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Utilization of Sorghum (*Sorghum bicolor* L. Moench.) hybrids in Kenya: A review

Moses Oyier*[1], James Owuoche[1], Erick Cheruiyot[1], Maurice Oyoo[1], Justice Rono[2]

[1]*Department of Crops, Horticulture and Soils, Egerton University, Kenya*

[2]*Department of Biochemistry and Molecular Biology, Egerton University, Kenya*

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Abstract

Hybrid seeds are known to increase productivity of many crops including sorghum (*Sorghum bicolor* L. Moench). This review was conducted to reveal the extent of sorghum hybrid seed utilization in Kenya and how non-utilization constrains sorghum production. Hybridization is one of the major discoveries that contributed to the green revolution which saved countries that were at the brink of famine. Although this is generally known, utilization of sorghum hybrid seeds is uncommon in Kenya. Even though low productivity is associated with climatic, edaphic, economic and agronomic factors, the contribution of the genotype cannot be ignored. The use of sorghum hybrid seeds has the potential to increase sorghum production for food, malting, brewing, baking, ethanol and fodder. Sorghum has both industrial and domestic utility making it an excellent crop for improving livelihood of rural communities living in agriculturally low potential areas in Kenya. Being a C4 crop, it has the ability to grow well in a wide range of climatic conditions making it an important crop for a country like Kenya. The use of hybrid seeds can be justified for almost all crops. However, for a multipurpose crop like sorghum, utilization of hybrid seeds cannot be ignored. Suggestions on how to improve the utilization of sorghum hybrid seeds have also been made.

* **Corresponding Author:** Moses Oyier ✉ oyierkilli2@yahoo.com

Introduction

Sorghum (*Sorghum bicolor* L. Moench.) is the fifth most important cereal crop in the world after rice (*Oryza sativa*), barley (*Hordeum vulgare L.*), wheat (*Triticum aestivum*) and maize (*Zea mays*) (Taylor, 2009). Being a C4 crop, it is highly adapted to a wide range of climatic conditions including marginal lands hence can be grown without competition with the other weather sensitive crops (Khawanja *et al.,* 2014). It can grow at an altitude range of 900m to 2500m, temperatures of 12 to 37^{o}C and an optimum rainfall of 550 to 800 mm (Srinivasa, Rao and Kumar, 2013). Sorghum does well in a wide range of soils such as alvisols and vertisols and can tolerate pH of 5.5 to 8.5 (Du Plessis, 2008). Kenya has a wide range of climatic and edaphic factors that can favor sorghum growing. Although Kenya has high production potential of the crop, it has remained under utilized (Muui *et al.,* 2013).The aim of this paper is to assess the utilization of sorghum hybrids in Kenya.

Kenya's agricultural productivity rests on the quality of improved seeds (Denning *et al.* 2009). Correct selection of seeds also come with incentives for better management practices. Use of improved varieties makes the subsistence farmers grow to commercial production due to increased productivity (Altieri *et al.*, 2012). Studies indicate that 78% of total seeds for the top 7 grains grown in Kenya is from the informal sector and not the seed industries (Tegemeo Institute, 2004). The seed industries in Kenya have been known to be slow in the production of seeds that target the rural poor for fear of failing to get returns on their investment (Nyoro and Ariga, 2004). The rural poor farmers are known to depend on their saved seeds and have low capacity to purchase the improved seeds (Lipton and Longhurst, 2010). This makes the seed companies unwilling to produce seeds of crops such as sorghum.

Even though researches conducted by various scholars around the world have revealed that sorghum hybrids can be better performing in various environmental conditions including drought, soil infertility, acidity and aluminum toxicity, production of the sorghum hybrid seeds has not been done by the seed companies (Chapman *et al.*,2000). This is likely because of the fear that the companies would not realize the return on their investment due to low purchase of the products. This vicious situation has led to continuous low productivity of sorghum in Kenya. However, the realization of sorghum as an industrial crop has created a new increased demand for sorghum making it an important crop that will demand improved seeds to meet its market requirement (Vermeris *et al,* 2007).

