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Genetic Variability of Ethiopian Sorghum [*Sorghum bicolor (L.)*] landraces: Review

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Abstract: **Sorghum [Sorghum bicolor (L.) Moench], a cereal crop of family Poaceae, is believed to be originated in Ethiopia and Sudan. It is an important food security crop mainly in semi-arid and tropical parts of the African countries. The crop is indigenous to Ethiopian as far as its domestication has long time and genetic diversity exhibited variation among cultivated and wild relatives of the crop concentrated in the country. The existence of tremendous amount sorghum variability exhibiting native genetic variation to drought, disease and insect resistance, having good grain quality and high lysine, made Ethiopia as genetic resource reservoir ranking first in contributing germplasm collection worldwide in today's sorghum breeding program. Ethiopian 'zera zera' sorghum landraces and line developed from them being involved in hybrid development at ICRISAT and other countries in modern sorghum breeding program. Currently, sorghum is the third important cereal crop in both area coverage and production becoming the second in 'injera' making after 'tef' in Ethiopia. Ethiopia has a diverse sorghum germplasm which adapted to a range of altitudes and rainfall conditions. Characterization and identification of sorghum germplasms which provide desirable traits for genetic improvement is a basis in plant breeding. DNA based molecular marker and PCR based are the best to characterize and identify sorghum genotypes which provide desirable traits as compared to field experimental evaluation due to time and environmental effect. Genetic improvement is the cost-effective means of enhancing sorghum productivity for different end-uses. A better understanding of the genetic diversity in sorghum would greatly contribute to crop improvement with a view to food quality and other important agronomic traits. The Ethiopian Center of Crop Diversity contains enormous wealth of genetic variability in the sorghums. It needs some concerted effort to adequately collect and preserve this genetic variability before it is invaded and destroyed.**

Keywords: **sorghum, genetic variability, germplasm, diversity, PCR, ICRISAT, 'zera zera'.**

1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important grain crop globally after maize, wheat, rice, and barley (FAO, 2015). It is the main staple food crop for more than 500 million people in Africa, Asia and Latin America particularly in semi-arid tropical regions where drought is the major limitations to food production (Ejeta, 2005). About two third of sorghum grain produced worldwide is used for human consumption in developing countries (Ejeta, 2005, 2017).

Sorghum is naturally self-pollinated monocotyledon crop with the degree of spontaneous cross pollination, in some cases, reaching up to 30% depending on panicle type (Poehlman and Sleper, 1995). The annual domesticated sorghum is diploid (2n = 2x = 20) and tropical origin C_4 crop (Dicko *et al*., 2006).

Sorghum is an indigenous crop of Ethiopia where tremendous amount of variability exists in the country (Adugna, 2007), having a diversity of both domesticated and wild relatives which revealed Ethiopia as center of origin and diversity

(Mekibeb, 2009) supported by Vavilonian center of origin and diversity (Vavilov, 1951). Ethiopian sorghum landraces exhibit native genetic variation for drought resistance (Borrel *et al.*, 2000), having huge source of high lysine (Singh and Axtell, 1973), good grain quality and resistance to disease and insect (Yilma, 1991), post flowering drought tolerance (stay-green trait) (Borrel *et al.*, 2000), source of zera zeras sorghm popular at ICRISAT still today in developing food type hybrid (Reddy *et al.*, 2004).

Ethiopia is one of the major Sorghum growing country in Africa next to Sudan and Nigeria (FAOSTAT, 2019). Despite the versatile and multitude importance, however, the full genetic potential of sorghum cannot be harnessed in Ethiopia because of limitations simultaneously imposed by attacks from abiotic and biotic stresses. These includes; drought, stem borer, grain mold and the parasitic weed "striga" (Belu, *et al*., 2008). Since sorghum is a C_4 grass, it has clear advantages over other grain crops because of its ability to return economic yields in hotter and drier environments (Bryden *et al.*, 2009). Under favorable condition, sorghum has a high yield potential as compared to the other major cereals such as rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) (Reddy *et al*., 2012).

In Ethiopia, the crop grown entirely by subsistence farmers primarily to meet the need for food, feed, traditional brewing and construction purposes. Although sorghum is cultivated both in tropical and temperate climates (Poehlman and Sleper, 1995), it is widely grown in the arid and semi-arid tropics because of its unique adaptation to harsh and drought prone environments where other crops can least survive and food insecurity is rampant (Adugna, 2007). It requires a deep, well-drained fertile soil (PH 5.0 – 8.5) and a warm, frost-free period, average temperature (27°C to 30℃) to grow and develop well (Craufurd *et al.*, 1999).

Sorghum is produced for its grain which is used for food, feed and stalks for fodder and building materials in developing countries, while it is used primarily as animal feed and in sugar, syrup, and molasses industry in developed countries (Dahlbert *et al.*, 2011). It is major food and nutritional security crop to more than 100 million people in Eastern horn of Africa (Gudu *et al.*, 2013) including Ethiopia, providing a principal source of energy (70% starch), proteins, vitamins and minerals (Duodu *et al.*, 2003).

