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Sun Loving Sorghum – A Better Option for the Sustainable Production (Production and Use of Sorghum (Sorghum Bicolor) and Its Adaptability to Sri Lanka - a Review)

Kaluthanthri D.V. S, Dasanayaka P.N.

Institutional affiliations: Department of Botany, Faculty of Applied Sciences,
University of Sri Jayewardenepura, Nugegoda, Sri Lanka.

Abstract - *Sorghum bicolor* (L.) Moench is an annual, monoecious plant with one or many tillers and more similar in appearance to maize (*Zea mays*). This plant is one of the most important crops in the world and considered as one of cereals with the best drought tolerance. This crop is cultivated in the semi-arid parts of the world spreading over 105 countries. The major aim of this article is to document the adaptability of sorghum to Sri Lanka. Sorghum can be consumed into a wide variety of foods, such as baked products, tortillas, couscous, gruel, steam-cooked products, semi-leavened breads, popped form, fermented or non-fermented porridges and alcoholic or non-alcoholic beverages. Furthermore it has considerable medicinal values. Noteworthy, sorghum can be cultivated on the uplands in Sri Lanka during Maha season both in dry, wet and intermediate zones of the country and as well as during Yala season with a requirement of supplementary irrigation depending on the rainfall received. However the bitter truth is that the climatic zones in Sri Lanka have been experienced considerable changes. Since there is a little opportunity to mitigate the climate change, we would have to adapt to the changing environments. Given that the ability of sorghum to thrive under diverse climatic and soil conditions, it can be considered as a better option for our country in the face of climate change.

Keywords - *Sorghum Bicolor*, Cereal, Climatic Change, Drought, Tolerance.

I. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) which belongs to the family *Poaceae* is one of the most important crops in the world. This plant is more similar in appearance to maize (corn). However *Sorghum bicolor* is an annual, monoecious plant with one or many tillers. Also it is 100 – 600 cm tall plant. It has a solid, usually erect stem, finely branched roots and alternate, simple leaves. Inflorescence is a terminal panicle comes out of flag-leaf sheath at heading time.

At the beginning Linnaeus (1753) grouped this plant under the genus of *Holcus*. As reported by Clayton (1961), Adanson is the person who used the term 'sorghum" for the first time whereas Moench separated the genus *Sorghum* from genus *Holcus*. Genus *Sorghum* was divided into five sub genera namely *Sorghum, Chaetosorghum, Heterosorghum, Parasorghum and Stiposorghum* by Celarier (1959). Furthermore sub genus *Sorghum* had been classified into three species as *S. halepense, S. propinquum* and *S. bicolor* by Harlan and Wet (1972) and De Wet (1978). According to De Wet (1978) and Mann *et al.* (1983), three sub species as *S. bicolor* subsp. *bicolor, drummondii and verticilliflorum* can be recognized in the species *S. bicolor*.

There are three types of Sorghum as wild, weedy and cultivated sorghum. Weedy sorghum has been originated resulting from the hybridization between the cultivated and wild types. Apparently sub genus *sorghum* representing all annual wild, weedy and cultivated taxa (Harlan and De Wet (1972); De Wet (1978)). Likewise *Sorghum halpense* and

Corresponding Author: Dasanayaka P.N.

Sorghum propinquam are wild sorghums whereas *Sorghum bicolor* subsp. *drummendii* and *Sorghum bicolor* subsp. *verticilliflorum* are annual weeds. *Sorghum propinquam* is distributed in Sri Lanka other than the cultivated forms. *Sorghum bicolor* subsp. *drummendii* may grow as a weed wherever sorghum is cultivated. Singularly only *Sorghum bicolor* subsp. *bicolor* contains cultivated sorghum (De Wet (1978); Mann *et al*. (1983)).

Out of all currently cultivated cereals, this can be considered as one of cereals with the best drought tolerance. Therefore sorghum is considered as the "camel of the crop" in the world of crops. Still there is a room for improving the quality and the yield of the crop when growing under irrigated conditions (Solaimalai *et al*. 2001). This crop is well adapted to grow in arid and semi-arid regions of the world. Africa, Central America and South Asia are at the front with respect to the production area of sorghum. Currently more than 500 million people in more than 30 countries depend on sorghum as their dietary staple. Therefore sorghum is particularly important to food security in the arid and semi-arid regions of the world. Sorghum is consumed into a wide variety of foods including baked products, fermented or non-fermented porridges, alcoholic or non-alcoholic beverages, confection and molasses (Dahir *et al*. 2015). Other than being important as a human food, sorghum is also used for fodder and feed for animals, building materials, fencing, fuel and brooms (Bantilan *et al*. 2004).