Hybridization has the potential of increasing sorghum productivity by more than twice the potential under the same conditions as the non hybrids (Rooney *et al.*, 2007). House *et al.* (1997) reported that utilization of hybrid sorghum seeds can significantly increase yields. Bantilan *et al.*, (2004) quantified the increase potential of hybrid utilization between 20 to 60% (House *et al.*, 1997; Bantilan *et al.*, 2004). Hybridization has the potential of increasing both the grain and the plant biomass accumulation in sorghum Zeng *et al.*, 2011). For Kenya to realize high productivity in sorghum, the challenges facing sorghum hybrid utilization have to be circumvented. Researchers have to tailor their studies to the market needs of the sorghum crop (Pingali and Traxler, 2002). There is need for the government to motivate the farmers by seed subsidies through active involvement in hybrid seed development.

Importance of sorghum

Grain sorghum is food for millions of people living in the arid and semi-arid tropics (Sing and Sing, 1992; Sharma and Ortiz, 2000). In Kenya, it is grown for subsistence in Western, Nyanza and Eastern provinces. It is a food security crop with good storage properties. Various communities have diversified the use ranging from *ugali*, porridge, *githeri* and even as a beverage (Leder, 2004). Sorghum is rich in carbohydrates and proteins but lacks preference due to the presence of phenolic compounds resulting to high tannin concentration in the seed coat (Jansman, 1993). It is believed that the tannins are an adaptive mechanism to protect the grains from birds as many bird resistant varieties have high tannin content (*Husle et al.,* 1990).

Sorghum forms a good alternative to farmers living in the arid and semi arid lands giving them an opportunity to harvest from the otherwise non productive land with minimal input. It is therefore a source of livelihood for the rural communities who would otherwise not get anything from farming.

In USA, sorghum is one of the most preferred fodder crops with quick biomass accumulation and high value calories (Almodares *et al.,* 2011). Forage sorghum can therefore be a major contributor in the development of livestock industry (McDermott *et al.,* 2011). It is easily made into silage with high protein content if harvested at the correct time. Sorghum has not been utilized for forage in developing countries (Rooney *et al.,* 2007). This is particularly because the most common variety is the grain sorghum which does not have good forage properties. In Kenya for example, there is no production of forage sorghum yet there is high demand for fodder. Sweet sorghum has been known to have high sugar content in the stem and has both ethanol and forage production potential (Rooney, 2007). With the efforts to reduce consumption of fossil fuels to reduce global warming, sweet sorghum has the potentials of playing the double role through food and energy provision (Yuan, 2008). The growing of sweet sorghum has not been adopted by the Kenyan farmers.

Production of sorghum hybrids

Hybridization refers to the act of mating organisms of different varieties or species resulting to a hybrid offspring. Studies have indicated that the new offspring may have improved performance due to heterosis. Heterosis has been used in crop improvement for several decades (Duvick, 2005). It is believed to be caused by dominance and or over dominance gene actions (Birchler *et al*., 2010; Kaeppler, 2012). Sorghum is a self pollinated crop except for isolated instances of cross pollination. Studies have established that the crop is about 6% cross pollinated (Sing, 1995). Self pollination makes hybrid seed production challenging due to complex procedures in emasculation.

However, with the discovery of male sterility among some varieties of sorghum, hybrid production has been made highly feasible. Application of male sterility in hybrid production involves identification of the male sterile line (A line), male fertile line (B line) and the restorer line (R line).

The use of male sterile line enables mass production of seeds since emasculation occurs naturally due to the non production of viable pollen. Cytoplasmic Male Sterility (CMS) is caused by a gene present in the cytoplasm. This kind can be transferred to a given strain using it as a pollinator. It has been utilized in hybrid production in several crops (Sing, 1995). In maize, Texas male sterile cytoplasm was used to make hybrids (Deway *et al*., 1996); in *Petunia* (Young and Hanson 1987), in sunflower (*Helianthus annus*) (Monenger *et al.,* 1994) and in beans (*Phaseulus vulgaris* (Abad *et al*., 1995), several hybrids have been produced. In sorghum, this has been reported in many varieties originating in India, Africa and America (Sane *et al.,* 1996). It is currently used in many breeding centers to produce sorghum hybrids. The technology is also used by seed companies for production of hybrid seeds which have contributed to significant increase in sorghum production especially in the USA.