Genetic diversity in the crop species is the gift of nature and arises due to geographical separation or due to genetic barriers to cross ability (Prasanna, 2010). A number of studies have dealt with estimating genetic diversity in cultivated sorghum using morphological traits as well as molecular level. The use of morphological traits is the most common approach utilized to estimate relationships between genotypes. The genetic variability of cultivated species or varieties and their wild relatives together form a potential and continued source for the development of improved crop varieties(Ahalawat *et al.*, 2018).

A better understanding of the genetic diversity in sorghum would greatly contribute to crop improvement with a view to food quality and other important agronomic traits. Therefore, there is a need to evaluate the available accessions for genetic diversity and identify the best accessions according to their performance. There are around 11,353 sorghum accessions collected and conserved in Ethiopian Biodiversity Institute gene bank, of which 8,913 accessions were characterized by plant breeders and other researchers, and further 2,440 sorghum accessions are yet to be screened for their potentially useful characters(Tesfaye, 2017). Therefore, reviewing the genetic diversity of Ethiopian Sorghum [*Sorghum bicolor* (L.)] landraces studies is the main objective of this paper.

2. LITERATURE REVIEW

Origin, Distribution and Adaptability of Sorghum; Brief

Ethiopia is the Vavilovian centers origin/diversity for sorghum (Vavilov, 1951). Sorghum originated in Africa, more known in Ethiopia, between 5000 and 7000 years ago (ICRISAT, 2005). Then, it was distributed along the trade and shipping routes around the African continent, and through the Middle East to India at least 3000 years ago. It then journeyed along the Silk Route into China (Dicko *et al.,* 2006). It was first taken to North America in the 1700-1800's through the slave trade from West Africa and was re-introduced in Africa in the late 19th century for commercial cultivation and spread to South America and Australia (Yitayeh, 2019). Currently sorghum is widely found in the dry lowland areas of Africa, Asia (India and China), the Americas and Australia (Dicko *et al.,* 2006). It is an economically, socially and culturally important crop grown over a wide range of ecological habitats in Ethiopia, in the range of 400-3000 m.a.s.l (Teshome *et al.,* 2007). Sorghum is a unique cereal crop in the lowland areas due to its drought tolerance (Kebede, 1991).

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Production, Productivity, Area Coverage and Economic Uses in Ethiopia; Brief

Worldwide; United States of America is top sorghum producer followed by India, Nigeria, Sudan, and Ethiopia (FAOSTAT, 2019). Ethiopia is the third largest producer of sorghum in Africa behind Nigeria and Sudan with a contribution of about 12% of annual production (Wani *et al.* 2011) and the second after Sudan in the Common Market for Eastern and Southern Africa (COMESA) member countries (USAID, 2010). It is the third most important crop both in sown area (ha) and total production (qt) after tef, maize and maize, tef, respectively; becoming third primary staple food crop in Ethiopia after tef, maize (CSA, 2015) and second most important crop for injera (common leavened flat bread) making next to tef (Adugna, 2012).

Currently, sorghum is produced by 5 million house holders and its production is estimated to be 4.6 million metric tons from nearly 2 million hectares of land giving the national average grain yield of around 2.5 tons per hectare (CSA, 2017). It covers 17% of the total area allocated to grains (cereals, pulses, and oil crops) and 14.58% of the area covered by cereals (CSA, 2017). The crop is cultivated in all regions of Ethiopia between 400m and 2500m altitude, mostly at lower altitudes along the country's Western, South-Western, North Eastern, Northern and Eastern peripheries (EIAR, 2014) and staple food crop on which the lives of millions of poor Ethiopians depend (Adugna, 2007, Tesfay, 2017).

In Ethiopia, sorghum is among the most important cereal crops, particularly in the lowland areas where rainfall is unreliable and crop failures due to frequent drought are communal. It plays a significant role for millions of food-insecure people living in such environments. It is a multipurpose crop because the grain is used to prepare food and beverages, and the juicy sweet stem of sorghum is often chewed by humans particularly in rural Ethiopia. The stem is also used for various purposes such as animal feed, fencing and fuel for cooking. The grains are used for human foods such as leavened bread (*Injera*), Porridge, "*Nefro*," infant food, syrup, and local beverages known as "*Tela*" and "*Arekie*". It can also be a potential source of ethanol production in the country that can be used as biofuel crop. (Tesfaye, 2017).

