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Full Length Research Paper

Assessment of indigenous knowledge associated with Sorghum (*Sorghum bicolor L. Moench*) seed selection and the seed quality attributes in Fafen Zone of Somali Region, Ethiopia

Abraham Mulu Oljira* and Mekennon Girma

Department of Dryland Crop Science, College of Dryland Agriculture, Jigjiga University, Ethiopia.

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Understanding agro-pastoralist's indigenous knowledge associated with sorghum seed selection, seed systems, and seed quality management will help to devise strategies for enhancing the food and feed security in crop-livestock mixed farming system. With this intention, indigenous knowledge practices of on-farm sorghum seed selection and evaluation of the seed quality were surveyed, which ultimately contributes to sorghum genetic diversity maintenance in the agro-pastoral production system. Here, semi-structured interviews, focus group discussions and sorghum field observation were used. A total of 30 agro-pastoralists were interviewed and 16 seed samples were collected from traditional storage. It was observed that six local varieties of sorghum were the dominantly maintained and cultivated by agro-pastoralists of the study area. Among local varieties '*Elmi jama'* is the predominated area allocated for sorghum production in both districts. Agronomic performance (drought resistance, stock borer, and bird resistance) and straw yield were highlighted as important criteria for making decisions to select sorghum to be used for seed selection and maintenance. Over 90% of the informants grow a local variety of sorghum by mixing early and late maturing varieties on the same plot of land to mitigate the risk of moisture shortage and/or drought season. Seed quality assessment from Gursum district showed better germination potential with an average of 86.99%. This research offers the status of seed selection practices and seed quality status in agro-pastoral context and recommends the way forward to enhance sustainability of sorghum seed maintenance.

Key words: Agro-pastoralist, local variety, seed maintenance, seed quality, sorghum, crop-livestock system

INTRODUCTION

Sorghum is an important traditional and multi-purpose cereal crop grown by smallholder farmers of Ethiopia (Girma et al., 2019a). Ethiopia is recognized as a center of origin and diversity (Girma et al., 2019b), and immensely contributed to global sorghum genetic pool. Linked to sorghum domestication in this area, the crop has several uses for the community and no part of this plant is ignored. The leaves were used as fodder, stalks

*Corresponding author. E-mail: abrahammulu@yahoo.com.

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mainly used for fuel, fencing and roofing materials in rural areas. In the lowland areas characterized with moisture stress with marginal soil, sorghum is well adapted under drought condition and considered as a model crop (Kidanemaryam, 2019). Most importantly, sorghum grow in a wide range of agro-ecologies, particularly in the moisture stressed areas of Ethiopia (Abebe et al., 2020) where other crops could least survive. Sorghum is a strategic crop in the eastern part of Ethiopia (Mekbib, 2006). The ecology was characterized with shortage of moisture and farmers livelihoods were strongly dependent on crop livestock mixed production systems.

Although sorghum is the third important crop next to *teff* and maize in Ethiopia, the yield is below the world average. The sorghum worldwide average yield is 1314 kg/ha; developed countries is 3056 kg/ha and that of developing countries is 1127 kg/ha. The Ethiopian national average yield account for up to 2000 kg/ha (EIAR, 2014). One of the reasons for low yield productivity was related to seed delivery system.

In Ethiopia, sorghum formal seed industry is not developed yet (Eltayeb and Sana, 2010). Due to the fact that seed is an essential input in farming and most of the farmers in marginal agro-ecologies solely rely on local seed system, this study explored the indigenous on-farm seed selection, maintenance and seed physiological quality attributes.

MATERIALS AND METHODS

The assessment was conducted in Jijiga and Gursum districs of Fafen Zone, Somali Regional State in 2013/2014 cropping seasons. The districts received mean annual rainfall ranges from 380.1 to 756 mm and the mean temperature during the growing period in the area ranges from 20.1 to 22.5°C. Target areas were characterized to the warm semi-arid to cool and humid agro-climatic zone. The altitude is between 500 and 2500 m.a.s.l. The average annual temperature ranges from 27.5-18°C, the average annual rainfall ranges from 200 to 1400 mm, and the potential evapo-transpiration were estimated to be from 1438 to 2099 mm (Oromia Water Works Design and Supervision Enterprise - OWWDSE, 2012).

