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# Participatory varietal selection of intermediate altitude sorghum (*Sorghum bicolor* (L.) Moench) genotypes in Western Part of Ethiopia

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**Seven sorghum genotypes obtained from Melkassa Agricultural Research Center and local check collected from Assosa district were evaluated in randomized complete block design with three replications under farmers' participatory selection scheme in western part of Ethiopia during 2013 main cropping season. The objectives of this experiment were to select superior intermediate sorghum varieties in the study area and to identify farmers' preference and selection criteria. Farmers' set; grain yield, early maturity and bird damage resistance as selection criteria at maturity stage of the crop. The results of analysis of variance indicated highly significant differences among genotypes for all traits tested at 1% probability level. The highest mean grain yield was obtained from the genotype Adukara (4017 Kg ha$^{-1}$) whereas the lowest from the variety Geremew (1050 Kg ha$^{-1}$). Likewise, local-check (8667 Kg ha$^{-1}$) and Adukara (7651 Kg ha$^{-1}$) had given comparatively the highest above ground biomass yield which will be used as a good source of feed for animals in the study area. The maximum percentage of bird damage was recorded from early matured genotypes Geremew (33.34%) and IS-9302 (31.67%) whereas the least obtained from late matured genotypes Adukara (5%), Baji (8%) and local-check (10%). Farmers' evaluation of direct matrix ranking showed Adukara (score 27) and RAYA (score 25) were the most preferred genotypes and IS-9302 (18) the least one. Likewise, pair-wise ranking revealed that Adukara and RAYA were chosen equally, six times by farmers to be the most important ones. Therefore, the genotypes Adukara and RAYA were chosen for their performance in the experimental field and also acceptable from farmers' participatory evaluation. Thus, based on the results of this study and previous works done on sorghum in Assosa Agricultural Research Center the selected varieties need to be multiplied and distributed to farmers.**

**Key words:** Bird damage, direct-matrix, genotype, pair-wise ranking, participatory evaluation, selection scheme.

## INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereal crop grown in arid and semi-arid parts of the world. It is the fifth leading cereal grain worldwide after wheat, rice, maize and barley with average productivity of 1.4 tons ha$^{-1}$ and area coverage of about 40 million hectare and total production of 61.1 million ton (FAO, 2008). It is a staple food for millions of the poorest and most food insecure people in the semi-arid tropics (SAT) of Africa and Asia. It is one among the few resilient crops that can adapt well to future climate

change conditions, particularly the increasing drought, soil salinity and high temperatures. Over 60% of the total area devoted to sorghum in the world is in developing countries. According to FAO (2008), the area under sorghum production in Africa is about 24.23 million ha and total production and average yield being 21.9 million tons and 0.9 ton $ha^{-1}$, respectively.

Ethiopia is third largest sorghum producer in Africa next to Nigeria and Sudan (FAO, 2008), where the crop is one of the major food cereals like: Tef, wheat, maize and barley (CSA, 2013). It ranks third in area cultivated and in total production among cereals. It is grown in 12 of the 18 major agro-ecological zones including the lowland, mid and high altitude areas of the country (MoARD, 1998), which covers a wide range of ecological habitats, in the range of 400 to 3000 m.a.s.l. (Teshome et al., 1997). The current sorghum production in Ethiopia is estimated to be 3,604,262 tons on an area of 1,711,485 ha of land giving the national average grain yield of 2.11 tons per hectare (CSA, 2013).

