

The Genetic Improvement of Sorghum in Ethiopia: Review

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Abstract
Sorghum is the most known drought tolerant crop as compared to other cereal crops due to it's ability to withstand poor soil fertility and high temperature. As Ethiopia is the centre of origin and diversity for sorghum, the crop has been cultivated for thousands of years and hence the heritage of the crop is expected to be rich. Sorghum is mostly grown as food grain in the developing country while in the developed countries, as an animal feed. The yield and quality of sorghum is affected by many factors such as drought, Striga, insect pests (stalk borer, midge, and shoot fly), disease (grain mold, anthracnose and smut). 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. In Ethiopia, sorghum improvement for yield,quality, early mature, biomass, resistance to drought, Striga, diseases and wide adaptability prioritized by national sorghum improvement program to satisfy end-users demand. Fifty two sorghum vareites, which contained desirable traits as compared to landraces, released in Ethiopia.
Keywords: Sorghum breeding, genetic diversity, sorghum improvement, genetic variablity
DOI: 10.7176/JBAH/9-3-06

1. Introduction

Sorghum (Sorghum bicolor L. Moench) is a C4 tropical crop (Dillon et al., 2007; Smith and Frederiksen, 2000, Mindaye TT *et al*., 2015). It is able to withstand low soil fertility and high temperature conditions (Tolk *et al*., 2013).

Sorghum is an indigenous crop to Ethiopia, which is the sixth largest sorghum producing country in the world with sorghum contributing 16.4% of the total annual cereal grain production and is ranked third in both total area coverage and productivity (CSA, 2017). Currently, the national average productivity of sorghum in Ethiopia is 2.5 tons/ha (CSA, 2017).

In the arid and semi-arid tropics of Africa and Asia, sorghum is mostly grown as a food grain crop while in the developed world the majority of the grain produced is used for animal feed (Rakshit et al., 2014). Sorghum grain is preferred next to tef, a small cereal grain crop, for the preparation of the staple leavened bread (injera). The grain has also use for the preparation of locally prepared beverages. In addition, the stover is equally valued as the grain, which can be used as animal feed, fuel wood and construction purposes.

Current rate of yield and production advance in sorghum is not adequate. Drought is one of the major yield limiting factors. Over eighty percent of sorghum in Ethiopia is produced under sever to moderate drought stress condition (EIAR, 2014). A major challenge of sorghum production in these parts of the country is lack of high yielding and stable varieties, lack of improvement works in genetic yield potential , abiotic stresses such as drought, soil fertility decline (Gebrekidan H., 2003). In addition, Biotic stresses such as diseases, insects and weeds (especially Striga) are also yield limiting factors. Therefore, this paper was prepared with the objectives of reviewing the genetic improvement of sorghum in Ethiopia

2.1 Origin, distribution and adaptability of sorghum

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.

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).

2.2 Botany and Taxonomy of Sorghum

The genus Sorghum has been classified into fivesubgenera: *Eu-sorghum,Chaetosorghum, Heterosorghum, Para-*

sorghum and *Stiposorghum*. Although this classification is convenient, however it does not stand for evolutionary relationships (Dillon *et al.,* 2004). The *Eu-sorghum* comprises the cultivated species *S. Bicolor* (L.) Moench and its subspecies are *drummondii, arundinaceum*, and wild species includes *S. xalum* Parodi, *S. halepense* (L.) Pers. and *S. propinquum* (deWet, 1978). The *Eu-sorghum* section is originated from Africa or Asia Doggett (1976), DuVall and Doebley (1990). Sections *Chaetosorghum* and *Heterosorghum* consist of *S. macrospermum* and *S. Laxiflorum* and both of these species are annuals and polyploids (Lazarides *et al.*, 1991). Section *Stiposorghum* includes ten species (Lazarides *et al.* 1991). *Para-sorghum* Section is comprised seven African, Asian, Australian and Central American species. The basic number of chromosome of species in each section is five. The species belong to *Para sorghum* and *Stiposorghum* are mostly diploid (2n = 20), however a few species are tetraploid or hexaploid.