Sampling procedure

Multi-stage purposive random sampling procedure was followed from higher to lower administrative levels, with agro-pastoralists being sampling units. Eight sorghum producing villages and 16 farmers/agro-pastoralists were selected for interview. The interview was conducted between August to October 2014 using pretested semi structured questionnaires administered by trained enumerators and researchers. Researchers and agro-pastoralists observed sorghum field and assessed the sorghum plant selection criteria, particularly for seed purposes.

A four-stage sampling procedure has been used to select potential areas of sorghum production Somali region. It involves the selection of administrative regions, zones, districts and villages.

First stage: From Fafen Zone, two sorghum producing districts (Jijiga and Gursum) were purposively selected.

Second stage: From selected districts, two villages were purposively selected based on the area allocated for sorghum crop production.

Third stage: Within each of the two selected villages, at least two major sorghum producing villages were selected randomly by considering the proportional area planted by sorghum in the villages.

Fourth stage: From selected villages, sixteen experienced sorghum producer agro-pastoralist's were selected.

Seed quality analysis

Sorghum stored for seed propose was collected from local stores and analyzed for physical and physiological quality parameters. One kilogram of sorghum seed was collected from farmers/agro-pastoralists stores using sample bag. The seed is submitted to Jigjiga University Dryland Crop Science Laboratory for physical and physiological evaluation.

Physical purity test

Each working sample was divided into two 350 g portions for physical purity analysis. The components were separated into pure seed and inert matter and each component was weighed using analytical balance. Finally, the percentage composition of the seed lot was calculated based on the weight of each component.

$$\text{Purity percentage} = \frac{\text{Weight of pure seed}}{\text{Total weight of sample}} \times 100$$

Physiological quality test

For germination test, forty-eight seeds were placed on moistened filter paper in the Petri-dishes. Seeds in Petri dishes were placed on working board at room temperature. First and final counts were made on 5 and 9 days after planting.

$$\text{Germination percentage} = \frac{\text{Number seeds germinated}}{\text{Number seeds on tray}} \times 100$$

Statistical analysis

The average value of panicle length, panicle weight, seed physical purity and physiological quality test were calculated and illustrated in table form.

RESULTS AND DISCUSSION

Indigenous folk names associated with sorghum seed selection

In the target study areas, sorghum is known by the collective folk name '*harur*'. This study has identified six sorghum landraces predominantly produced in the Jijiga and Gursum district of the Somali region (Table 1). Each local landrace are their own specific varietal names and help the farmers to describe, identify and distinguish. The agro-pastroalists have particular names and identify the cultivars with local names such as '*Eilmi-jama'*, '*Wogera*',

Table 1. Study location and list of sorghum landraces owned by interviewed agro-pastoralists.

District	Kebelle	Village	Local name	Altitude (m.a.s.l)
Gursum	Kuramatana	Kontame	Elmi-jama, Wegera, Asse	1721
	Kumijaro	Guta	Elmi-jama, Dongae, Asse	1523
	Kuramatana	Hajje	Elmi-jama, Dongae	1761
	Kumijaro	Aliwal	Elmi-jama, Dongae, Ahmednasir, Wagara, Asse	1517
Jigjiga	Haroreys	Debeleweyni	Elmi-jama, Adengab	1842
		Kutle	Elmi-jama, Asse	1784
	Turuad	Wollego	Elmi-jama, Asse	1763
	2nd Turuad		Asse	1761

Source: Own Survey (2014).

