Review Article

Overview of sorghum (*sorghum bicolor.*L), economic importance, ecological requirements, and production constraints in Kenya

Abstract

Sorghum Sorghum bicolar (L) Moench) is an important cereal crop grown in arid and semi-arid areas. It is rank as the fifth key cereal crop after wheat, maize, rice and barley globally and acts as a source of grain, animal feed, pasturage, fodder, fiber, fuel, bioethanol, alcoholic beverages as well as building materials. In Kenya, sorghum production is done mainly by smallholder farmers as a key food and cash crop. Most of the country's crop production is mainly in the arid and semi-arid regions with an altitude of between 800 and 2,000 m above sea level. The country's average sorghum yield ranges between 0.7-1ton/ha compared to variety specific average yield of >2 tons/ha. The production is mainly constrained by myriad of factors such as climate change effects, poor agronomic practices, poor fertility management practices, lack of ready markets, lack of organized market infrastructure, poor research- extension- farmer linkages and access to credit facilities as well as poor sorghum processing and value addition technologies. The current work reviews the sorghum crop, with emphasis on its biology, economic importance, ecological requirements, the current production status in Kenya and production constraints.

Keywords: Sorghum, production constraints, arid and semi-arid regions, soil fertility, marketing.

1.0 Introduction

Sorghum (*Sorghum bicolor (L) Moench),* is a cereal crop ranked the world's fifth most important cereal grain after wheat, maize, rice and barley (1,2, 3). The crop is native to Africa with Archaeological evidence supporting that it was first cultivated in north eastern Africa- near the Egyptian-Sudanese border around 5,000–8,000 years ago (4, 5, 6, 7). It was then distributed to other parts of Africa through migration and middle east and Asian countries such as India and China through trade routes (8; 9; 10). At the end of 19th Century, slave trade introduced sorghum to the United States of America from cultivated farms in North Africa, South Africa and India. Overland trade routes also led to sorghum introduction to Mexico, Argentina and eventually Australia where it became a major summer crop accounting for 5% of global export (7).

The crop is commonly known in English as broomcorn, chicken-corn, common wild sorghum, durra, feterita, forage sorghum, grain sorghum, sweet sorghum, great millet, milo, Rhodesian sudan grass, shallu, shattercane, sordan, sorghum, Sorghum-Sudan grass, and Sudan grass (11). It is a member of the tribe Andropogoneae of the grass family (Poaceae) and comprises of about 25 species and five subgenera (12, 13). Some of these species have grown as cereals for human consumption or pastures for animals or production of raw materials for industries. One of these species is *Sorghum Bicolor (L) Moench,* which comprises wide range of cultivated sorghums globally. The other species are wild or weedy with varying degrees of interspecific compatibility ranging from 0% to 100% (14; 15; 7). The five subgenera on the other hand are: Chaetosorghum, Heterosorghum, Parasorghum, Stiposorghum, and Eusorghum (16; 17). Among the five subgenera, Eusorghum which comprises the cultivated species, S. bicolor (L) Moench has been classified into five races based on flower morphology namely: Bicolor Guinea, Caudatum, Kafir and Durra. (18; 19). Early bicolor sorghum is believed to have arisen from subspecies venticilliforum in Central Africa (20) while Caudatum, Kafir, Guinea and Dura were created by crossing early bicolor with wild forms of sorghum.

The sorghum crop is a C4 annual or short-lived perennial grass that typically has one generation per growing season. Its root system is fibrous comprising of seminal roots, which appear at germination, and nodal, crown or adventitious roots, which emerge later from the shoot (21; 22). Development of the seminal root-system is largely determined by the genetic background, while post-embryonic roots, crown and brace roots produce the major portion of root biomass at the adult stage and react strongly to environmental conditions (23; 22). Lateral roots have a large influence on root architecture and their function in water and nutrient uptake is essential (24). Leaves are typically green, grass like and flat, not as broad as those of maize. It has a small leaf area, long, narrow and pointed leaf blade. Stomata occur on both surfaces of the leaf. Leaves have rows of motor cells along the mid rib of the upper surface which roll up leaves rapidly during moisture stress. The leaves develop on the opposite side of the stem and are covered by a thin wax layer. Their number is however determined by environmental conditions and varies from 8 to 22 leaves per plant.