Sorghum includes three species, *S. halepense, S. propinquum* and *S. bicolor. Sorghum halepense* is also known as Johnson grass, derived from a natural cross between *S. arudinaceum* and *S. propinquum* (Doggett, 1976). *Sorghum propinquum* is a perennial species related to *S. bicolor* (Sun *et al*., 1994). By using Harlan and deWet‘s system which is based on spikelet morphology, *Sorghum bicolor* has been classified into five races.

The five basic races of *Sorghum bicolor* are *bicolor, guinea, caudatum, kafir and durra*; and ten intermediate races under *S. bicolor*. It is a cereal of a remarkable genetic variability; with more than 30,000 selections present in the world genetic collections (Assefa and Staggenborg, 2010). Most of the tropical sorghums are short day plants and their response to day length is an important adaptation (Prasad and Staggenborg, 2009).

Grain sorghum belongs to the family of Poaceae, tribe *Andopogoneae*, sub-tribe *Sorghinae*, and genus *Sorghum*. In 1794, Moench established the genus *Sorghum* and brought the sorghums under the name *S. bicolor.* All cultivated sorghum belongs to *Sorghum bicolor* subsp. *bicolor* (Dicko *et al.,* 2006).

2.3 Importance of Sorghum

2.3.1 Global Context

As compared to other cereals, sorghum is a drought tolerant crop and able to withstand low soil fertility (Tolk et al., 2013, Mindaye TT *et al*., 2015). It is a main crop for more than 500 million people in the developing world mainly in the 30 sub Saharan Africa and Asian countries (Kumar *et al*., 2011), but it is also grown as a feed crop in the developed world. In addition, sorghum is a preferred feedstock for biofuel production due to its high biomass production and high water use efficiency (Packer and Rooney, 2014; Reddy *et al*., 2005a).

The sorghum production area globally has shown a mixed trend, and while the overall sorghum production area has declined from year to year mainly in USA, China and India, there is a steady increase in production area in most African countries (especially Sub Saharan Africa) and Australia (Rakshit et al., 2014). Sorghum productivity over the past four decades has shown a yield improvement of 1 to 4% per year in many countries including USA, Australia, and China

(Rakshit *et al*., 2014). The increased productivity of sorghum has maintained the total production and it has remained the fifth most important cereal crop in total grain production in the world (Kumar *et al*., 2011). The sorghum grain produced has contributed 2.7% of the top five major cereal grain produced globally over the past decade (FAOSTAT, 2015).

The increase in sorghum productivity is the outcome of both improved varieties and improved management practices. The use of hybrid varieties with improved management have been provided in yield increases that have been achieved in many developed and a few developing countries (Kumar *et al*., 2011; Smith and Frederiksen, 2000). To-date the total sorghum production area in USA and Australia is planted to hybrids and in China and India more than eighty five % of sorghum growing areas is planted with improved varieties including hybrids (Reddy et al., 2006; Rakshit, 2014). The adoption of hybrids has contributed to increased sorghum productivity in many countries, for instance in China productivity has increased by 3.9 % and in India by 2 % per annum (Rakshit et al., 2014).

2.3.2 Ethiopia Context

Sorghum has diverse agro-ecological adaptation in Ethiopia and is cultivated in the three major Zones in the country which can be categorized into highlands >1900 meter above sea level (masl), intermediate between 1600-1900masl and lowland agro-ecologies <1600masl (Kebede and Menkir, 1987; Tesso *et al*., 2011). It is the major crop in the dry lowlands which accounts for 66%, on average, of the total cultivated areas of the country (Gebeyehu *et al*., 2004).

There are different systems of sorghum production 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 reduce 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 majority of the grain produced (74%) is used for household consumption and the remaining used for sale and seed purpose (CSA, 2014). Sorghum grain in Ethiopia is generally traded within the country (USAID, 2010). Sorghum grain is preferred next to teff 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 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.