'*Asse*', '*Dongae*' and '*Ahmednasir*'. Sorghum field observation with the key informants and researchers identified that the landraces folk names given were linked to distinct morpho agronomic attributes such as plant height, days to maturity, seed color and bird resistance. Furthermore, the folk names were related to the original source of the material, morphology, end use and name of the person who introduced it to the particular location.

Nevertheless, vernacular names may not always correspond to botanical distinctiveness, although they are quite often descriptors used for variety identification. This indicates that the farmers understand crop genetic diversity on the farm and the value associated to it, and such folk names are extremely useful (Liu, 2013). In our study, the agro-pastoralists classified the sorghum local varieties by seed color, grain head, panicle type, bird resistance and days to maturity. The target communities' practices agro-pastoral production system which relies both on livestock and crop farming, and the sorghum dynamic classification is an indicator for recognition that the significant contribution of the crop is as human food and livestock feed security. Sorghum is widely grown in the Fafen valley of of Gursum districts; particularly in Kumijaro area. This study covers the altitude range of 1517-1842 m.a.s.l (Table 1). Despite the variation in altitude and sorghum cultivars and agronomic practices, six varieties were showed wide adaptation across the elevations studied.

Crop and varietal mixture (poly-cultivar)

In our study, we identified that the agro-pastoral communities have special planting calendar for sorghum landraces. Through field observation and key informants' interview, we noted that there was special linkage between sorghum seed maintenance and planting. For instance, every agro-pastoralists were maintaining an average of 2-5 sorghum cultivars per household. In our view, these practices can be considered as climate change coping strategies practiced at small-scale level. Similarly, Yemane et al. (2009) reported that the North Ethiopia farmers manage different crop landraces as a climate change coping mechanism. In this study, we noted that the indigenous seed selection was complimented with the need to mitigate the risks of drought by planting diversity of sorghum on a single farm. Using this kind of indigenous knowledge, the agro-pastoralists minimize on-farm micro-environment associated risk such as insect damage, diseases protection, and drought, and hence obtain biomass and biological yield, at the same time prolong varietal stability (Altieri and Merrick, 1987). The sorghum farming communities had established varietal mixtures sorghum production strategy.

The varietal mixture prepared based on different days to maturity was a key indigenous strategy implemented by the agro-pastoralists to cope with the biotic and abiotic stress existing in the study areas.

On the other hand, the reasons for using intra-specific varietal mixture were agronomic and gastronomic followed by different secondary uses (feed, fuel wood). Such strategy was commonly practiced in Sub-Saharan Africa and particularly in Ethiopia for other crops such as legumes (Ruelle et al., 2019). Varietal mixture composition was made in order to meet the differential food grain preferences of household members. The agronomic reasons for the use of varietal mixture include stable yield, reduced lodging, diverse maturity groups for minimization of moisture stress risk, confusing birds attack and improved soil fertility utilization. The gastronomic reasons were taste, baking quality, digestibility and diversity of diet. The different secondary uses were feed, fuel wood and construction materials. Several previous studies have shown that many farmers prefer sorghum due to its cultural practices and end uses (Barnaud et al., 2007; Missihoun et al., 2012; Muui et al., 2013; Mekbib et al., 2009).

Dynamics of on-farm seed selection

In each cropping season, the household head is the

Table 2. Local varieties and corresponding seed quality parameters.

Local variety	Seed characteristics	Farmers target	Maturity period (month)
Elmi-jama	White	High yielder and bird resistance	6
Ahmed Said	Red seed colour	Low yield and bird resistance	4
Wagara	Pure white and large head panicle	High yielder and not bird resistance	5
Asse	Red color and	Low yield and bird resistance	3
Adengab	White	Low resistance	5.5

Table 3. Sorghum seed selection based on panicle length and panicle weight.