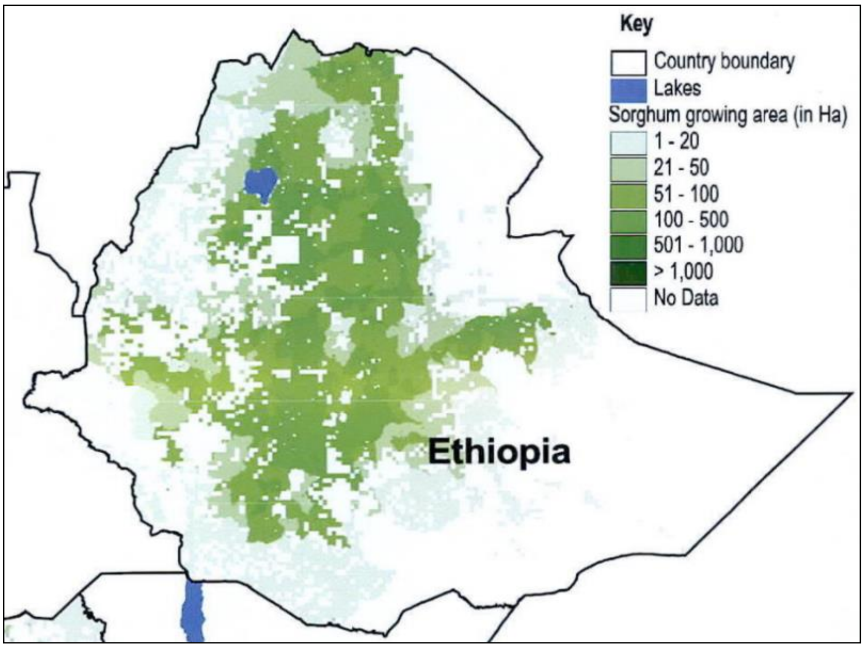

Figure 1: Sorghum growing areas of Ethiopia (Source – Adugna *et al*, 2005)

According to the CSA, 2018 Ethiopia is the sixth largest sorghum producing country in the world with sorghum contributing 17% of the total annual cereal grain production. Sorghum has a wider agro-ecological adaptation in Ethiopia and is cultivated in the three major agro-ecological zones in the country, which can be broadly classified into highlands >1900 meter above sea level (masl), intermediate between 1600-1900masl and lowland agro-ecologies <1600masl (Tesso *et al.*, 2011). Gebeyehu *et al.*, 2004 also states as it is the dominant crop in the dry lowlands which accounts for 66%, on average, of the total cultivated areas of the country. There are a wider ranges of sorghum production systems that can be differentiated in relation to the amount of rainfall received and targeted uses (Gerorgis, 1990; Wortmann CS, 2009). Multiple cropping systems has been practiced in low moisture areas to overcome the effect of drought (Gerorgis, 1990) and sole cropping has been reported as the dominant cropping system in the major sorghum growing area of Ethiopia (Wortmann CS, 2009). The very complex production systems and the very diverse growing environments have been the challenge for the development and dissemination of improved technology.

Since 2018 the total area covered with sorghum annually has increased by 0.77% and productivity has increased by 7.96% (CSA, 2018). The increase in productivity has come despite the fact that more than 90% of the total sorghum area is cultivated by small holder farmers who mainly use traditional methods of cultivation which is characterized by low utilization of improved varieties and fertilizers. Fertilizer (both natural and commercial) has only applied to 2.56% of the total area cultivated with sorghum (CSA, 2018). The overall increase in productivity could therefore be related to the genetic potential of farmers selected varieties (Mekbib, 2006) and use of improved management practices including row spacing and tied ridge to conserve moisture.

The majority of the grain produced (72.6%) is used for household consumption with the remaining proportion being used for sale and seed purpose (CSA, 2018). Sorghum grain is preferred next to tef, a small cereal grain crop, for the preparation of the staple leavened bread (injera). Although there is variability in the grain quality depending on the end use product, larger seed size, while and light red types of sorghum grains are predominantly preferred for the preparation of injera. The grain has also use for the preparation of locally prepared beverages and the stover used as animal feed, fuel wood and construction purposes(Yitayeh, 2019).

Taxonomic classifications and Landraces

Sorghum was believed that there were 20 to 30 species of genus Sorghum that are recognized until now, and these are classified into five sections: *Stiposorghum, Parasorghum, Eu- sorghum, Heterosorghum and Chaetosorghum.* Under the section Eu-sorghum, three species are recognized: *S. halepense (L.)* Pers. occurring in India, *S. propinquum (Kunth) Hitchc* found in Southeast Asia and S. bicolor (L.) Moench, which originated in Africa (De Wet, 1978). All classified under genus Sorghum. De Wet's recognized *S. bicolor* (L.) *Moench* representing all annual cultivated, wild and weedy sorghums along with two rhizomatous taxa, *S. halepense* and *S. propinquum.* All types of the S. bicolor (the primitives) propagated with seeds except the rhizomatous taxa's which reproduces through both seed and rhizome production. Sorghum bicolor was further broken down into three subspecies: *S. bicolor sub spp. bicolor, S. bicolor sub spp. drummondii* and *S. bicolor sub spp. verticilliflorum*. The cultivated sorghums are classified as S. bicolor sub spp. bicolor and represented by agronomic types such as grain sorghum, sweet sorghum, and Sudan grass and broom corn.