2.4 Sorghum production constraints

The national average sorghum productivity in Ethiopia is 2.5 tons/ha (CSA, 2017). Several production constraints were identified as hindrance for sorghum production and productivity enhancement. The major constraints include drought, Striga, insect pests (stalk borer, midge, and shoot fly), disease (grain mold, anthracnose and smut), soil fertility decline, inadequate adoption of the existing improved varieties, lack of high yielding and good quality sorghum varieties, and postharvest management practices (grain storage managements) such as storage pest control strategy and identifying alternative uses of sorghum grain.

2.5 Sorghum genetic variability

2.5.1 Sorghum genetic variability in the world

Characterization and identification of sorghum varieties which provide desirable traits for genetic improvement is a basis in plant breeding. Kimber *et al.* (2013) presented details of the major world sorghum collections and breeding lines of 150,000 accessions. Morphological variability of sorghum has been used for the development of sorghum core collections which represent the world collections to use in plant breeding (Grenier et al., 2000; Dahlberg *et al*., 2004, Mindaye TT *et al*., 2015). However, characterization and analysis of morphological traits and diversity of sorghum germplasm collections is too challenging due to time and environmental effects (Newbury and Ford-Lloyd, 1997).

The discovery of different types of DNA based molecular marker systems provided to characterize and structure large number of genotypes without any effect. Hybridization based RFLPs (Restricted Fragment Length Polymorphism) markers were the first DNA marker system identified that could differentiate homozygote and heterozygote loci (Botstein *et al*., 1980). RFLP markers have been used for genetic variability studies in different crops including in sorghum (Deu *et al*., 2006; Ahnert et al., 1996) and in maize (Pejic *et al*., 1998). The RFLP marker system is technically demanding, however, and found not to be suitable for high throughput and low cost screening.

The polymerase chain reaction (PCR) technique provide to increase both sample throughput and sample cost for marker screening. PCR based marker systems include RAPDs (Random Amplified Polymorphism) (Williams *et al*., 1990); AFLPs (Amplified Fragmented Length Polymorphism) (Vos *et al*., 1995) and SSRs (Simple Sequence Repeat) (Tautz *et al*., 1986) all of which have been widely used in various studies in many crops including in sorghum (Agrama and Tuinstra, 2003; Perumal *et al*., 2007) and maize (Garcia *et al*., 2004).

Both the hybridized and PCR based markers have had different applications to sorghum. A recent genetic variability study of global set of sorghum genotypes using SSR markers showed that landraces originating from Africa had the largest number of polymorphic alleles and the Eastern African genotypes had the highest variability followed by western African genotypes (Billot *et al*., 2013). Genetic variability and the genetic basis of racial classifications in sorghum have also been studied using different types of DNA based markers (Brown *et al*., 2011; Morris *et al*., 2013; Perumal *et al*., 2007; Ramu *et al*., 2013).

The next generation sequencing techniques (NGS) has offered new opportunities for sequencing and resequencing whole-genomes or targeted regions of genome (Edwards *et al*, 2013; Poland and Rife, 2012). Genotyping by sequencing (GBS) has been introduced as a tool to discover polymorphic markers while genotyping with high-throughput sequencing approaches with a low cost per data point (Gupta *et al*., 2008; Poland and Rife, 2012).

The recent resequencing of many sorghum genotypes showed the structuring of genotypes based on racial grouping and also identified genetic variability which could be useful for genetic improvements (Mace *et al*., 2013). In addition, genome wide markers generated by GBS have also been used for diversity analysis and understanding the genetic basis of complex traits and adaptation in sorghum (Morris *et al*., 2013; Wang *et al*., 2013).