Kebele	Village	Local name of sorghum	Panicle length (cm)	Panicle weight (g)
Haroresa	Debelweyni	Elmi-jama	12.5	43.39
Haroreys	Gutale	Elmi-jama	11.5	89.17
Aliwalle	Dinga	Ahmed seid	10.83	75.43
Kuramatana	Kontame	Elmi-jama	22	151.6
Welago	Turuad	Elmijama	12.5	96.59
2^{nd} Turuad	Turuad	Adengab	12.5	157

decision-making unit (mainly the household head) a cultivar which type and how much seeds of a given variety apply to a plant. Seed selection take place at different times, for instance, prior to the harvest, at the time of harvest, after the harvest, at different places e.g. in the field, at a drying or storage facility, or in the home. Table 2 illustrates the farmers' on-farm seed selection parameters for each local variety. Likewise, Bellon (1996) reported how farmers decided to maintain a pool of genetic resources since the beginning of crop domestication. The quality parameters such as seed color, bird resistance and days to maturity were the main on-farm seed selection criteria. On top of this, the on-farm selection practices of agro-pastoralists were found to include leaf main vein colors (white, yellow, reddish brown), ever green stalk indicator for drought tolerance and uses as fodder, bent panicle indicator for bird resistance, healthy stalk indicator for tolerance to stalk borer. Interestingly, agro-pastoralists in the study areas have had enormous indigenous experience on diversity of sorghum seed selection and promoting local sorghum varieties for a decade. The farmers were found to be practicing several crop improvements approaches such as introduction, simple mass selection, modified mass selection, modified bulk selection, and pure line selection. This indicates that, the sorghum agro-biodiversity in the study area is highly dynamic and strongly associated with livestock production. This revealed the significance of local knowledge and suggests the consideration of small scale-farmers interests in seed system improvement (Berg,1993; Seboka and Hintum van, 2006).

The seed selection diversity criteria detected in these study villages has paramount significance for the establishment of on-farm conservation programmes; however, it should be well analyzed using biodiversity indices. Similarly, diversity of local variety maintenance practices was reported in Alamata and Raya-Azebo woredas at nothern Ethiopia by Yemane et al. (2009) and in eastern Ethiopia by Mekbib et al. (2009). Teshome et al. (2007) reported that farmers in south Welo were using intra- and inter-specific crop diversities in their field, and as a result, over 30 different sorghum landraces were found in a single field. This practices could also allow the farmers to exploit different microclimates and derive multiple nutritional values and harvest security in times of unpredictable environmental stress. This finding was in agreement with previous report of Brush and Meng (1998), in which crop mixture is purposively practiced for cultural reasons, tastes, gifts, local identity, and for market preference.

Sorghum yield indicators used for seed selection

It was known that the selection of local varieties for seed is usually based on several criteria. Among these, panicle length and panicle weight are predominantly used in our study area. Panicle length and panicle weight were sorghum yield components strongly correlated with sorghum yield. It was obvious that the agro-pastoralists recognized the importance of these traits and included it in their seed selection criteria. The highest panicle length was observed for 'Elmi-jama' grown in Kuramatana, whereas that of panicle weight was observed for 'Adengab' grown at 2^{nd} Turuad (Table 3). Both local varieties have a characteristic of long days to maturity with availability of soil moisture (Table 2). The majority of respondent farmers had begun selection before harvesting for a number of traits such as big and long

Table 4. Physical purity of sorghum seed samples obtained from agro-pastoralist storage.

District	Parameter	
	Physical purity (%)	Hundred seed weight (g)
Gursum	84.58	3.51
Jijiga	89.92	2.78

panicles, early maturing types, straw quality, disease free and good tiller capacity. They also exercise based on indicators selection of morpho-types from other farmers' field through careful day-to-day observation of plant morphology at farmers' field and obtain access by making an agreement before harvesting. A number of characters are also mentioned upon which farmers focus when selecting individual plants after harvesting and during storage, such as yield, bigger seed size and colour.

Sorghum seed system in the target area

This study reveals that the informal seed system is dominantly operated in the area. The sorghum seed used for planting could be either own saved or seed obtained from relatives and from other informal networks. The informal seed exchange system enhances the resilience of sorghum production to unpredicted weather such as increased temperatures and diminished rainfall occurring in the areas which resulted in crop failures. In the study areas, seed production was observed as an integral part of grain production. Seed quality controls were also purely informal and solely based on belief and trust between farmers.