Globally, USA is leading in sorghum production for the animal feeds (Stewart *et al*., 2005) while India is leading in grain sorghum production (Fig. 4) (Almoderas and Hadi, 2009). There has been a declining trend in the production of sorghum in Kenya (Connelly, 1994; Thornton, 2010). Many sorghum hybrids have been developed to meet various needs (Edgerton, 2009). There are those which have been improved specifically for fodder, ethanol and grains. Several seed producing companies have released various sorghum hybrids for use in other countries (Tripp and Rohrbach, 2001). Utilization of hybrid seeds is highest in the USA which also happens to be leading in production (Steduto *et al*., 2012). Use of hybrid sorghum has also been reported in Ethiopia where productivity of 6.2tha^{-1} was realized (Patil, 2007).

In both Nigeria and Niger, hybrid sorghum outperformed the local varieties (House *et al*., 1997). In Sudan (former), Ejeta, (1986) reported that hybrid sorghum out performed local varieties by between 50 and 85% under field conditions and between 300 to 400% under irrigation (Ejeta, 1986). There is high correlation between the utilization of sorghum hybrid seeds and productivity. These studies suggest that utilization of sorghum hybrid seeds can increase sorghum production in Kenya. Currently, there is no production of sorghum hybrid seeds in Kenya for farmers. No farmers in Kenya are currently planting sorghum hybrids due to their unavailability. This is probably due to the fact that sorghum growing and consumption was left for the rural poor whose purchasing power is low and cannot support the commercial seed industries.

Trends in sorghum production in Kenya

According to the statistics of the Food and Agriculture organization in 2014-2015, sorghum production in Kenya is inadequate (FAOSTAT, 2014). Kenya has been known to have significantly low production of sorghum (Fig. 1). Even though Kenya has a higher potential than this, low production has continued to be realized. This is associated with poor agronomic practices, poor choice of seeds and taking sorghum as a last priority crop among other constraints. The highest sorghum production in Kenya was realized in 2005 and the lowest production was realized in 2008 (Figure 1) after the post election violence. Sorghum yield potential has remained low even when there is an increase in the area occupied by the crop (Fig. 2). Low productivity has been contributed to by the poor choice of seeds and over reliance on the local varieties whose productivity is comparatively low.

Sorghum in Kenya has been mainly produced from the improved varieties and local varieties. A survey conducted by Timu *et al.* (2014) in eastern Kenya revealed that both the local and improved varieties are being grown in the area (Table 2) (Timu *et al*., 2014). It is evident that there are no sorghum hybrids currently planted by farmers in Kenya. Currently, there are 17 seed companies operating in Kenya (Table 1).

Table 1. Seed companies in Kenya, their products and current location.

Name of the company	Seeds produced	Location
Pannar Seed (Kenya) Ltd	Maize, grain sorghum, sunflower (*Helianthus annus*), soybean(*Glycine max*), dry beans(*Phaseolus vulgaris*), wheat, pasture	Nairobi
Kenya Seed Company Limited	Maize, wheat, sunflower, finger millet (*Eleucine coracana*), sorghum, rice, legumes, pasture, indigenous vegetables and horticultural crops.	Kitale
Monsanto Kenya Ltd	Alfafa(*Medicago sativa*), Canola (*Brassica napus*), corn/maize, sorghum, soybean, sugarbeats (*Bata vulgaris*), wheat	Nairobi
Amiran Kenya Ltd	Tomatoes (*Solanum lycopersicam*), Onion (*Allium cepa*)	Nairobi
Agri –Seed Co	Maize, wheat, soybean, cowpea(*Vigna unguiculata),* sorghum, ground nuts (*Arachis hypogea*) and sugar beans	Nairobi
Pioneer Hi-Bred Kenya	Alfafa, Canola, corn/maize, sorghum, soybean, sugarbeats, wheat, sunflower, mustard (*Brassica spp*.)	Nairobi
Simlaw Seeds	Tomatoes, cabbages, Asian vegetables, water melons (*Citrullus lanatus*), pepper(*Capsicum anuum*), carrots (*Daucus carota)*	Nairobi
East African Seed Company	Maize, wheat, sunflower, finger millet, sorghum, rice, legumes, pasture, indigenous vegetables and horticultural crops.	Nairobi
Bayer EA Ltd	General	Nairobi
Western Seed Company	Maize, beans, sunflower	Kitale
Syngenta East African Ltd	Tomatoes, cabbages, sweet paper	Nairobi
Dry Lands Seed Ltd	Maize, pigeon pea (*Cajanus cajan*), beans, sorghum, green grams (*Vigna radiate*)	Machakos
Olerai Seeds	Maize and sweet potatoes (*Impomea batatas)*	Narok
Kenya Highland seed Company	Horticultural seeds	Nairobi
Freshco Kenya Ltd	Maize, vegetables (OPV and hybrids), legume seeds	Nairobi
Starke Ayres Kenya Ltd	Lawn seeds, vegetable and flower seeds	Nairobi
Elgon Kenya Ltd	Maize, cabbages, vegetables, water melon, onions	Nairobi