All the cultivated sorghum taxa of the world have been classified by inflorescence type, grain and glumes into five races (Durra, Bicolor, Caudatum, Kaffir and Guinea) and intermediates involving all of the pair-wise combinations of the basic races (de Wet, 1978; Harlan and de Wet, 1972). The entire races were differentiated morphologically based on their inflorescence, grain and glumes. The race bicolor has its grain elongated, with glumes clasping the grain, which may be completely covered or exposed. This race is mostly grown west of the Rift valley and also on a minor scale almost everywhere in Africa. Guinea is primarily West African with a secondary center in Malawi and Tanzania. Durra is dominant in Ethiopia and westward across the continent, covering the driest parts near the Sahara. Its grain is rounded and the glumes are very wide (House, 1985).

Four of the five sorghum races and wild forms are present in Ethiopia except Kaffir (Awegechew, *et al.*, 1997). Stemler *et al*., (1977) described and discussed the diversity of sorghum grown in Ethiopia for the races Bicolor, Durra, Durra-Bicolor, Caudatum and Guinea based on Ethiopian sorghum collections and field observations. The geographic pattern of distribution of each race appears to be determined by the topography and climate variation present in Ethiopia. Accordingly, sorghum race Durra is the main crop of the eastern highland region and mid elevation terrace of the north, while Caudatum race is grown primarily in hot, dry valleys and lowland savannas in the south and west of Ethiopia. The intermediate race Durra-Bicolor predominates in the southwestern highland region, where cooler temperature and rain are higher than eastern and northern region. In contrast, Bicolor and Guinea races represents a very small part of Ethiopian sorghum diversity and both are mostly found in the Rift Valley region (Taye, 2018).

Qualitative morphology characterization work on Ethiopian landraces along with introduced lines of sorghum from abroad and neighboring Eritrean accessions also shows the differential distribution of these different panicle types. This indicated the adaptive significance of panicle compactness and shape reflected the distribution patterns of different races of sorghum in Ethiopia. In their studies, the patterns of distribution of the different panicle types appeared to follow the temperature, humidity and rainfall patterns of Ethiopia and Eritrea. The compact and semi-compact panicle types were more frequent in Eritrea and in relatively hot and dry regions of Ethiopia such as Hararge, Tigray and Wello. The loose panicle types with dropping branches occurred abundantly in relatively cool and wet regions of Ethiopia such as Wollega, Illubabor, Shewa and Sidamo (Amsalu and Endashaw, 1998).

Germplasm Resources and Collections in Ethiopia

Ethiopia is the center of origin and diversity for many crops including sorghum (Vavilov, 1951). There is huge source high lysine (Singh and axtell, 1973), good grain quality and resistance to disease and insect (Yilma, 1991) and post flowering drought tolerance (stay-green trait) (Borrel *et al.*, 2000). Primarily, considering genetic variability and diversity of sorghum in Ethiopia, collection started in between 1958 and 1960 by Jimma Agricultural Technical School (Chala, 2018). Later this activity was taken over by ESIP and continued collections since the 1970s (IBC, 2012). After ESIP started in full-scale in 1973, it served as home for the popular zera zeras (caudatum race) type sorghums, which were extensively used as parents in ICRISAT sorghum improvement programs until the 1990s and being extremely provided germplasm for the improvement of food type sorghums (Reddy *et al.*, 2004). Through the early 1980s only, ESIP had amassed a collection of approximately 5500 accessions (Doggett, 1988). Nationally, the ESIP made good progress with release of the varieties, Awash 1050, the popular ETS series, and Gambella 1107 (E 35-1) that has been widely used in ICRISAT breeding programs (Reddy *et al.*, 2004 and Taye, 2018).

Ethiopian Sorghum Landraces

All five major races of sorghum have been identified in the Ethiopian sorghum collections, with the durra and bicolor racial types and their derived sub-races predominating (Doggett, 1988). Indeed, of the five morphological races of sorghum (*bicolor, guinea, caudatum, durra and kafir*), all, except kafir, are grown in Ethiopia (Harlan and de Wet, 1972). Nationally, since Ethiopia has a diverse wealth of sorghum germplasm adapted to a range of altitudes and rainfall conditions, Ethiopian farmers grow mixed sorghum landraces of diverse forms in their fields for various local purposes (Asfaw, 2014). Similarly, Reddy *et al.* (2004) reported that distinct types of sorghum from Ethiopia are zera-zeras, durras and durra-bicolor derivatives. The zera-zera type of sorghum, which originated on the border between Ethiopia and Sudan which is the sub-type of the race caudatum, is known for its grain appearance or grain type and disease resistance and has been used widely in many plant breeding programs (Prasada Rao and Mengesha, 1981).