The farmers and agro-pastoralists in the study area also obtained seeds from various sources, such as exchange, neighbours and market, through payment in cash. The flow of seeds of named varieties from nearby spatial scales and villages was evident in this study. For instance, there was much similarity between the names of sorghum varieties grown in both Jijiga and Gursum districts and even eastern Ethiopia (Mekbib et al., 2009), and as the areas are close to one another, the informal seed exchange as part of the local network might cause similarity of sorghum local names. For instance, in bad seasons where drought and birds attack led to crop damage, seed saving may totally fail and seeds may be obtained through market networks with reliable source.

Farmers/agro-pastoralists in the study area use their own farmer-saved seeds (unless unpredicted factors such as drought cause complete crop failure) although they may obtain seeds through exchange, gift or purchase. On the other hand, farmers' practice of exchanging seed lots for the same named varieties across different large spatial scales has been noted in a number of studies (Almekinders et al., 1994), though an assessment of the direction of the seed flow, the structure of the genetic diversity within the landraces as well as the ethno-botanical knowledge associated with the landraces at respective sites is deemed important for better understanding and utilization of the landraces. Moving landraces within and/or across similar ecological zones could be a powerful way of improving yield production stability. Seed exchange network can be established as a means of facilitating access to locally adapted sorghum genetic resources. However, this may require the establishment of mini-community seed banks (satellite seed banks) designed and managed by farmers themselves. The satellite community seed banks could facilitate mobilizing masses of useful local germplasms at faster rate and can reduce transaction costs.

In our study, majority of the farmers/agro-pastoralists responded to retain their produce and depend on their own seeds; however, during bad season, exchange seeds and sources of named varieties in kinds, either from neighbours, relatives and markets exists along with seed aid. This was probably due to lack of modern varieties that suits their local environment or farmers criteria and that were the main reasons causing reluctance to use and rather stick to their own genetic resources adapted to their locality.

From the focus group discussion, it was noted that women farmers play the leading role in cleaning of stored seeds. The main storage systems used were plastic bags, storage jars and underground pits. However, underground pit storage is mainly used for grains, even though few farmers are storing part of their seed with farmers witnessing severity of mold damage. In our previous study, we identified that the underground storage pit affected the seed quality attributes including germination and market preference (Mulu and Belayneh, 2016). Interesting seed storage practices explored in our study includes mixing sorghum seed with common bean seed to confuse the pests and minimize the damage from storage pest.

Physical seed purity analysis

The physical purity and hundred seed weight of local varieties seeds obtained from storage were illustrated in Table 4. The physical purity of seeds obtained from Jigjiga district (89.92%) was higher than the one collected

Table 5. Germination percentage of sorghum seed samples collected from on farm storage.

District	Villages	Germinated (n=48)	Germination (%)
Gursum	Kuramatana	41	85.42
	Adade	39	81.25
	Adade2	42	87.50
	Welago	29	60.42
	Adade	43	89.58
	Kuramatana2	20	41.67
		Mean	86.99
Jijiga	Tururwad	29	60.42
	Haroreys	18	37.50
	Tururwad 2nd	35	72.92
	Haroreys 2nd	6	12.50
		Mean	35.77

from Gursum district (84.58%). Conversely, higher hundred seed weight was observed for Gursum districts.
The physical purity analysis indicated that the contamination with panicle residue appeared to be the major impurity observed in the study samples.