In Benishangul-Gumuz Region cereals covers over 77% of grain crops cultivated land mainly sorghum, millet and maize. Out of the area cultivated for grains, sorghum, maize and finger millet took up an area of 27, 20.30 and 12%, and yielding 30, 33 and 8% of the regional grain production, respectively. The area covered, total production and average yield of sorghum was estimated to be 65,933.36 ha, 130, 995 tons and 1.99 tons $ha^{-1}$, respectively (CSA, 2013). Therefore, it is the most dominant crop grown as staple food in the region. Despite the economic importance of the crop in attaining food security and food self-sufficiency in the study area, very little have been done to change the livelihood of sorghum producing farmers through generation, adaptation and dissemination of sorghum technologies. So the contribution of improved varieties of sorghum is almost negligible mainly due to poor participation of farmers in the selection process, poor intervention of improved agricultural technologies (absence of improved varieties), birds damage to early maturing varieties, diseases (grain mold, head smut, anthracnose) and insect pests (shoot fly and stalk borer) (AsARC, 2011). Thus it is crucial to evaluate the sorghum genotypes in their agro-ecology using the participatory varietal selection (PVS) approach so as to provide choices of varieties to the farmers for increasing production in their diversity of socioeconomic and agro-ecological conditions. PVS also helps to disseminate the adoption of released varieties in larger areas; allow varietal selection in targeted areas at cost-effectiveness and also in less time and as a consequence help seed production and scaling-up at community level.

The approach of participatory varietal selection in Ethiopia has been done on many crops including common bean (Firew, 1997; Assefa et al., 2005; Asrat and Fitsum, 2008; Mekonen et al., 2010), sorghum (Eshetu and Ketema, 2001), maize (Eshetu and Habtamu, 2002), tef (Belay et al., 2006), barley (Abay et al., 2008; Yetsedaw et al., 2010) and wheat (Alebachew, 2012). So far the involvement of farmers in decision making process has been observed in the region on some rice varieties on different approach, that is, through Farmers' Research Group (FRG) by Assosa agricultural research center (AsARC) (Personal communication). Otherwise PVS for mid-altitude genotypes of sorghum was not done in the study area. Hence, it was found imperative to evaluate the introduced new sorghum genotypes for their performance and farmers' preferences for achieving good quality, high yielding and farmers' preferred varieties thereby enhancing sorghum production and productivity in the region.

Therefore, this study was conducted to evaluate and select the best performing mid-altitude sorghum genotypes and to identify farmers' preference and selection criteria for sorghum varieties in the study site.

## MATERIALS AND METHODS

### Description of the study area

The study was conducted in western part of Ethiopia at Assosa district, which is located at an attitude of 1547 m.a.s.l.. The area is situated in the East of Assosa town and West of Addis Ababa at about 4 and 660 km distance, respectively.

Assosa district has uni-modal rainfall pattern, which starts at the end of April and extends to mid-November, with maximum rainfall received during June to October. The total annual average (2000-2012) rainfall of Assosa is 1276.22 mm. The mean annual air temperature is 23°C from 2000 to 2012. The major soil types found in Assosa area is Nitisols.

### Experimental design and procedures

A total of eight sorghum genotypes (Birmashi, Baji, Geremew, IS-9302, BARC-acc-18, RAYA and Adukara) including a local check collected from Assosa district were used for this study. The experiments were laid in randomized complete block design (RCBD) with three replications from June to December 2013. During planting, the seeds were manually drilled at a rate of 8 kg/ha into five meters long four row plot spaced 0.75 m apart. At approximately 21 days after planting the seedlings were thinned to 0.20 m distance between plants. Nitrogen and phosphorus fertilizer were applied in the form of urea (46% N) and Diammonium phosphate (DAP) (18% N and 46% $P_2O_5$) at the rate of 50 kg $ha^{-1}$ urea and 100 kg $ha^{-1}$ of DAP, respectively. DAP fertilizer was applied at the time of planting (as basal application), whereas urea was applied in the form of split application, half of it together with DAP during planting and the rest as top dressing before heading. Hand weeding was practiced as frequently as needed. Birds were

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**Table 1.** ANOVA of growth, yield and yield components of intermediate altitude sorghum genotypes tested at Assosa district during 2013 main cropping season.