In addition, the Ethiopian sorghum collections have been used as a source of genes for important agronomic traits globally, including stay green genes for post flowering drought tolerance (Kebede *et al.*, 2001), better grain quality and increased yield potential (Prasada Rao and Mengesha, 1981) and high lysine and enhanced protein digestibility and starch digestibility. Moreover, studies identified two sorghum lines native to Ethiopia (B35 and E36-1) as sources of “stay-green” for drought tolerance, which are currently used in marker assisted breeding programs (Reddy *et al.*, 2009). Wu *et al.*, (2006) also identified seven sorghum lines of Ethiopian origin resistant to Green bug- ETS2140 (PI452752), ETS3447 (PI455203), ETS3805 (PI455812), ETS4159 (PI456490), ETS4167 (PI456504), ETS4565 (PI457212), ETS4614-B (PI457314). IS 12662C (SC 171), the source of A2 cytoplasm (the sterile line) for the development of hybrids, which belongs to the Caudatum Nigricans group (Guinea race) was also obtained from Ethiopia (Schertz, 1977). Another example is E 35–1 (Gambella 1107), a selection from the Ethiopian zera-zera sorghum landrace, which has now been introduced for direct cultivation and in the modern breeding program in many countries (IBC, 2007; Reddy *et al*., 2009); some superior varieties of Ethiopian origin were released in India, Eritrea, Burkina Faso, Zambia, Burundi and Tanzania (Reddy *et al.*, 2006).

White grain Zera-zera germplasm accessions from Sudan and Ethiopia were found as less susceptible to disease under natural conditions and possessed desirable food quality used to develop sorghum variety (Thankur *et al*., 2006). For instance, CSV 4 variety devolved from Zera-zera germplasm was subsequently used as a restorer parent of several hybrids and used as one of parent in developing hybrid being used at ICRISAT in crossing program to generate genetic variability for resistance to disease (Thankur *et al*., 2006). Furthermore, several zera-zera germplasm accessions and their derivatives having high yielder and adapted lines has been used extensively in crossing to widen the genetic base of disease resistant lines (Murthy *et al*., 1980; Thankur *et al.*, 2006). The above traits also confirmed by different scholars us; in Ethiopia sorghum land races; there is huge source high lysine (Singh and axtell, 1973), good grain quality and resistance to disease and insect (Yilma, 1991) and post flowering drought tolerance (stay-green trait) (Borrel, *et al.*, 2000; EIAR, 2014).

Table 1: Ethiopian sorghum races presented according to their ecological distribution (Modified from Stemler *et al.*, 1977).

Ethiopian Sorghum landraces	Ecological Distribution	Major Growing Regions/Zone
DURRA	Eastern highland regions and mid-elevation terrace of the north	North Wello, South Wello, East Harerghe
CAUDATUM	Hot dry valleys and lowland savannas in N and W Ethiopia	Metekel, Central and South Tigray, Gambella (Z1)
DURRA-BICOLOR	S-W Highland regions where Temp. and raining higher than N and E regions	Jimma, Illubabor, West Wollega
BICOLOR and GUINEA	Rift valley regions of Ethiopia	North Shewa, Benchi Maji, East Shewa*

*E/Shewa representing the only bicolor populations in the study while N/Shewa and Benchi Maji is guinea

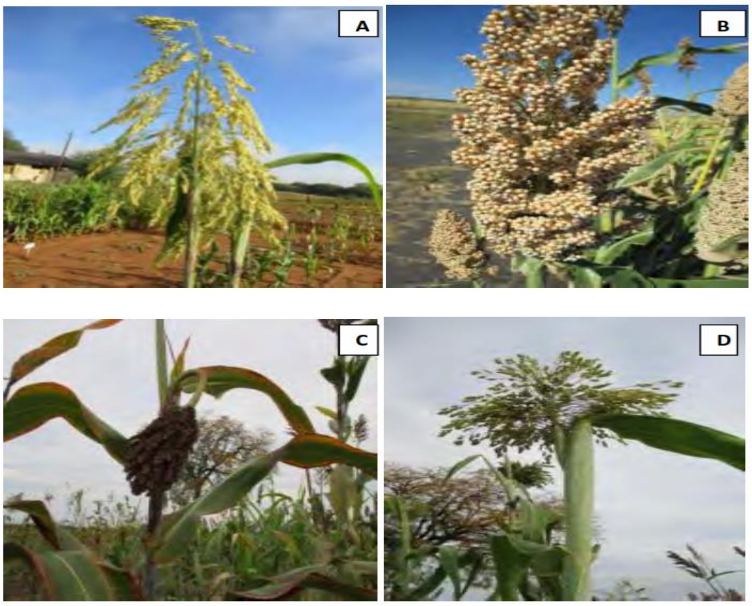

Figure 2: Sorghum basic races by their basic spiklet types (Harlan and De wet, 1972) photo by Motlandi, 2016 (A:Guinea, B:caudatum, C: Durra and D: Bicolor) (Olani, 2017)

Genetic variability Studies of Ethiopian Sorghum Landraces

Crop improvement program requires understanding and proper assessment of genetic variability among germplasm collections and efficient utilization of such variability in breeding programs. It is an important step toward reliable grouping of accessions and identification of subsets of core accessions with possible utility for specific purpose. Various biotic and abiotic factors contributed to the low productivity of sorghum. Among the abiotic factors, drought is the single most important cause of yield loss in sorghum production all over the world though sorghum is an excellent drought tolerant crop. Drought stress can cause total crop failure. It can devastate sorghum both at vegetative and reproductive growth stages. Hence, drought tolerance is particularly desirable trait in sorghum to sustain the life of several millions of people living in drought prone areas of Ethiopia and elsewhere. Hence, there is imperative to focus on breeding programs with the objectives of selecting best varieties that are suitable for desirable characters as well as improving traits related to economically important traits.