Seven seed companies are involved in production of sorghum seeds. However, most of the companies only produce the improved variety seeds and not hybrids. Companies like Pannar produce hybrid sorghum but only sold in other countries like South Africa. Pioneer and Monsanto produce hybrid sorghum seeds though are currently not available in the Kenyan market.

There is poor adoption of new technologies in Kenya especially in sorghum farming. To improve the production trend, it is essential to ensure the use of hybrid seeds as well as the adoption of new technologies (Chepng'etich *et al*., 2015).

Sorghum Varieties in Kenya

Several varieties of sorghum are currently grown in Kenya. The improved varieties such as *Seredo, Serena, Gadam, Sila* and *Kari Mtama* are available with may seed stockists all over the country. The local varieties are currently rare and can only be found with a few farmers in the rural areas.

Table 2. Sorghum varieties grown in Kenya, their description and regions commonly grown.

Variety	Description	Status	Regions in Kenya
Serena	● Brown seeds, It has a long stem and good root system, Red coloration in the midrib, height ranges from 150 to 160 cm, smaller compact panicle, grains brown in color	Improved variety	Western and Nyanza regions, Performs well in the moist mid altitude region and the semi arid lowland .
Seredo	Height 150 to 160 cm, large and oval health, thicker stem, grains brown in color.	Improved variety	● Perform well in moist altitude and the semi arid lowlands ● It is widely adaptable
Gadam	● Semi-dwarf 100-130cm, grey chalky, drought resistant Has excellent malting qualities	Improved variety	● Performs well in the coastal strip arid lowland
Sila	White, attractive to birds	Improved variety	Performs well in western, eastern and coastal region
Kari *mtama* 1	Height 50-170 cm, white grains, highly susceptible to bird's infestation.	Improved variety	Performs well in western, eastern and coastal region
Kari *mtama* 3	Height 50-170 cm, white grains, highly susceptible to birds infestation.	Improved Variety	Performs well in Eastern Kenya
Gopari	Brown seeded, slightly bird resistant	Local variety	Lower altitude along the lake region
Migogo nyuol edero/kisudi	Deep red grains, bitter and highly resistant to birds	Local Variety	Lower altitude along the lake region
Andiwo/Igumba	White, susceptible to bird infestation, very good in porridge	Local Variety	Lower altitude along the lake region
Ochuti/Andiva	Deep red in color,	Local Variety	Lower altitude along the lake region
Kiambere	Brown seeded variety with good taste in *ugali* and porridge	Local Variety	Performs well in Eastern Kenya
Gatururu	Red grains, low yield	Local Variety	Performs well in Eastern Kenya
Muceru	Red grain, low yield	Local Variety	Eastern Kenya

Comparison of Production of other crops with sorghum in Kenya

Agricultural productivity in Kenya has been characterized by performance below the global standards (Louwaars and De Boef, 2012). Louwaars and De Boef argued that the overall low productivity is due to the seed that farmers are planting. For example, the current productivity of maize is 2t/ha. This was the global average in 1960 for maize production yet maize is one of the crops for which mostly hybrid seeds are planted.

According to FAOSTAT, sugarcane (*Saccharum officinarum*) production is the highest in Kenya followed by maize, potatoes, bananas and sweet potatoes (Fig. 3).

The high area of arable land under sugar cane in Kenya compromises food security (Naylor, 2007). Being a cash crop, there is motivation in the development of the planting materials hence the success in productivity. Similar efforts put on sorghum production are capable of making Kenya a food secure nation.