2.5.2 Sorghum genetic variability and potential in Ethiopia

Ethiopia is a center of genetic diversity for many crops such as sorghum, barley, tef, chickpea and coffee, mostly represented in the country by landraces and wild types. Much of this crop diversity is found in small scale farmers, have played a great role in the creation, maintenance and efficient utilization of resources (Worede *et al.,* 2000; Abe, 2010**).**

Ethiopia has a diverse sorghum germplasm which adapted to a range of altitudes and rainfall conditions. The five major races of sorghum have been identified in the Ethiopian sorghum collections, with the durra and bicolor types and their derived sub-races predominating (Cuevas and Prom, 2013; Doggett, 1988; Reddy *et al*., 2002; Teshome *et al*., 1997). The zerazera type of sorghum, which is the sub-type of the race caudatum, is known for its grain appearance or grain type and disease resistance (Prasada Rao and Mengesha, 1981). In addition to these, the Ethiopian sorghum collections have been used as a source of genes for important traits, including stay green genes for post flowering drought tolerance (Haussmann *et al*., 2002; Kebede *et al*., 2001), grain quality and increased yield potential (Prasada Rao and Mengesha, 1981) and high lysine and enhanced protein digestibility (Singh and Axtell, 1973) and starch digestibility (Gilding *et al*., 2013).

Analysis of genetic diversity is important for crop improvement and provides available genetic resources and a basis for stratified sampling of breeding populations (Mohammadi and Prasanna, 2003, Isaac K. A. *et al*., 2016). Accurate assessment of the levels and patterns of diversity can be invaluable in the analysis of genetic variability in cultivars (Smith, 1984; Cox *et al*., 1986), identification of diverse parental combinations to create segregating progenies with maximum genetic variability for further selection (Barrett and Kidwell, 1998) and in introgressing desirable genes into the available genetic base (Thompson *et al*., 1998).

Characterizing the extent and structure of crop genetic diversity is important to know the genetic variability available and its potential use in breeding programs. It is also important to devise appropriate sampling procedures for germplasm collection and conservation and the establishment of core collections (Brown, 1995; Hayward and Sackville-Hamilton, 1997; Ramanatha Rao and Hodgkin, 2002).

Analysis of the extent and distribution of genetic variations between and within populations in a crop are important to understand its evolution and to sample genetic resources for breeding and conservation purposes (Milligan *et al*., 1994, Lakkakula S., 2015).

In Ethiopia, A number of genetic variability studies of sorghum have been conducted using qualitative and quantitative traits. 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, Mindaye TT *et al*., 2015). Similar findings have been reported using 59 Western Ethiopian sorghum landraces (Gebeyehu, 1993) and using 415 sorghum landraces with simple sequence repeats (SSR) and inter simple sequence repeats (ISSR) markers from four zones North Welo, South Welo, Oromiya and North Shewa (Haile Desmae *et al*., 2016).

2.6 Sorghum breeding

2.6.1 Sorghum breeding in the world

As explained in the previous section sorghum has diverse genetic variability. Conservation and understanding of the genetic structure of the world collections and breeding lines is essential to make them more accessible and useful for genetic improvement through pure line selection or crossing (Kimber, 2013). Many worldwide sorghum collections have been conserved in the USA and ICRISAT in addition to national collections maintained by individual countries where sorghum is important (Kimber et al., 2013; Kumar *et al*., 2011). However, only very small number of these collections has been well characterized and used by breeding programs (Kimber *et al*., 2013).

The type of farming system, production constraints and quality of end use product are vital in designing genetic improvement activities. Defining the breeding objective and creating genetic variability for the trait of interest are the primary and vital steps for effective crop genetic improvement (Haussmann et al., 2012). This can be done by designing crossing in targeted genomic regions between cultivated lines (Rooney, 2004) and wild relatives (Jordan et al., 2011a; Muraya et al., 2011) to find desirable traits. Different selections methods have been used in sorghum based on heritability of targeted traits and objectives of interest such as inbred line or hybrid. The pedigree breeding is the most commonly used for pure line development (Rooney *et al*., 2004). In this method segregating generations of the cross are made between parental lines which undergo repeated self pollinating and selection for the traits of interest until the lines maintain uniformity. The backcross method is used for the introgression of one or two desirable genes such as diseases resistance. Population improvement through recurrent selection can also be used to broaden the genetic basis and increase the frequency of favorable alleles in the breeding populations (Dweikat 2015).