| Sources of variance | Degree of freedom | DTF (no.) | DPM (no.) | PLH (cm) | HWPPt (g) | NKPH (numbers) | NHPPL (numbers) | TKW (g) | GY(kg/ha) | AGBM (kg/ha) | HI (%) | BIRD Dam (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep | 2 | 18.48$^{ns}$ | 53.59$^{ns}$ | 356$^{ns}$ | 193$^{ns}$ | 109312$^{ns}$ | 179$^{ns}$ | 1.59$^{ns}$ | 393867$^{ns}$ | 253867.8$^{ns}$ | 36.91$^{ns}$ | 25.00$^{ns}$ |
| Tret | 7 | 1527** | 1068** | 15668** | 4968** | 970203** | 356** | 39.93** | 3215856** | 19527592** | 164.32** | 295.83** |
| Erorr | 14 | 19.77 | 21.34 | 632.32 | 92.63 | 213245.30 | 68.23 | 1.59 | 12818287 | 382340.6 | 24.84 | 12.50** |
| Mean | | 105.26 | 157.74 | 191.19 | 76.91 | 1990.47 | 45.26 | 22.81 | 2425.9 | 5852.47 | 42.78 | 17.20 |
| C.V. (%) | | 4.22 | 2.93 | 13.15 | 12.51 | 23.19 | 18.25 | 5.53 | 14.76 | 10.57 | 11.65 | 20.53 |

**Highly significant at 1% probability level ; ns, non-significant at 5% probability leve. DTF, Days to 50% flowering; DPM, Days to physiological maturity; PLH, Plant height; HWPPt, Head weight per plant; NKPH, Number of kernels per head and NHPPL, Number of heads per Plot; TKW , Thousand kernel weight; GY , Grain yield; AGBM , Above ground biomass; HI, Harvest index; BIRD Dam (%), Bird damage estimation in %.

found to be the most important biotic stresses that occurred in the study site. Even though it was very difficult to manage and monitor bird injury, it was tried to be protected by manual guards and data were recorded by estimating bird damage (%).

### Data collection

Data were collected on plant and plot basis for different agronomic traits. For data collection on plant basis, ten plants were randomly taken from the two middle rows of each plot excluding the two rows on both sides of each plotas borders and the mean value of those ten plants was calculated and used as plot data for analysis. Plant height (cm), head weight per plant (g), number of kernels per head, thousand kernel weight (g) and percentage of bird damage were recorded on plant basis; whereas days to 50% flowering, days to physiological maturity, number of heads per plot, grain yield (kg $ha^{-1}$), above ground biomass (kg $ha^{-1}$) and harvest index (%) were recorded on plot basis.

### Participatory varietal selection procedures

Qualitative data on mid-altitude sorghum genotypes including local check were collected using participatory approach of direct matrix and pair wise ranking methods. Farmers' were selected randomly based primarily on their experience for growing sorghum, considering gender and their willingness to participate in the research. At first focus group discussion (FGD) were held to determine challenges and constraints of sorghum production in the study area. Then farmers were allowed to prioritize the challenges and set their demands to combat the aforementioned constraints. Direct matrix ranking gave more detailed evaluations in to the merits and demerits related to the evaluated genotypes. Pair wise ranking was a useful tool whenever it is important to explore and discuss the criteria for decision making between and among alternatives.

The genotypes were evaluated using farmers' selection criteria. A total of twenty farmers of both sexes (male=13, female=7) participated in the study. Farmers were allowed to set their own selection criteria and then both male and female participants prioritized and jointly agreed on preferred characters. All of them were tabulated in a matrix scoring table, and each selection criterion was compared with another in a pair wise fashion. The rank assignments were determined from the number of times each selection criterion was preferred by the group. A direct matrix table was prepared for the mid-altitude sorghum genotypes listed in the row and characteristics preferred by farmers in the column. Scores were given to each variety based on the selection criteria (5 = very good, 4 = good, 3 = average, 2 = poor, and 1 = very poor). During direct matrix ranking farmers have given rating of importance (a relative weight) of a selection criterion ranked from 1 to 3 (3 = very important, 2 = important and 1 = less important) and rating of performance of a variety for each traits of interest (selection criteria) was given based on their level of importance on the basis of common agreement of evaluators'. The score of each variety was multiplied by the relative weight of a given character to get the final result and then added with the results of other characters to determine the total score of a given variety. Scoring and ranking were done on consensus, and differences were resolved by discussion as indicated by de Boef and Thijssen (2006).