Ethiopia is a center for genetic diversity for many domesticated crop plant species such as sorghum, barley, tef, chickpea and coffee, largely represented in the country by local landraces and wild types that are exceptionally adapted to adverse environmental conditions due to their genetical diverse forms (Abe, 2010). Much of this crop diversity is found in small fields of small-scale farmers, have played a great role in the creation, maintenance and efficient utilization of resources (Worede *et al.*, 2000). Being Sorghum is an indigenous crop of Ethiopia, tremendous amount of variability exists in the country (Adugna, 2007). Globally, in sorghum breeding program, Ethiopia serves as sorghum genetic resource reservoir for favorable genes to which it is the Vavilonian center of origin and diversity (Vavilov, 1951) ranking first among countries that have contributed sorghum collections at International Crop Research Institute for Semi-Arid Tropics (ICRISAT) (Prasada *et al.*, 1989).

Ethiopian sorghum germplasm collections have already been noted as sources of valuable genes for several agronomic characteristics such as grain yield (Doggett, 1988; 1991, Kebede, 1991), pest resistance (Faris *et al.*, 1979), cold tolerance (Singh,1985) and protein quality (high lysine)- IS11167 and IS11758 (Gebrekidan and Kebede, 1979; Singh & Axtell, 1973). Similarly, Prasada *et al.* (1989) and Harlan (1992) reported that, sorghum landraces from Ethiopia are valuable sources of desirable genes for modern plant breeding programs.

Over the years, a number of studies have dealt with estimating genetic diversity in cultivated sorghum using morphological traits (Zongo *et al.*, 1993, : Appa *et al.*, 1996 : Ayana *et al.*, 1998, Kumar 1999 ; Dahlberg *et al.*, 2002, Shehzad *et al.*, 2009, and Adugna 2014). The use of phenotypic characters is the most advisable method most often used to estimate relationships between genotypes. Significant variation for qualitative traits has been reported using 34 sorghum landraces obtained from five of the main sorghum growing areas of the country (Abdie *et al*., 2002). Genetic variability studies for both qualitative and quantitative traits using genotypes representing specific and across the different sorghum growing regions have also been conducted (Ayana and Bekele 1998; Desmae, 2007) and have shown the extent of genetic variation in addition to differentiation of panicle compactness and shape according to geographic regions (Abdie *et al.*, 2002; Ayana and Bekele, 1998). In contrast, a study by (Ayana *et al.*, 2000) has reported a weak genetic differentiation based on agroecological adaptations and regions using 80 sorghum landraces genotyped based on the genetic distance computed using 20 RAPD markers. A large set of accessions from the Northern part of the country, genotyped using SSR and ISSR markers, also showed the high variability among accessions with limited variability among geographic origins (Desmae, 2007). Such low differentiation among the regions could be due to gene flow due to exchange of seed between regions; however, the limited number of markers used for both studies may have also impacted on the result. A high level of marker polymorphism has been reported between 45 Ethiopian sorghum landraces from the Eastern highland agro-ecology using SSR and AFLP markers (Geleta *et al.*, 2006).

Mace *et al.* (2013) reported a Study using SSR markers also identified the enormous genetic variability present within the Ethiopian sorghum collections maintained in USA, National Plant Germplasm System, in comparison to accessions obtained from different countries of origin. Such a high level of diversity within Ethiopian genotypes was also found in the recent whole genome resequencing study in sorghum which highlighted the potential for using previously untapped diversity for genetic gain through breeding. A recent study done by Admas and Tesfaye (2018) described a remarkable genetic diversity and evidenced by many landrace collections made in the country.

A total of 258 advanced lines including a local cultivar “Deber” were evaluated in 2016/17 at Humera Agricultural Research Center, Northern Ethiopia. Results revealed significant difference for yield and yield attributing traits among genotypes. Higher range of genotypic coefficient of variation (GCV) (3.13–37.44) and phenotypic coefficient of variation (PCV) (5.11–38.08) values were observed. Yield per panicle (YPP) (97%) and harvest index (HI) (31%) were the highest and lowest broad sense heritable (H^2) traits, respectively. Higher estimate of GAM observed for yield per plant (YPP) (75.93%) followed by head weight (HW) (62.36%). Moreover, plant height (PH) (23.51, 83, and 44.22), YPP (37.44, 97, 75.93), HW (31.88, 89, 62.36), biomass (BM) (29.21, 74, 51.94), and grain yield (GY) (32.99, 78, 60.25) were traits with higher estimate of GCV, H^2 (%) and GAM, respectively. This study showed wider genetic variability in the tested genotypes. Therefore, hybridization and selection on these genotypes for a desired trait with high (H^2) coupled with higher GCV and GAM were recommended to be effective for developing superior sorghum cultivars.