The discovery of cytoplasmic male sterility in sorghum was used for commercial hybrid development in the USA. The higher performance of hybrids and the requirement for farmers to purchase F1 seed every season attracted private sector investment, with remarkable achievements being made in inbred and sorghum hybrid development over the past five decades in the USA, Australia and China (Jordan et al., 2003; Rakshit et al., 2014; Smith et al., 2010). Sorghum genotypes originating in tropical environments are late in maturity, tall in plant height and photoperiod sensitive and due to these not readily adaptable to the temperate environments. Changing of these genotypes into early maturing, short plant stature and photoperiod insensitive types was initiated in 1963 in the USA to make them suitable to the mechanized farming systems in the developed world (Stephen et al., 1967). The converted lines have been used as inbred parents for hybrid development in many developed countries (Klein et al., 2008, Smith et al., 2010) and increasingly their use is expanding to breeding programs in the developing world (Axtell et al., 1999).

The changing program was reinitiated in 2009 to exploit sorghum sequence information for rapid conversion of the exotic sorghum collections (Kimber et al., 2013). ICRISAT has also developed a number of varieties targeting the semi-arid tropics of Africa and Asia (Kumar et al., 2011). Inbred lines have been developed for hybrid breeding targeting Asia, which have also been started to be used by breeding programs Africa (Kumar et al., 2011, Reddy et al., 2007).

Allelic variation in recently released sorghum hybrids, and cultivars released in the 2000s, has been shown to have the lowest number of new alleles as compared to previously released hybrids (Smith et al., 2010). Therefore, there has been potential to expand the extent of genetic variability in improved lines using the world collections and the wild relatives as gene sources developed by ICRISAT (Upadhyaya et al., 2009, Ramu et al., 2013).

Increasing the efficiency and effectiveness of genetic improvement for complex traits, mainly grain yield, is the major interest in plant breeding especially in the developing countries. Following the discovery of molecular markers, a number of QTLs linked to quantitative traits in sorghum have been mapped (Rami et al., 1998; Mace and Jordan, 2011). Many QTLs linked to important traits have been identified over the past two decades including stay green (Crasta et al., 1999; Xu et al., 2000), striga resistance (Haussmann et al., 2004), fertility restoration (Klein et al., 2005; Jordan et al., 2011b) and photoperiod sensitivity (Chantereau et al, 2001; Crasta et al., 1999). The sequencing of the whole genome sorghum (Paterson *et al*., 2009) and resequencing multiple genotypes (Mace *et al*., 2013) in addition to the development of integrated QTL maps (Mace and Jordan, 2011) and a consensus map for major effect genes (Mace and Jordan, 2010) have been identified as useful resources for marker assisted breeding in sorghum (Gao *et al*., 2013). However, to-date the implementation of molecular markers in routine sorghum breeding activities has been found limited (Ejeta and Knoll, 2007).

2.6.2 Sorghum breeding in Ethiopia

The Ethiopian farmers have traditionally made selections of landrace genotypes adapted to particular environment and management practices such as intercropping (Georgis et al., 1990, Mindaye TT et al., 2015) with good quality traits such as larger grain size and different colors for various end uses and good plant biomass (Mekbib, 2006,). Collection and conservation of the large number of sorghum landraces has been undertaken since 1970s and to date more than ten thousand sorghum collections are maintained in the EIB (Ethiopian Institute of Biodiversity) and the national sorghum improvement program in melkassa agricultural center (Kimber et al., 2013; Tanto and Abdi, unpublished). Ethiopia is also the major contributor for global sorghum collections at ICRISAT and in the US National Plant Germplasm System (Cuevas and Prom 2013; Dahlberg *et al*., 1997).