II. Origin, Domestication And Distribution Of Sorghum

According to Vavilov (1926) the old Abyssinian (today's Ethiopian ancestors) area could be the centre of origin of sorghum. However De Wet and Harlan (1971) described more broad area than that as the centre of origin. Snowden (1935) suggested separate centers of origin for different species of sorghum. As reported by Mann *et al*. (1983), origin and early domestication of sorghum probably happened in northeastern Africa, north of the equator and 10^0E latitude approximately 5000 years ago. Carbonized seeds of sorghum found with consistent radiocarbon dates of 8000 years from the early Holocene archaeological site at Nabta Playa near the Egyptian-Sudanese boarder, supported that the origin of sorghum happened 3000 years earlier than the previously suggested and 10-15^{0}E latitude further north than that of the previously reported (Wendorf *et al*. 1992). Etuk *et al* .(2012) reported that sorghum had been domesticated in Ethiopia (Doggett, 1965) and people who migrated into Ethiopia through the middle East or through Arabia may have domesticated the wild sorghum which occurred as weed in their wheat fields (Pursglove, 1972). According to Doggett (1970) cultivated sorghum was taken from Ethiopia to West Africa at an early date across Sudan to upper Niger River where sorghum was grown in Neolithic time. Also sorghum was taken from Ethiopia to East Africa by hunters and food gathers. Sorghum was taken from East Africa to India probably during the 1st millennium BC and reached to China along the silk route from India in the early Christian era (Purseglove, 1972).

III. Reproductive Biology

Sorghum is a diploid (2n=20), self pollinated crop but capable of out crossing in various frequencies. Wind and insects such as honeybees, wild bees and beetles contribute to the out crossing yet the out crossing rates are in the range of less than 10% to 73% (Barnaud *et al*. 2008). As described by Vanderlip and Reeves (1972), there are ten growth stages of sorghum as emergence, 3 leaf stage, 5 leaf stage, panicle initiation stage, flag leaf visible in whorl, boot stage, 50% flowering, soft dough stage, hard dough stage and physiological maturity. However Eastin (1972) has described three growth stages namely planting to panicle initiation, panicle initiation to flowering and flowering to physiological maturity. According to Schertz and Dalton (1980) and Lansac *et al*. (1994) longevity of sorghum pollens is limited to two to four hours but the pollens are highly functional for about 30 minutes after the anther dehisce. As described by Ayyangar and Rao (1931), Stephens and Quinby (1934) and Maunder and Sharp (1963), stigmas are receptive for a day or two after blooming but sometimes may remain receptive up to a week or more. Pollen grains are germinated immediately after contact with receptive stigma.

IV. Nutritive Values Of Sorghum

Polysaccharides, proteins and lipids can be considered as the major nutritive components of sorghum (Martino *et al*. 2012). Minerals such as phosphorus, potassium and zinc can be also found in sorghum depending on the place of cultivation (Martino *et al*. (2012); Shegro *et al*. (2012)). Several B-complex vitamins (thiamine, riboflavin and pyridoxine) and fat-soluble vitamins (D, E and K) are reported to present in sorghum (Ochanda *et al*. (2010); Martino *et al*. (2012); Cardoso *et al*. (2014)).

V. Medicinal Values Of Sorghum

As sorghum is a gluten free cereal, consumption of sorghum products can be recommended for patients

suffering from celiac disease (Taylor *et al*. 2006). Sorghum rich in dietary fiber and has a low glycemic index. Therefore sorghum can be helpful in control of diabetes (Park *et al*. 2012). There is a rare class of plant pigments known as 3-Deoxyanthoxyanins (3-DXA) which possess unique chemical and biochemical properties and may be useful in helping reduce incidence of gastrointestinal cancer. According to Yang *et al*. (2009), sorghum is the only known natural food source of the 3-DXA in significant quantities.