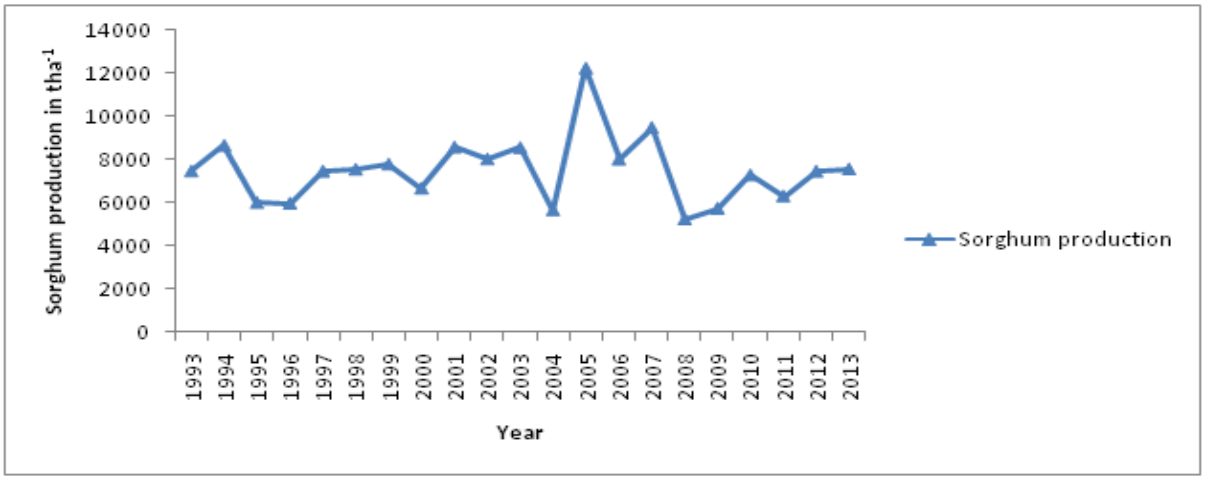

Fig. 1. Trends in sorghum production in Kenya 1993 to 2013 (Source: FAOSTAT).

Factors influencing Sorghum production in Kenya

Eighty percent of Kenya land area is favorable for growing of sorghum. Sorghum can do well in the high lands, midlands and lowlands. Sorghum can tolerate a wide range of soils both alvisols and vertisols which are predominantly found in various parts of the country. It is more tolerant to alkaline salts and can do well in a pH ranging from 5.5 to 8.5. Sorghum has the ability to withstand short periods of water logging and can do well in soils with high clay content. The optimal production of sorghum can be attained at between 10 and 30% clay content (Lewandowski *et al.*, 2003).

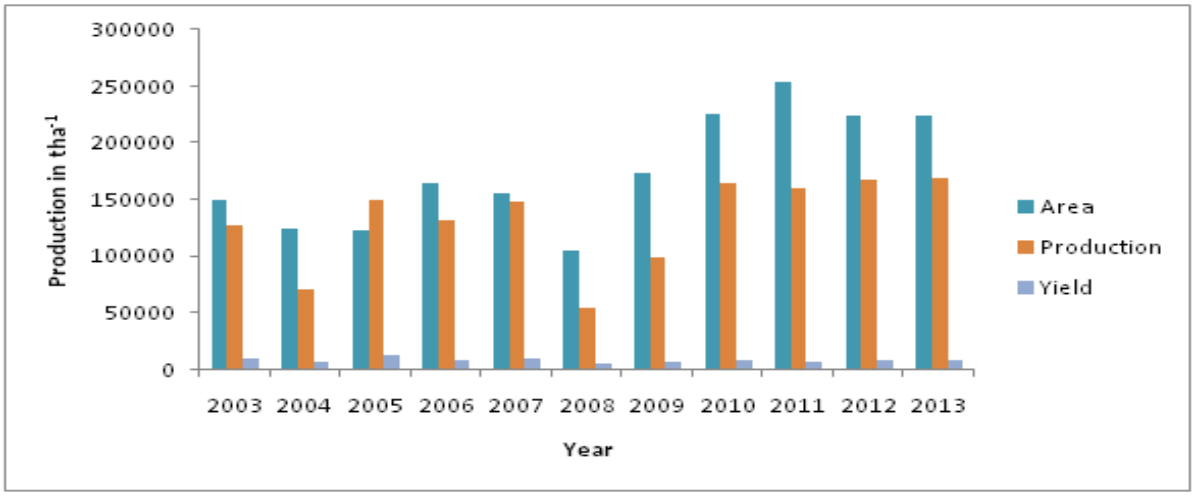

Fig. 2. Area harvested, production and yield of sorghum compared from 2003 to 2013 (Source: FAOSTAT).