Physiological quality

Seed germination of seeds varied across the districts. Seed samples collected from Gursum exhibited relatively better germination (86.99%) than those obtained from Jigjiga districts (35.77%) (Table 5). However, germination percentage of seeds produced in Jijiga district systems did not fulfil the national standard set (85%) for sorghum seed in Ethiopia. Germination percentages of seed samples collected from different villages were considered; those from Adade (89.58%), Adade (87.5%) and Kuramatana (85.42%) fulfilled the national seed standard whereas none of those seed samples were collected from Jijiga districts (35.77%). Seed samples that had not shown germination percentage was 90%. About 66% of the seed samples had a germination capacity of within 80% for Gursum district. Nonetheless, if more than one quarter of seeds planted by farmers is not viable, then this poses a threat to food security in the region and should be an area of concern. More so, it is not usually true that all seed lots exceeding “the critical minimum germination” are equally good in the eventual test of quality and emergence in the field. This is because, the lower the germination, the poorer the performance since deterioration has occurred even though all lots met the minimum germination recommendation. While it is sometimes possible to compensate for reduced germination by increasing sowing rates so as to achieve a desired population as practiced by many farmers in the district, a point is reached where there can be deleterious effects on yield and quality.

The results of seed quality test reveal that more than one quarter of sorghum seeds used for planting were inadequate in quality parameters including physical seed quality and physiological germination test. This proportion of seed with inadequate quality can lead to poor crop stand and generation of inferior seed quality.

Conclusion

Indigenous seed selection practiced in Fafen Zone has been contributing to enhancement of sorghum genetic resources pool. The contributions of farmers/agro pastoralists are critical to the conservation, use and enhancement of biodiversity. The two districts farmers managed to maintain more than six locally named varieties. Many of the sorghum local varieties are exquisitely fitted to the specific niches and highly associated with the livelihood of the crop livestock farming systems. However, the seed quality is very poor and below national standard. Furthermore, seed quality comprised of more quality aspects and, therefore, it is recommended that further research has to be conducted on storage, seed health and genetic aspects to enable the clarification of the extent to which seed quality affects crop production. In order to make indigenous sorghum seed selection sustainable, it is imperative to take farmer seed selectors as partners in the research extension programs and improve the seed storage mechanisms.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abebe A, Aemiro B, Getawey G, Tesfaye A, Alemu L (2020). Evaluation of sorghum (*Sorghum bicolor* (L.) Moench) variety performance in the lowlands area Of Wag Lasta, North Eastern Ethiopia, Cogent Food and Agriculture 6(1):1778603 doi:10.1080/23311932.2020.1778603

Almekinders CJM, Louwaars NP, de Bruijn GH (1994). Local seed systems and their importance for an improved seed supply in developing countries. Euphytica 78:207-216.

Altieri MA, Merrick LC (1987). In situ conservation of crop genetic resources through maintenance of traditional farming systems. Economic Botany 41(1):86-96.

Barnaud A, Deu M, Garine E, McKey D, Joly HI (2007). Local genetic diversity of sorghum in a village in northern Cameroon: structure and dynamics of landraces. Theory and Applied Genetics 114:237-248.

Bellon MR (1996). The dynamics of crop infraspecific diversity: A conceptual framework at the farmer level. Economic Botany 50(1):26-39.

Berg T (1993). The Science of plant breeding-support or alternative to traditional practices. In: W. De Boef., K. Amanor., K.Wellard and A. Bebbington (Eds.). cultivating knowledge: genetic diversity, farmer experimentation and crop research. Intermediate Technology Publications Ltd, UK, 72-77 pp.

Brush SB, Meng E (1998). A Farmers' valuation and conservation of crop genetic resources. Genetic Resourses in Crop Evolution 45:139-150.

EIAR (2014). Ethiopia Strategy for Sorghum. Retrieved from https://www.k-state.edu/smil/docs/country_resources/Ethiopian%20Strategy%20for%20Sorghum.pdf

Eltayeb EAA, Sana HAA (2010). Sorghum (*Sorghum bicolor (L.) Moench.)* Seed Quality as Affected by Type and Duration of Storage. Agriculture and Biology Journal of North America 1(1):1-8.