Sorghum breeding activities in Ethiopia began in the early 1950s (Gebrekidan, 1980). Pure line selections and pedigree breeding have been the major breeding activities targeting the three major agro ecologies for the past decades. Using these methods a number of open pollinated sorghum varieties have been released for production (Gebeyehu *et al*., 2004). However, these varieties have had very low adoption rates to-date due to weak extension system (Cavatassi et al., 2011). The major factor for poor adoption is due to improved varieties lack farmers preferred traits such as plant height, grain size etc. (Beyene, 2012; Mekbib, 2006; Wubeneh and Sanders, 2006). The eighty five percent of the improved varieties released for the lowland and intermediate environments developed using introduced lines and their characteristics are short plant stature, early maturity and lower grain size (Adugna, 2007, Mekbib, 2006). In contrast, all the varieties released for the highland environment have been pure lines selected from the highland landrace collections; however, these released improved varieties only have limited yield advantage compared to the farmers' selected varieties or landraces which is one of the factors attributed to their lower adoption rate by farmers (Mekbib, 2006). Fifty two sorghum varieties has been released (forty eight are open pollinated and four are hybrid varieties) from the past to date in Ethiopia (Melkassa unpublished manual).

2.7 Sorghum improvement

Sorghum can be genetically transformed by using Agrobacterium (Alina M. et al., 2017) to improve nutritional quality due to it's low in lysine content, a high-lysine gene HT12 can be inserted into the sorghum gene using Agrobacterium vector together with a herbicide resistant gene bar. This way can increase 40-60% of lysine (Zhao et al., 2003). The benefit of improved transgenic lysine variety is to eradicate malnutrition. Africa Biofortified Sorghum (ABS) project developed improved sorghum lines through the process of genetic engineering techniques (Africa Biofortified Sorghum Project, 2009). The transgenic lines had high protein digestibility, improved amino acid score, and protein digestibility corrected amino acid score in contrast to untransformed sorghum lines (Vendemiatti et al., 2008). However, in Ethiopia, genetic engineering has not been yet done to improve sorghum. Stay-green QTLs were introgressed from improved to the farmer preferred Ethiopian local sorghum varieties and eight lines were advanced to the next esting (Asfaw A. and Alemu T., 2014). The Ethiopian breeding program used molecular markers to begin rapidly introducing a major gene for resistance to Striga into locally adapted landraces. 359 plants were advanced to the next level of testing(Melkassa unpublished progress report, 2015/2016). Genetic progress achieved over time from a breeding program is useful to develop effective and efficient breeding strategies by assessing the efficiency of past improvement works in genetic yield potential and suggest on future selection direction to facilitate further improvement (Abeledo et al., 2003, Mihret Y., 2015). Due to an excellent adaptation to drought, water logging and salinity, sorghum can grow in poor soils where growth of other cereals such as maize cannot be possible (ICRISAT, 1996, Lakkakula S., 2015). Therefore, the genetic improvement of sorghum for tolerance to drought and salinity through breeding would help to further increase its productivity in soils prone to drought and salinity.

3. Summary and Conclusion

In general, having diverse sorghum genetic diversity is important to increase genetic improvement of sorghum for many desirable traits, mainly for yield through breeding using advanced tools. However, in Ethiopia, progress is slow because of shortage of trained man power, infrastructure, conventional plant breeding etc. As the potential of genetic diversity in Ethiopia, the research is carried out in our country by scientists/researchers based at higher learning institutions and research institute. Hence, we can exploit the genetic potential of sorghum for high productivity, quality and production in our country. In spite of its prime importance in the Ethiopian agriculture, the major bottlenecks constraining production of sorghum are lack of high yielding and stable varieties, lack of improvement works in genetic yield potential , abiotic stresses such as drought, soil fertility decline (Gebrekidan H. 2003). In addition, Biotic stresses such as diseases, insects and weeds (especially Striga).The major areas of focus in the future sorghum genetic improvement include: advancing human capacity, improving productivity of sorghum, improving quality of sorghum, developing of tolerance/resistance to abiotic stresses using biotechnological tools such as molecular markers etc., and Developing of tolerance/resistance to biotic stresses such as diseases, insects, weeds etc.

Acknowledgements

The reviewer acknowledged the Researchers who had studied improvement of sorghum genetics in Ethiopia in early 1950s in absence of facilities.

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