Sorghum can survive a wide range of moisture conditions. The amount of rainfall received in Kenya on average ranges from 300 to 2500mm per year making it possible for sorghum production in most places Sorghum can survive drought due to its drought tolerance mechanisms including folding of leaves, smaller leaf surface area limiting transpiration and rapid stomatal closure. This makes sorghum a suitable crop for the marginal lands in Kenya. Sorghum also does well in warm weather.

Relatively higher temperatures are needed for germination and growth. For germination, minimum temperatures of 7 to 10 ^{o}C is required. Warmer temperatures of 15 ^{o}C leads to rapid germination with 80% of the crops germinating within 7 days (Du Plessis, 2008) For optimum growth, temperature of 27 to 30 ^{o}C is required.

However, a drop to 21 ^{o}C may still not affect productivity. Temperatures in Kenya is favorable in most parts of the country except for the highlands where it can sometimes be lower making it difficult for good growth and panicle formation. Extremely higher day and night temperatures can also hinder development of the flower.

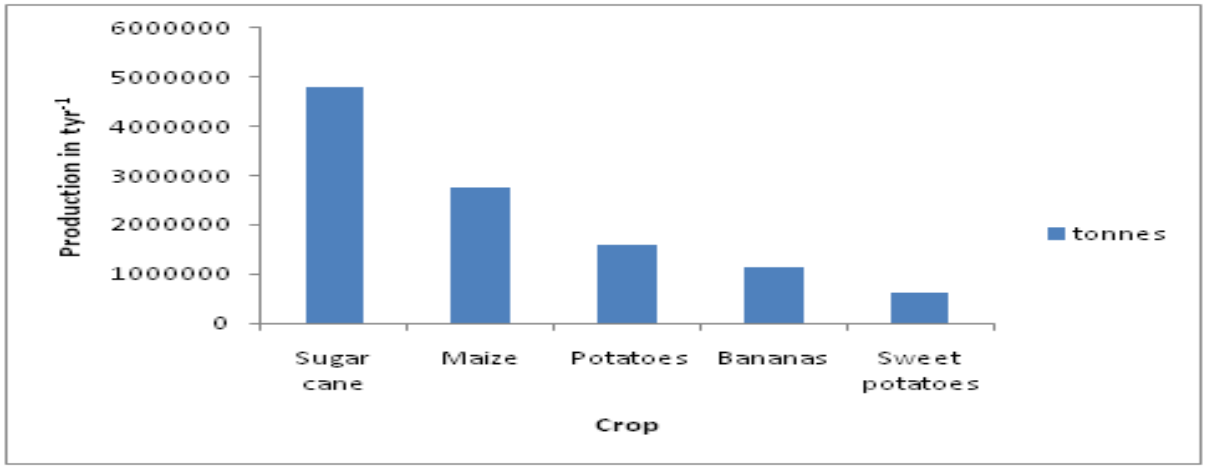

Fig. 3. Top five crops produced in Kenya (Source: FAOSTAT).

Biotic factors affecting sorghum production in Kenya

Biotic factors cause economic loses to sorghum growing farmers. The most common diseases are headsmut caused by fungi (*Sorosporium reilianum*).

Insects such as shoot fly (*Atherigona soccata)* also cause loses. Jotwani [48] observed that shoot flies can cause up to 50% loss in India (Jotwani, 1982). In Kenya, it is unclear whether they cause economic loses. Planting of resistant varieties is the easiest management option for shoot fly in sorghum (Sharma *et al*., 2005). Aphids (*Sipha flava*), maize stalk borer (*Busseola fusca*) and ball warm are potential threats to the production of sorghum but can be managed by using integrated pest management practices. Birds are the most destructive sorghum pests. Depending on the season and the variety, birds can cause up to 100% loss in sorghum production. They can be managed by avoiding offseason planting and bird scare for small holder farmers.

Economic factors affecting sorghum production

Sorghum production has mostly targeted household consumption. This has resulted to low market for sorghum especially at the local level. This has to a large extent discouraged its production. The emergence of industrial utilization of sorghum products has created new market demands for the products. Currently, there is increased demand for sorghum for brewing, baking, and ethanol industries. In order to realize the full potential of sorghum, it is necessary to develop sorghum hybrids which can meet the rising market demand.