According to Taye *et al*., (2018) the combined and specific location performance of the released and pipelines sorghum varieties in the Ethiopian breeding program for grain yield and yield component traits was found significantly different. This result indicated the wider genetic variability of the improved varieties in grain yield performance. This has also been reflected on phenological and yield component traits. The mean plant height across environment was 170 cm with the

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range of 128 to 211 cm. However, the result generally showed that most valued traits such as plant height, total biomass and grain size of the released sorghum varieties are not comparable to the farmers‟ preferred varieties (Mekbib, 2006) and has been contributed for the low adoption of the improved sorghum varieties.

According to kasahun (2017) study clearly indicates there was genetic diversity among the Sorghum accessions. Land races on a farm are acknowledged as the main source of genetic diversity for gene banks and breeding programs, yet many studies have shown that genetic erosion is occurring on farmer varieties because of the utilization of high-yielding varieties. It has also been suggested, however, that only landraces which are not used for specific reasons are subjected to genetic erosion, while those which are selected by farmers for certain desirable traits are likely to survive on a farm alongside improved variety. Based on all the parameters used to see if there was diversity among the sorghum accessions, the tested genotypes showed genetic variability for the traits considered.

According to Kassahun (2017) Genotypes (119) are grouped into 13 cluster groups, which consists of 51 genotypes for the largest cluster and a single accession for four cluster groups (clusters 10, 11, 12, and 13), having different values of squared distance for each cluster group ranging from 13.5 to 56, which dendrogram clearly shows that there is a diversity of the sorghum genotypes (figure 3).

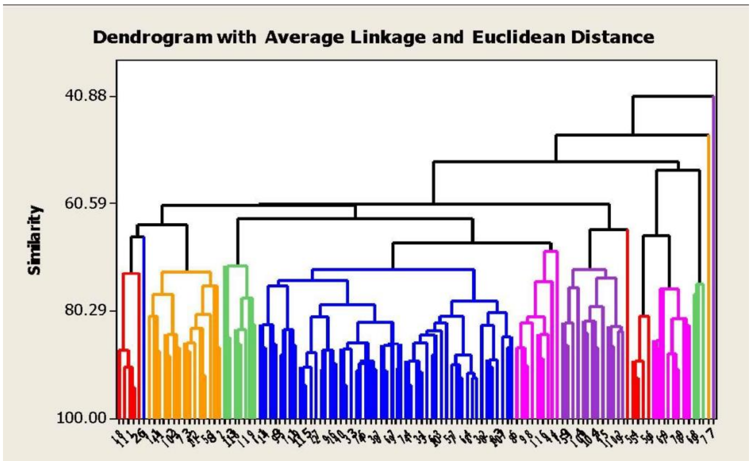

Figure 3: Cluster analysis of 119 sorghum genotypes (kasahun, 2017)

The score plot of 119 accessions based on the first two principal components is presented in *Figure 4*. Accessions (arranged by their plot number) were distributed in different groups, which clearly showed genetic diversity among sorghum accessions.

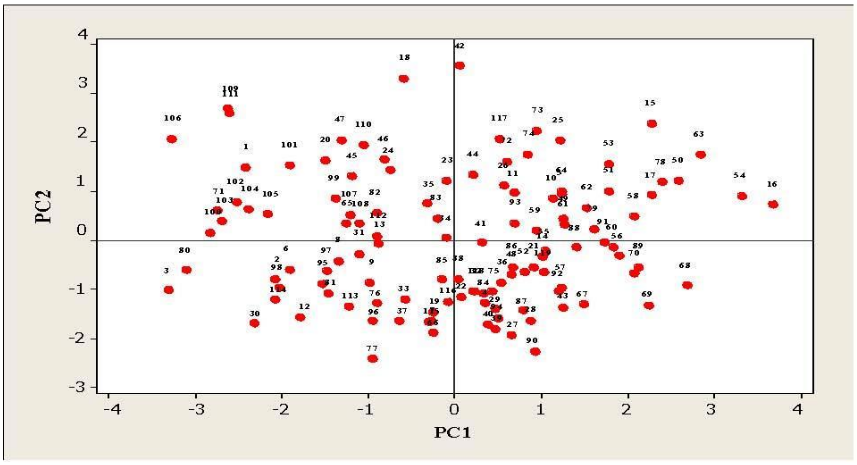

Figure 4: Distribution of sorghum accessions for the first two principal components using nine quantitative traits given in their order of arrangement (kasahun, 2017)

