      |
| Birmash           | IS9302 |       |       |      |
| Grain color       | 4      | 44    | 40    | 48   | 40   | 48   | 60   | 12   |
| Head size         | 7      | 63    | 77    | 63   | 63   | 77   | 105  | 28   |
| Pedicel length    | 6      | 60    | 78    | 54   | 54   | 72   | 90   | 54   |
| Earliness         | 5      | 45    | 65    | 45   | 50   | 60   | 65   | 45   |
| Disease and pest  | 3      | 21    | 24    | 24   | 21   | 30   | 33   | 18   |
| Plant height      | 1      | 6     | 10    | 9    | 9    | 10   | 12   | 12   |
| Stalk vigor       | 2      | 18    | 26    | 30   | 22   | 24   | 30   | 20   |
| Total score       | 257    | 320   | 273   | 259  | 321  | 395  | 189  |
| Rank              | 6      | 3     | 4     | 5    | 2    | 1    | 7    |

significant differences among the tested genotypes for Anthracnose response showed the presence of tolerance variation among genotypes. Germew, Birmash and IS9302 were less affected by Anthracnose while severity was high for Local check (Table 9). In some experiment season had extended rainfall which has favourable for Anthracnose development. Demissie et al. (2008) reported sorghum leaf anthracnose was fungi diseases that predominantly occur in warm and moist environments’. However, Birmash and IS9302 was better than local cultivar under the same condition. Generally, varieties IS9302 and Birmash were high yielder, medium maturing, optimum plant height and moderately resistant to anthracnose among tested genotypes (Table 9).

As a stability statistic, the genotype performance measure ($P_1$) of Lin and Binns was estimated, thus genotypes with the least ($P_1$) values are considered the most stable. From this study, the most stable genotype that ranked first for $P_1$ and for mean yield were IS9302 followed by Birmash which gave greater mean yield than grand mean (Table 10). Genotypes with least Ecovalence have smaller fluctuations across environments and therefore are stable. The most stable genotypes according to the Ecovalence method of Wricke that ranked first were Baje followed by IS9302 that have least Ecovalence score. These genotypes had also high yield performance ranking third and first, respectively. Similarly, genotypes that have least values of static stability are considered the most stable. According to static stability like Ecovalence the same genotypes IS9302 followed by
Belay & Wale, Cogent Food & Agriculture (2021), 7: 1871809
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Figure 1. GGE biplot based on environment focused scaling for environment comparison.

Where E1 = Dembia (2015), E2 = G/zuria (2015), E3 = G/zuria (2016), E4 = Takusa (2015), E5 = Takusa (2016) and 1 = Charie, 2 = Dagim, 3 = Baje, 4 = Germew, 5 = Birmash, 6 = IS9302 and 7 = Local Circles are marker of the environment, used as angles to compare the environments AEA is line that passes through biplot origin and average environment.

Baje were found the most stable. Therefore, based on Lin and Binns’s, Wricke’s Ecovalence and Static stability parameters the best yielding genotypes that ranked first and third got the least values of those parameters and were found to be the most stable with respect to the performance across environment (Table 10). In agreement with this study (Abate, 2016; Alberts, 2004; Adugna Asfaw, 2007) who evaluated the stability of sorghum genotypes in different environments also reported that selection based on those parameters favor higher-yielding genotypes than lower-yielding genotypes. According to GGE biplot comparison, representative environment is an environment having smallest angle with the Average Environment Axis (AEA) and represents mega or test environments whereas discriminating environment is an environment that has the longest vector length from biplot origin to its marker and creates greater variation among genotypes, vice-versa for environments with short vector (Aktas, 2016; Dia et al., 2016; Yan, 2001). The result in this study showed angles between environment vectors are small, indicating similarity of environments and represents test environments Figure 1. However, environments such as E4 (Takusa 2015) and E5 (Takusa 2016) had the smallest angle with the AEA and short vector length from biplot origin to its marker. Hence, this environment is identified to be the most representative and can be used in selecting superior genotypes with stable performance. Therefore, the study areas were considered as samples of the same macro-environment those genotypes with specific adaptation were recommended for sorghum growing midlands of North Gondar.

Every farmer’s member, including women and men, made discussions during selection. Farmers were focusing more on yield-related preferences (head size, panicle length,) and other parameters (earliness and grain color) to select varieties (Table 11). This result clearly showed that farmers major selection criterion is yield-related preferences to increase the productivity of sorghum in the study areas. Double cropping has known a day’s mostly practiced in the study areas, so earliness and early maturing varieties were interests among farmers. The result
obtained from farmers’ preference in three districts and overall combined presented in (Table 12–15) showed IS9302, Dagem and Birmash were selected as best varieties similarly across locations. Hence, this shows farmers have the ability to select well-adapted and preferred varieties under their circumstances using their own criteria. The same varieties had also better performance and stability from data analysis. The result from this study revealed that farmers’ participation can effectively be used to identify acceptable varieties and increase the efficiency and effectiveness of a breeding program (Ceccarelli et al., 1996).

7. Conclusion

Combined Analysis of variance exhibited highly significant difference among treatments. Environment and Genotype by Environment Interaction also contributed significant effect on performance of yield and some yield components. From the tested genotypes IS9302, Baje and Birmash are medium maturing type and high yielder with optimum plant height across location. Generally, based on GGE biplot and other stability parameters IS9302 showed best performance and stability which had higher grain yield than the grand mean across tested environments. They exhibited average responsiveness with better adaptability for the study areas showed that, this can be recommended for the test and similar environments. Farmer participation in the breeding of crop varieties for low-resource farmers is necessary to ensure acceptance and eventual adoption. Thus, farmers have been selected genotypes IS9302, Dagem and Birmash that represent their conditions with their trait of interest and selection criteria. The overall results of the present study showed that IS9302 was selected by data analysis as well as farmers. Therefore, this variety is recommended for production in the mid land areas of North Gondar and similar agro ecologies.

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Author details

Berhanu Fentie Belay1
E-mail: berhanufentie@gmail.com
Mesfin Fenta Wale 2
E-mail: mesfinfenta3@gmail.com
1 Gondar Agricultural Research Center, P.O.Box, 1337, Gondar, Ethiopia.

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