Challenges

Farmer's attitude towards sorghum has greatly affected its production. Many farmers only grow sorghum for household consumption. This is due to the fact that grain sorghum has been characterized with low production, low prices and inadequate market.

There are no hybrid sorghum seeds in the market. This is due to the fact that seed industries are not willing to invest in the production of sorghum seeds with the market base as the rural poor communities. Crop development challenges include the fact that sorghum is a self pollinated crop and that the development of hybrid seeds will depend on the successful utilization of male sterile lines with those that have the ability to restore fertility.

This has been overcome by the availability of the male sterile lines in various research stations.

Opportunities

The diversity of sorghum makes it have very many uses such as animal feeds, human food and industrial sorghum which can be used in baking, brewing and ethanol processing industries. The demand for sorghum is growing and its potential utilization is hindered by continued low production.

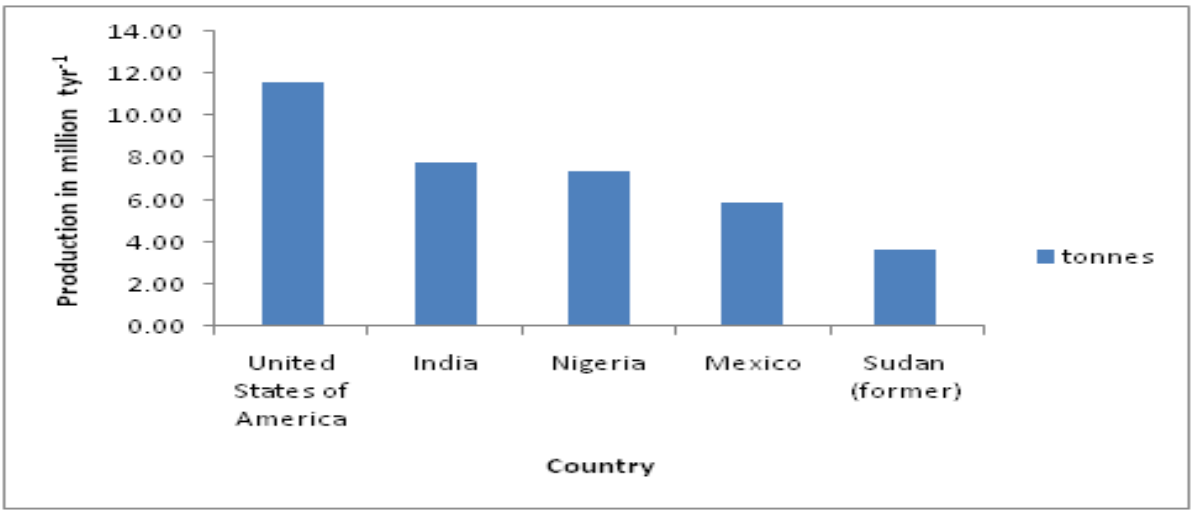

Fig. 4. Leading countries globally in the production of sorghum (Source: FAOSTAT).

The brewing and baking industries are in need of sorghum to help diversify their products (Kilambya and Witwer, 2013). Kenya imports sorghum from neighboring countries despite its production potential. Health consciousness and blood sugar related complications demand the consumption of high fiber and low calorie foods. This has boosted the demand for sorghum and other related grains which have been associated with low income earners. The availability of technology and skill for the development of sorghum hybrid seeds by the Kenya Agriculture and Livestock Research Organization (KALRO) as well as universities offers good opportunity for seed improvement.

Conclusion

This review is an eye opener to the Kenyan government, especially the agricultural sector and can help improve their efforts in enhancing agricultural productivity of orphaned crops such as sorghum. Kenya has high sorghum production potential since the soil and climatic factors are highly favorable for sorghum production. There are many seed companies involved in sorghum seed production with both the technology and capacity for seed production. Production of hybrid seeds aimed at meeting the market needs of sorghum products is necessary to boost sorghum production. Many hybrids have been developed by researchers but are currently facing production challenges due to low market value of sorghum seeds. Efforts by researchers, involvement of the seed companies, incentives by the government and community participation in production will ensure utilization of sorghum hybrid seeds in Kenya, a situation which will contribute to food security.

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