### Statistical analysis

Microsoft Excel software programmes were used in the calculations of treatment parameters means and summary of tables presented wherever required. The data were analyzed using PROC ANOVA in SAS software version 9.00 with treatment and replications as the class variables and the response variables were the traits on which data were collected. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 5% probability level.

## RESULTS AND DISCUSSION

### Performance evaluation of mid-altitude sorghum genotypes

The results of the analysis of variance (ANOVA) showed highly significant ($P < 0.01$) differences among the mid-altitude sorghum varieties for all characters measured (Table 1). This result confirmed the results of previous studies done by Abdella (1991), Girma (2006) and Mihret (2012). They found that cultivars of grain sorghum were significantly affected by phonological growth as well as yield and yield related parameters.

**Table 2.** Mean values of growth, yield and yield components of intermediate altitude sorghum varieties at Assosa district.

| Varieties | Mean values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DTF (no.) | DPM (no.) | PLH (cm) | HWPPt (g) | NKPH (numbers) | NHPPL (numbers) | TKW (g) | GY (kg/ha) | AGBM (kg/ha) | HI (%) | BIRD Dam (%) |
| IS-9302 | 92.00$^{d}$ | 138.67$^{ef}$ | 150.33$^{c}$ | 47.63$^{de}$ | 1529.30$^{cd}$ | 44.33$^{abc}$ | 22.00$^{cd}$ | 1116.70$^{de}$ | 2605.60$^{de}$ | 43.13$^{bcd}$ | 31.67$^{a}$ |
| Birmash | 86.33$^{de}$ | 149.67$^{d}$ | 163.00$^{c}$ | 50.67$^{de}$ | 1797.10$^{bcd}$ | 41.33$^{bcd}$ | 23.00$^{bc}$ | 1983.30$^{c}$ | 5633.30$^{c}$ | 34.69$^{de}$ | 18.33$^{b}$ |
| Baji | 88.00$^{de}$ | 144.67 $^{de}$ | 160.83$^{c}$ | 42.63$^{de}$ | 1920.50$^{bcd}$ | 59.67$^{a}$ | 23.00$^{bc}$ | 2750.00$^{b}$ | 6700.00$^{bc}$ | 40.87$^{cd}$ | 8.33$^{de}$ |
| BARC-acc-18 | 125.00$^{b}$ | 173.67$^{b}$ | 281.33$^{a}$ | 117.30$^{b}$ | 2462.10$^{ab}$ | 52.33$^{ab}$ | 19.67$^{ef}$ | 2933.30$^{b}$ | 7516.70$^{ab}$ | 39.27$^{de}$ | 16.67$^{bc}$ |
| Geremew | 88.67$^{de}$ | 151.00$^{c}$ | 131.17$^{c}$ | 54.10$^{d}$ | 1333.30$^{d}$ | 28.00$^{d}$ | 20.33$^{de}$ | 1050.00$^{e}$ | 2066.70$^{e}$ | 50.67$^{ab}$ | 33.33$^{a}$ |
| RAYA | 82.00$^{e}$ | 136.00$^{f}$ | 124.00$^{c}$ | 32.93$^{e}$ | 1391.90$^{cd}$ | 38.33$^{bcd}$ | 18.00$^{f}$ | 1716.70$^{cd}$ | 3433.30$^{d}$ | 49.69$^{ab}$ | 20.00$^{b}$ |
| Adukara | 137.33$^{a}$ | 191.00$^{a}$ | 155.50$^{c}$ | 124.83$^{ab}$ | 2142.40$^{bcd}$ | 58.33$^{a}$ | 30.67$^{a}$ | 4016.70$^{a}$ | 7550.08$^{ab}$ | 53.43$^{a}$ | 5.00$^{e}$ |
| Local | 136.33$^{a}$ | 177.00$^{b}$ | 222.17$^{b}$ | 141.17$^{a}$ | 2235.10$^{bc}$ | 34.00$^{cd}$ | 24.00$^{bc}$ | 2700.00$^{b}$ | 8666.70$^{a}$ | 31.26$^{e}$ | 10.00$^{de}$ |
| Mean | 105.26 | 157.70 | 191.19 | 76.91 | 1990.47 | 45.26 | 22.81 | 2425.93 | 5852.47 | 42.78 | 17.22 |
| C.V. (%) | 4.22 | 2.93 | 13.15 | 12.52 | 23.19 | 18.25 | 5.53 | 14.76 | 10.57 | 11.65 | 20.53 |