Sorghum stems range from solid and dry, to succulent and sweet consisting of nodes and internodes which are covered by thick waxy layer. The waxy layers' role is to reduce transpiration and increase drought tolerance (25). Under favorable conditions, more internodes develop, together with leaves producing long stems while more nodes lead to development of lateral shoot. The general diameter of sorghum stem varies from 5mm and 30mm.

Sorghum has a cultivar specific compact panicle in terms of shape and color. Heads are carried on main stem or peduncle with primary and secondary branches on which the florets are borne. Peduncle is usually straight and its length varies from 75 to 500 mm with each panicle containing from 800 to 3000 kernels which are usually partly enclosed by glumes whose colour ranges from black, red, brown or tan. The flowers mostly self-pollinated with approximately 6% being cross pollinated and they normally open during night or early morning, with those at the top of the panicle opening first, and take approximately 6 to 9 days for the whole panicle to flower (26; 27). Ripe sorghum seed is partially enclosed by glumes that are removed during threshing and/ or harvesting. The seeds are oval to round shaped and may be red, white, yellow or brown in colour and are made up of testa, embryo and endosperm. Although coloured pericarps have yellow or red seeds most pericarps and testas are normally dark brown or red brown in color.

2.0 Economic Importance of Sorghum

Sorghum bicolor (L.) Moench is a multipurpose crop cultivated across the globe as a source of either grain, sweet stem, animal feed, pasturage, fodder, fibre, broomcorn, fuel, bioethanol, alcoholic beverages, and building materials (28; 29). Although most developed countries grow sorghum for either forage, animal feed or industrial purposes, the crop is cultivated as an important food crop in most arid and semi-arid regions of the world (28; 7). The grain Sorghum is used to make semi-leavened bread, fermented and none fermented porridges, cakes as well as brewing traditional beers in Kenya and other African Countries (30; 31; 32; 33).

Sorghum plays an important role as a food security crop because of its nutritional quality as well as ability to survive in harsh environmental conditions. Depending on the variety, it contains significant amounts of minerals such as phosphorus (P), potassium (K), calcium (Ca), zinc (Zn), magnesium (Mg), iron (Fe), and sodium (Na), as well as vitamins such as A, B, D, E, K and β-carotene (34; 35; 36; 37; 38). On average, 100 g of grain has about 72.1 g carbohydrates, 12.4g water, 10.6 g proteins, 6.7 fibers, 3.5 g lipids and provides about 1,377 KJ energy (38). Starch is the dominant carbohydrates which is stored as granules in the endosperm consisting mainly amylose and amylopectin (39). Sorghum is also a rich source of fiber found in pericarp and endosperm cell walls and accounts for about 6 to 15 g per 100 g of grain (36). The protein content is broadly divided into prolamin such as kafirins and non – prolamin such as globulins, and albumins. Kafirins are the principal form of protein storage in sorghum grain that account for 70% of total protein in sorghum whole grain. The remaining albumins, glutelins and globulins account for only 30% (40; 41). The grain is also rich in glutamic acid, proline and leucine and low in lysine (42; 43; 44;). Sorghum proteins have low digestibility due to high degree of polymerization and extensive disulfide bridges that are resistant to enzymatic digestion in digestive tract. Their strong interaction with tannins and starch also hinders protein digestion (40; 45; 46).

Despite these characteristics, the low starch and protein digestibility compared to other cereals makes sorghum a promising food source for people with obesity and diabetes. Lipid in sorghum grain on the other hand is constituted of primarily unsaturated fatty acids, with polyunsaturated fatty acids being the most abundant and primary fatty acids include; Oleic, linoleic, palmitic, linolenic and stearic acids (47; 38). Sorghum grain also contains important bioactive compounds such as anti-cancer, hypocholesterolemia, anti-obesity, anti-inflammation, and anti-diabetic (48; 49; 50). An example of these bioactive compounds are variety specific phenolics compounds containing unique 3-deoxyanthocyanins which are rare or found in minimal concentrations in other cereal grains (49; 37; 50). Some sorghum varieties especially ones with pigmented testa contain tannins, which serves as a strong antioxidant in human bodies (37; 50). The grain is mostly used as a staple food for significant number of people in arid and semi-arid areas in the tropics and as an emerging heathy gluten free food product in other regions (42). Like any other grains, some sorghum varieties however, contain phytic acid, trypsin inhibitors, and other compounds classified to have anti-nutritional components that may have detrimental consequences to human body.