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According to Adugna *et al.*, (2002) Estimates of Shannon–Weaver diversity indices study indicated that sorghum landraces in North Shewa and South Welo were very high due to the ecological heterogeneity and climatic variations. The grouping of all the sample sorghum landraces into 5 clusters was on the basis of their morphological characters from all the five-ecosites. The cluster analysis was used to obtain a dendrogram of the 34 sorghum landraces (Fig. 4). The dendrogram clearly indicated the close relationship between sorghum landraces from almost all ecosites and the clustering was basically dependent on the panicle compactness and shapes, the stem and the grain type of the landraces. However, there existed landraces from the same ecosite distributed over most clusters, indicating variation among landraces within a given ecosite. The overlapping of the clustering patterns of the sorghum landraces was a hint for the lack of strong sorghum landrace differentiation, which could mean the presence of gene flow among landraces. For all the clusters the distance within and between cluster centroid was detected (data not shown). All the clusters were different from one another indicating that the sorghum landraces under the study were morphologically variable with some extent of non-uniformity.

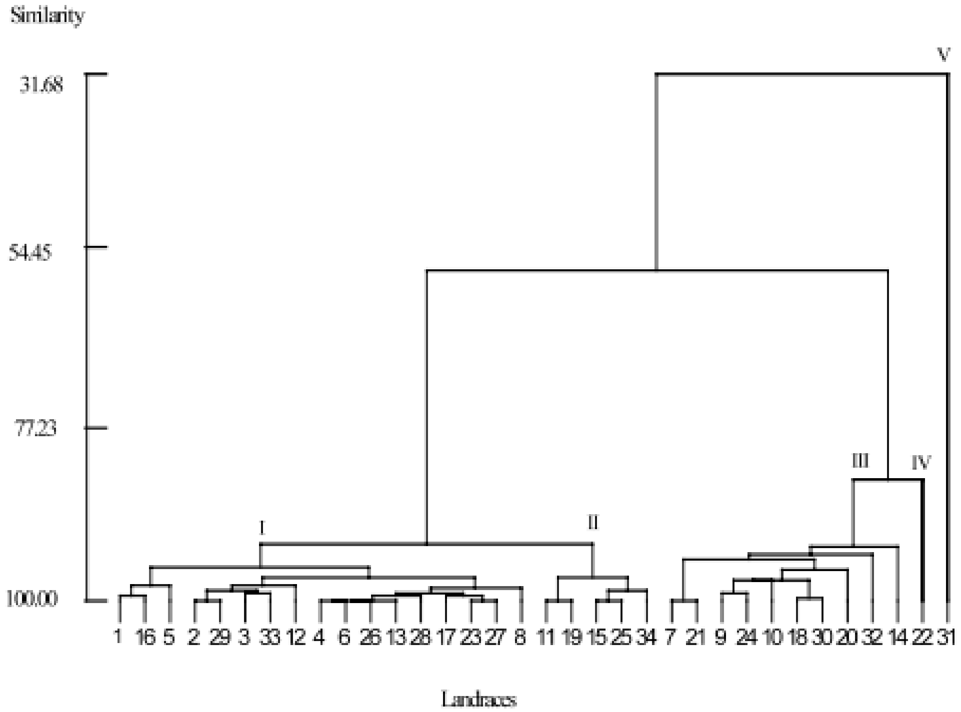

Figure 5: Dendrogram showing the clustering patterns of the 34 sorghum (*Sorghum bicolor* (L.) Moench) landraces in North Shewa and South Welo, Ethiopia (Adugna *et al.*, 2002)

3. CONCLUSION

Plant breeding is facing challenge to feed the ever-increasing population with diminishing cultivable land and dynamic climate change. Modern plant breeding has achieved some success in this regard. However, it has resulted in the genetic vulnerability because of narrow genetic base of cultivated varieties in many crops. Hence, there is a need of paradigm shift in plant breeding focusing on diverse genetic resources. Genetic diversity has now been acknowledged as a specific area that can contribute in food and nutritional security. Better understanding of genetic diversity will help in determining what to conserve as well as where to conserve. Genetic diversity of crop plants is the foundation for the sustainable development of new varieties. So, there is a need to characterize the diverse genetic resources using different statistical tools and utilize them in the breeding program. Morphological data in combination with molecular data are used for precise characterization of germplasm resources. With the advent of high throughput molecular marker technologies, it is possible to characterize larger number of germplasms with limited time and resources.

Sorghum improvement research in Ethiopia has come a long way from using simple methods like mass selection to advanced level of selection using molecular markers for trait improvement. Efforts are underway to use new genomic tools for sorghum improvement facilitated by the availability of aligned genome sequence. In addition to the yield and quality, biotic and abiotic constraints and the presumed climate change effects profoundly influence the sorghum area and its importance globally.

In summarizing, the Ethiopian Center of Crop Diversity contains enormous wealth of genetic variability in the sorghums. It needs to collect and preserve the germplasm genetic variability before it is invaded and destroyed by improved uniform varieties in modern technology.

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