VI. Foods From Sorghum

Sorghum is consumed into a wide variety of foods, such as baked products, tortillas, couscous, gruel, steam-cooked products semi-leavened breads, popped form, fermented or non-fermented porridges and alcoholic or non-alcoholic beverages (Anglani, 1998). Moreover, it can be used to prepare foods for both adults and children. According to Obizoba (1988) baby foods can be made using sorghum, maize gruels and sugar. Sorghum is a good source of B vitamins and contains minerals such as potassium and phosphorus mainly while calcium content is low (Hegedus *et al*. (1985); Khalil *et al*. (1984)). Snack food can be also made from sorghum. Tortillas, couscous, porridges and baked foods are the major foods prepared with sorghum (Rachie, (1969); Torres *et al*. (1994)). As reported by Bedolla *et al*. 1983 and Choto *et al*. 1985, sorghum and sorghum-maize mixtures are used to prepare tortillas. Couscous is the staple food in North Africa (Kaup and Walker, 1986). According to Dahir *et al*. (2015), the most popular traditional breads from sorghum are roti in India, injera in Ethiopia, kisra in Sudan, lahooh in Somalia and tortillas in Central America. Dada and Muller (1983) stated that the fermented porridge called as 'ogi' is the most weaning food for babies. In Africa and Asia, hard biscuits such as bread and cookies are made from composite flours containing sorghum and millet (Badi and Hoseney, 1976).

Sri Lankan foods such as rotti, string hoppers and pittu can be made using a mixture of sorghum and wheat flour. Sorghum and white rice can be mixed to make kiribath (milk-rice) as well (The Island, 2012).

VII. Other Uses

Other than being important as a human food, sorghum is also used for fodder and feed for animals, building materials, fencing, fuel and brooms (Bantilan *et al*. 2004). Sorghum is an excellent crop for production of renewable fuels (Kisgeci *et al*. 1983).

VIII. Sorghum Production

Sorghum is cultivated in the semi-arid parts of the world spreading over 105 countries (Rakshit *et al*. 2014). In Asia only India and China can be considered as the sorghum growing countries in massive scales. According to Rakshit *et al*. (2014) over the last four decades, cropping area of sorghum around the world has reduced at a rate of over 154,000 ha per year due to several reasons. In this case, countries like China, USA, India and Yemen showed a notable decline in the cropping area of sorghum. Change in food habit, low profitability of the crop and lack of government support are the reasons for the loss in cropping area in Asia whereas the government policy allowing marginal lands to be placed under the conservation reserve program and the competition with genetically modified maize hybrids are the reasons for the loss in cropping area in the USA. Nevertheless, the cropping area in several countries such as Brazil, Ethiopia, Sudan, Australia, Mexico and Nigeria has increased over the year because of new lands brought under sorghum cultivation and better water management. Developed countries contribute to more than one third of world's sorghum production. Enhanced yield levels can be observed in almost all of sorghum growing countries in the world except in Africa as a result of improved cultivars, higher input use, better resource and crop management. The highest annual yield levels for sorghum (2011-2013) have been recorded in Argentina followed by China, Mexico, USA and Australia (Hariprasanna and Rakshit, 2016).

In case of Sri Lanka, some decades ago, sorghum made its commencement here but failed to conquer much demand. However, according to past records, Sri Lanka showed the highest sorghum production of 5,586 tons in 1975 (Factfish, 2016). Still Sri Lanka has a world share of 0.0% for sorghum.

IX. Adaptability Of Sorghum To Sri Lanka

Sri Lanka is an island which is located in the North-equatorial tropical zone of the world. In here, seasons are determined by the rainfall distribution conducted by convectional precipitation and two monsoons. Basically there are two seasons locally called as "Maha" and "Yala". "Maha" season is influenced by northeast monsoon and continues from November to March whereas the southwest monsoon in May to September is considered to be the "Yala" season (Premaratne and Premalal, 2006). Noteworthy, sorghum can be cultivated on the uplands in Sri Lanka during Maha season and as well as during Yala

season with a requirement of supplementary irrigation depending on the rainfall received. There is also the potential to fit in sorghum soon after the "intermediate" crop to catch the inter monsoon rains. There is a vast extent of lands lies fallow in between two seasons for more than six months. These lands can be used for planting of sorghum to give an additional source of income to chena farmers (The Island, 2012).