5.0 Sorghum Ecological Requirement

Most sorghum varieties are annuals with a few perennial cultivars (51). The crop is drought tolerant and does well from 800-2000 meters above sea level. It requires well distributed rainfall of between 250-900 mm per annum and wide range of temperatures ranging from 10^0C to 30^0C (52; 53). It is best to plant sorghum when there is sufficient water in the soil and soil temperature is 15^0C or higher at a depth of 10 cm. As a short day plant, sorghum require short days and long nights. Temperature and day length, therefore, play an important role in growth and development after germination. A temperature of 27^0C to 30^0C is required for optimum growth and development while colder conditions during growth period contributes to delayed crop maturity. Increased day and night temperatures on the other hand delay flower initiation and development of premodia (54) and therefore a photoperiod of between 10 and 11 hours induce flower formation, while photoperiod of 11 to 12 hours stimulates vegetative growth (55). Although the crop is well adapted to grow in wide range of soils, it does best in deep, fertile, well drained loamy soils with pH 5.5-8.5. It is tolerant to shallow soils and short periods of water logging conditions and therefore can can grow well in soils with 10-30% clay, clay loamy and sandy loamy texture. (55; 56; 53). It however grows poorly on sand soils, except where heavy textured sub soil is present.

6.0 Sorghum Production in Kenya

Sorghum is ranked third after maize and wheat in terms of cereal production and has been noted to do well on a wide range of soils (57; 58). Its potential to catalyze regional development is considerably high because it is termed by (59) as a crop with vast untapped potential which can be harnessed in poverty alleviation, employment creation, and reducing malnutrition in the country. It is majorly grown in moist mid altitude, semi-arid lowlands, cold semiarid highlands to humid coastal eco- zones of semi-arid eastern, western and Coast areas of Kenya with semi-arid eastern having the greatest total area under sorghum (60; 53). Some of these areas include: Busia, Siaya, Kakamega, Kisumu, Homabay, Kuria, Migori, parts of Meru, Embu and Nyeri, Machakos, Kitui, Makueni, Mwingi, Tharaka nithi, Kajiando, Nakuru, Baringo, Laikipia, Naivasha, Narok, Taita taveta, Lamu, Kilifi, Kwale, Mombasa and someparts of Koibatek, rift valley and northeastern Kenya. Production in this regions is mostly carried out by small scale farmers for subsistence (61). According to (62), approximately 240,000 who holds farm sizes ranging from 0.4 to 0.6 Ha (1 to 1.5 acres) exists within the country. Most of these farmers intercropping sorghum with other crops such as maize, cowpea, beans and pigeon peas with exceptions of a few who grow sorghum for the beer industry (63).

The common varieties within the country are Gadama, Silla, Kari Mtama 1, Kari Mtama 2, IS76, E 1291, E6518, BJ 28, Ikinyaruka DP, Serena and Seredo (AIC,2002; 53; 65). The grain yield potential of each variety per 90kg bag is Gadama (8-20bags/acre), Silla (10-20bags/acre), Kari Mtama 1(11-17bags/acre), Kari Mtama 2 (15bags/acre), IS76(10-12bags/acre), E 1291(10-15bags/acre), E6518(12-17bags/acre), BJ 28(12-15bags/acre), Serena (10-20bags/acre) and Seredo(1-12bags/acre) (64; 65). Ikinyaruka DP, E6518, E 1291and Sila varieties are good for fodder production with a fodder yield potential of Ikinyaruka DP (8tons/ha), E6518 (3tons/ha), E 1291 (10-15bags/acre) and Sila(tons/ha) (66; 53).

Although FAO (2018) statistics shows that sorghum production within the Country have been increasing since 2010, Kenya still imports more than one third of its total consumption (67). The productivity potential ranges between 2-5ton/ha against the current realized productivity levels of 0.7 tons/ha with approximately half of the production being utilized as food, 1% as livestock feeds, one fifth processed and about fifteen percent lost through postharvest losses (61). Even though sorghum is utilized majorly as a source of food within the country, its demand for industrial use such as manufacture of starch, wax, syrup, dextrose agar, edible oils and beer has risen over the past years (39). Conversely, the global demand for sorghum and sorghum seeds is estimated to grow 2% by year 2028 annually with increased utilization of sorghum for biofuels, ethanol, livestock feed and food industry (68). This signifies the importance of capitalization on the crop for improved income and livelihood within the country.