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to DMRT where; DTF, Days to 50% flowering; DPM, Days to physiological maturity; PLH, Plant height; HWPPt, Head weight per plant; NKPH, Number of kernels per head and NHPPL, Number of heads per Plot; TKW , Thousand kernelweight; GY , Grain yield; AGBM , Above ground biomass; HI, Harvest index; BIRD Dam (%), Bird damage estimation in %.

Mean values of tested genotypes for the characters studied in Assosa district are given in Table 1. Among the tested varieties; mean days to flowering ranged from 82.00 for RAYA to 137.33 for Adukara. Earliness is a desirable attribute for sorghum production in dry land areas since early maturing varieties can escape drought conditions that set in during the latter growth stages and allow farmers as source of food and cash. As to days to physiological maturity, the earliest varieties were RAYA and IS-9302 with 136.00 and 138 days, respectively. The latest were local check and genotype Adukara with 177 and 191.00 days, respectively.

The mean plant height recorded was 191.19 cm with a range of 124.00 to 281.33 cm. The shortest plant height was recorded from the variety RAYA while the tallest plant height was recorded from the variety BARC-acc-18. There were significant differences among sorghum genotypes tested for above ground biomass ($p < 0.01$). The varieties Geremew (2066.70 kg ha$^{-1}$) and IS-9302 (2605.60 kg ha$^{-1}$) had the least above ground biomass production whereas the highest above ground biomass was recorded from local check (8667 Kg ha$^{-1}$) followed by Adukara (7551.00 kg ha$^{-1}$) and BARC-acc-18 (7517 kg ha$^{-1}$).

Table 2 shows the mean values for yield and yield components. The highest head weight per plant was obtained from the local check (141.71 g) and Adukara (124.83 g) whereas the lowest head weight was recorded from the variety RAYA (32.93 g). Among tested varieties BARC-accc-18 (2462.60), local (2235.10) and Adukara (2142.40) had the maximum number of kernels per head than the rest of the varieties, while, the minimum number of kernels per head was recorded by Geremew (1333.3) and RAYA (1391.90).

Among the tested varieties, Baji, Adukara, and BARC-acc-18 had high average number of heads per plot than the rest of the tested varieties. The maximum and minimum number of heads per plot was 59.67 for Baji and 34.00 for local cultivar respectively. The genotypes differed significantly for thousand kernels weight. The values ranged between 18.00 and 30.67 g with a mean of 22.81 g. The highest thousand kernel weight was exhibited by Adukara, whereas the lowest weight was recorded by RAYA. The mean harvest index ranged from 31.26% for local cultivar to 53.43% for Adukara (Table 1). Mean grain yield among tested varieties ranged from4016.70 Kg ha$^{-1}$ for the genotype Adukara to 1050.00 Kg ha$^{-1}$for the variety Geremew; with over all mean value of 2425.93 Kg ha$^{-1}$. The grain yields obtained from the varieties BARC-acc-18"(2933.30 kg/ha) and Baji (2750.99 Kg ha$^{-1}$) revealed a significantly ($P \leq 0.01$) higher grain yield than others and the local variety. The lowest yield was recorded for the variety Geremew, which could be due high bird damage recorded in the experimental field (Table 2). With regard to mean percentage of bird damage, Adukara (5.00%) and Baji (8.33%) were

**Table 3.** Direct matrix ranking evaluation of intermediate altitude sorghum genotypes by group of farmers' at Assosa district in 2013 main cropping season.