Girma M, Hussein S, Mark L, Dagnachew L (2019b). Assessment of farmers' perceptions of production constraints, and their trait preferences of sorghum in western Ethiopia: implications for anthracnose resistance breeding, Acta Agriculturae Scandinavica, Section B — Soil and Plant Science 69(3):241-249.

Girma G, Nida H, Seyoum A, Mekonen M, Nega A, Lule D, Dessalegn K, Bekele A, Gebreyohannes A, Adeyanju A, Tirfessa A, Ayana G, Taddese T, Mekbib F, Belete K, Tesso T, Ejeta G and Mengiste T (2019a). A Large-Scale Genome-Wide Association Analyses of Ethiopian Sorghum Landrace Collection Reveal Loci Associated with Important Traits. Frontiers in Plant Science 10:691.

Kebede Y (1991). The role of Ethiopian sorghum germplasm resources in the national breeding programme. In: J.M., Engels, J.G. Hawke and M. Worede, (Eds.), Plant Genetic Resources of Ethiopia. Cambridge University Press, Cambridge pp. 315-322.

Kidanemaryam W (2019). Review on Mechanisms of Drought Tolerance in Sorghum (*Sorghum bicolor* (L.) Moench) Basis and Breeding Methods. Academic Research Journal of Agricultural Science Research 7(2):87-99.

Mekbib F (2006). Farmers and formal breeding of sorghum and the implication for integrated plant breeding. Euphytica 152:163.

Mekbib F, Bjornstad A, Sperling L, Synnevag G (2009). Factors shaping on-farm genetic resources of sorghum (*Sorghum bicolor* (L.) Moench) in the centre of diversity, Ethiopia. International Journal of Biodiversity and Conservation 1(2):45-59.

Missihoun AA, Agbangla C, Adoukonou-Sagbadja H, Ahanhanzo C, Vodouhè R (2012). Gestion traditionnelle et statut des ressources génétiques du sorgho (*Sorghum bicolor* L. Moench) au Nord-Ouest du Bénin. International Journal of Biology and Chemical Sciences 6(3):1003-1018.

Muui CW, Muasya RM, Kirubi DT (2013). Identification and evaluation of sorghum (*Sorghum bicolor* (L.) moench) germplasm from Eastern Kenya. African Journal of Agricultural Research 8(37):4573-4579.

Mulu A, Belayneh Z (2016). Comparative Evaluation of Underground Pit Storage Systems for Grain Quality Attributes in Jigjiga and Awubarre Districts of Fafen Zone, Ethiopia. Advances in Crop Science and Technology 4:235. doi:10.4172/2329-8863.1000235

Oromia Water Works Design and Supervision Enterprise (OWWDSE) (2012). Land use Evaluation for Upper Fafen. Back Ground Information Somali Region.

Ruelle ML, Asfaw Z, Dejen A, Tewolde-Berhan S, Nebiyu A, Tana T (2019). Inter- and intraspecific diversity of food legumes among households and communities in Ethiopia. PLoS ONE 14(12):e0227074.

Seboka B, Hintum van T (2006). The dynamics of on-farm management of sorghum in Ethiopia: Implication for the conservation and improvement of plant genetic resources. Genetic Resourses and Crop Evolution 5(53):1385-1403.

Liu G (2013). Wild plant folk nomenclature of the Mongol herdsmen in the Arhorchin national nature reserve, Inner Mongolia, PR China. Journal of ethnobiology and ethnomedicine, 9(1):30.

Teshome A, Patterson D, Asfaw, Torrance JK, Arnason JT (2007). Changes of *Sorghum bicolor* landrace diversity and farmers' selection criteria over space and time, Ethiopia. Genetic Resourses on Crop Evolution 54:1219-1233.

Yemane T, Zeratsion A, Afewerk K, Berhane G (2009). A Dynamic Sorghum (*Sorghum Bicolor* (L.) Moench) diversity Management in Situ and Livelihood Resilience in South and Central Tigray Region, Ethiopia. Momona Ethiopian Journal of Science 1(2):67-94.