7.0 Factors Affecting Sorghum Production in Kenya

Despite the growing population and increased demand for climate smart crops such as sorghum within the country, the industry growth has been constrained over the years. The low performance is attributable to: poor agronomic practices, erratic rains due to effects of climate change, low processing capacity and efficiency, low marketability of brown and red sorghums and lack of harvesting mechanization technologies (60; 58; 31). Pest and diseases also pose a huge production challenge to small scale farmers because of either lack of management knowledge of capital (66; 69). The major pests include: sorghum shoot fly (*Antherigona varia*), stem borers (*Busseola fusca*), aphids, bollworm, weevils, aphids and birds such as Quelea quelea. According to 70 and 71, control of quelea birds is labour intensive and it is one of the reasons farmers avoid cultivation of white sorghum varieties which have less tannin opt for others cereals such as maize. Diseases on the other hand include: leaf spot, rust, leaf blight, anthracnose, ergot, head smut, and covered kernel smut which if the most damaging disease in dry areas (72; 53).

Most sorghum cultivation areas located in arid and semi-arid areas which are designated to be sensitive to climate variability and highly vulnerable to events such as droughts ((73; 74; 75). Owing to the fact that optimal crop growth and yield require provision of all nutrients in rightful forms and amounts, water plays a major role as a solvent for all soil chemical reactions (76). Most of the sorghum production areas within the country have however been experiencing erratic rains ad frequent drought over the past years (77). The constant dry spells coupled with poor water conservation technologies and limited agronomic knowledge base among other factors play an important role towards below optimal sorghum production within the country (69).

Although efforts have been made to promote sorghum production in many parts of the country, the crop has for a long time remained mostly a crop for rural families and local market. This phenomenon is attributable to the fact that the crop is generally considered to be a food crop for the poor and vulnerable populations in arid and semi-arid regions. Middle class urban dwellers who are endowed with comparative higher purchasing power therefore prefer other cereals over sorghum and its products hence the low demand in urban centers. Production of sorghum marketable products has also been another challenge because of existence of a weak link between farmers, local processors and market as well as poor consumer sensitized on utilization of the available sorghum based products (78; 31).

As an orphaned crop, use of certified seeds among farmers is limited. While farmers growing sorghum for East African breweries are able to constantly access and use certified seeds to meet the company's quality standards, majority of farmers producing for local market often prefer own saved seed (79).

Access to adequate agricultural information is very essential to increased agricultural productivity (80). According to (81), lack of information sources in rural areas restrains farmer's agricultural production. Public agricultural extension officers play an important role of linking farmers with current technologies and market. The research- extension – farmer link in Kenya has however been deteriorating over the years with the current extension: farmer ratio standing at 1800:1 compared to the FAO recommendation of 400:1 (82). As a result, many smallholder farmers have limited sources of useful and reliable, soil and water management, agronomic and marketing information leading to low uptake of technologies, crop production and yields in the region.

According to (83) and 84 efficient use of fertilizers is key in sorghum production. The current withdrawal of Kenyan government from fertilizer market and abandonment of price controls to encourage private investors have led to improved fertilizer distribution but led to increased prices which are unaffordable to most smallholder farmers. Additionally, sorghum farmers are not prioritized in the current subsidized fertilizer scheme operated by the government.

According to research carried out by (85, 86), there exists a positive relationship between new technologies adoption level and the availability of credit. Availability of credit eases the cash constrictions and enabling farmers to purchase inputs such as improved cultivars, fertilizer, pesticides with ease. Lack of collateral among rural small scale farmers in arid and semiarid areas however limit their access to credit facilities (87 and 88). Additionally, though government policies play a major role in cushioning farmers, unlike other crops, there exists limited specific legal or regulatory framework for sorghum production (89).

8.0 Conclusion and Recommendations

The review indicates that sorghum plays an important role as a source of food, animal feed, pasturage, fodder, fibre, fuel, bioethanol, alcoholic beverages, and building materials. It is also a wonder C4 plant that can grow well in arid and semiarid areas, its production within Kenya is however constrained by negative climate change effects, pest infestation and diseases infections and poor access to farm inputs. Other factors such as poor access to agricultural information, poor access to credit facilities, poor market infrastructure as well as value addition technologies are also key factors that has continuously limited sorghum production within the country. The review also revealed that there exists a huge untapped market for sorghum grains locally and globally. Achieving optimal production potential in order to tap the increasing demand and growing local and global market therefore requires adoption of climate smart technologies, improved flow of information to farmers, government policies, credit services as well as market infrastructure.

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