| Selection criteria | Grain yield | Bird damage resistance | Early maturity | Total | Rank |
|---|---|---|---|---|---|
| Relative weight | 3 | 2 | 2 | | |
| IS-9302 | 6(2) | 2(1) | 10(5) | 18 | 8 |
| Birmash | 9(3) | 4(2) | 8(4) | 21 | 5 |
| Baji | 12(4) | 6(3) | 6(3) | 24 | 3 |
| BARC-acc-18 | 12(4) | 6(3) | 6(3) | 24 | 3 |
| Geremew | 9(3) | 2(1) | 10(5) | 21 | 5 |
| RAYA | 9(3) | 6(3) | 10(5) | 25 | 2 |
| Adukara | 15(5) | 10(5) | 2(1) | 27 | 1 |
| Local check | 12(4) | 6(3) | 2(1) | 20 | 7 |

Number of participants = 20 (M = 13 and F=7), numbers in parenthesis indicated the performance rating value of each variety given from 1-5 (5=excellent, 4=very good, 3=good, 2=poor and 1=very poor) and numbers written in the bold indicate total score of a variety as per each selection criteria, which was obtained by multiplying the relative weight of each selection criteria with that of the performance rating number in the parenthesis.

**Table 4.** Farmers pairwise ranking of intermediate altitude sorghum varieties at Assosa district during main cropping season 2013.

| Varieties | IS-9302 | Birmash | Baji | BARC-acc-18 | Geremew | RAYA | Adukara | Local | Total score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| IS-9302 | x | | | | | | | | 0 | 8 |
| Birmash | Birmash | x | | | | | | | 1 | 7 |
| Baji | Baji | Baji | x | | | | | | 4 | 4 |
| BARC-acc-18 | BARC-acc-18 | BARC-acc-18 | BARC-acc-18 | x | | | | | 5 | 3 |
| Geremew | Geremew | Geremew | Geremew | BARC-acc-18 | x | | | | 4 | 4 |
| RAYA | RAYA | RAYA | Baji | RAYA | RAYA | x | | | 6 | 1 |
| Adukara | Adukara | Adukara | Adukara | Adukara | Adukara | RAYA | x | | 6 | 1 |
| Local | Local | Local | Baji | BARC-acc-18 | Geremew | RAYA | Adukara | x | 2 | 6 |

found to be significantly more resistant for bird damage among the tested genotypes. The highest bird damage was recorded from the varieties Geremew (33.33%) and IS-9302 (31.67%) being early to mature.

## Farmers' evaluation of mid-altitude sorghum genotypes

Selection criteria of farmers in the study area were based on a wide discussion and consensus and farmers set grain yield, early maturity and bird damage resistance as selection criteria during maturity stage of the crop. Direct-matrix was made with the criteria in the columns and tested varieties in the rows. PVS was done in the study site not only that farmers' cultivars were old but also none of the tested genotypes except local check were grown previously by farmers. Thus, some of the criteria farmers used may not coincide with the merits of improved varieties as to weed *striga* (*Striga hermantica*) resistance and some nutritional quality aspects. In other words the criteria farmers used in identifying the suitable varieties depend on the existing constraints and opportunities farmers faced in their micro environments.

Based on farmers' pair wise ranking results, grain yield, bird damage resistance and earliness were proposed as the three most important criteria in descending order. Buah et al. (2010) in participatory evaluation of drought tolerant varieties of maize and Yetsedaw et al. (2010) on participatory evaluation of malt barley reported similar selection criteria set by farmers. In addition, Alebachew (2012) found also the same selection criteria while farmers' evaluated wheat varieties in Tigray region. Direct matrix ranking evaluation of intermediate attitude sorghum genotypes indicated the total score ranged from 27 to 18 as indicated in Table 3. The highest score was given to the best genotype Adukara (score 27) followed by the variety RAYA (score 25). Out of the eight genotypes tested, IS-9302 (score 18) and local check (score 20) scored the minimum value to be the least preferred. Despite the advantage of earliness, the varieties Geremew and IS-9302 were susceptible to bird damage while the local check were late maturing and reasonably resistant to bird damage. Likewise, pair-wise

ranking revealed that Adukara and RAYA were chosen by farmers to be the most important ones (Table 4). Generally farmers' responded positively to the new genotypes evaluated. Farmers' evaluation indicated that there was alignment with researchers' criteria particularly for grain yield and bird damage resistance.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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