According to the traditional classification based on the rainfall distribution, there are three climatic zones in Sri Lanka, namely the Wet zone, Dry zone and Intermediate zone. The Wet zone covers the south-western region including the central hill country while the Dry zone covers the northern and eastern part of the country, being separated from the Wet zone by the Intermediate zone. The Dry zone has a distinct dry season from May to September and the Intermediate zone has a short and less prominent dry season. The Wet zone has no pronounced dry periods (Premaratne and Premalal, 2006). Sorghum can be cultivated on the uplands during Maha both in dry, wet as well as intermediate zones of the country.

However the bitter truth is that the all climatic zones in Sri Lanka have been experienced considerable climatic changes and as a consequence, entire flora and fauna including humans are getting affected in significant levels. Since there is a little opportunity to mitigate the climate change, we would have to adapt to the changing environments. In here, sorghum can be considered as a better option for Sri Lanka since sorghum able to thrive under diverse climatic and soil conditions. Nevertheless this sun loving crop is most suited to the hot, dry and arid districts of the country and requires less water. This cereal can be considered as one of the currently cultivated cereals that have the best drought tolerance. As described by Assefa *et al*. (2010), there are several drought tolerance or avoidance mechanisms of sorghum. The deep root system and higher root density help to increase water extraction depth and area respectively. In order to maintain carbon dioxide exchange, stomata remain open at wide range of leaf turgor. Furthermore, closed stomata at higher level of stress, leaf roll and waxy cuticle help to avoid further water loss. Formation of small vacuoles and production of antioxidant help to avoid cell rapture and to protect from lipid peroxidation respectively (Assefa *et al*. 2010). Sorghum can be grown successfully on a wide range of soils and tolerates a pH range from 5.5 to 8.5, some degree of salinity, alkalinity, and poor drainage (Dogget, 1988).

Sorghum possesses a number of water soluble allelochemical which are phytotoxic to the growth of certain weeds as well (Cheema and Khaliq, 2000).

On the other hand, it is said that the economy of Sri Lanka undergoes a process of structural transformation where the manufacturing and services sectors make higher contributions to economic development measured in terms of Gross Domestic Products than the agriculture sector (Central Bank of Sri Lanka, (2005); Sanderatne, (2005)). When the economy becomes less agriculturally oriented, agriculture and the food systems have to play vital roles through continuing to grow absolutely and generating important growth linkage to the rest of the economy. As discussed by Bandara *et al*. (2014), under such a circumstance, agriculture sector has to play several roles such as increasing the supply of food available for domestic consumption (food security), increasing the supply of domestic savings from agriculture sector (capital formation), releasing the agricultural labour force for specialized work in other sectors including the manufacturing and services (Labour mobility) and increasing the foreign exchange earnings through agricultural exports (agricultural trade). This is where the production of "other crops" such as sorghum becomes an important realm with respect to the overall economy of Sri Lanka.

In case of domestic agriculture, though the production of paddy remains as the core during last three decades it had lost its position in domestic agricultural arena to the "other food crops" (i.e. export agricultural crops, up country and low country fruits and vegetables, floriculture etc.). Therefore, emergence of food crop agriculture was an important economic transition took place during the post-independence period, starting from 1948 in Sri Lanka (Epaarachchi *et al*. (2002); Tudawe, (2000)).

Green chilli, red and big onion, cow pea and ground nut can be considered as the few of currently grown other crops in Sri Lanka. However, the 2017 output of several other crops including green chilli, red and big onion, cow pea, ground nut, millet and green gram is estimated to have decreased in Sri Lanka as a negative impact of drought (Coslet *et al*., 2017). This decrement in production explains why the drought tolerant crops need to be promoted and supported as a part of the crop diversification strategy.

X. Conclusion

It is a vivid point that sorghum is one of the most important crops of this era. The foregoing dedicates that this crop has the potential to grow in various areas of Sri Lanka

where other crops perform poorly. However more research and development on sorghum are required to resolve some serious technical problems and to adopt or develop technologies. Consideration of the facts such as facilitation of relevant authorities to research on sorghum, dissemination of research findings and promoting sorghum market in Sri Lanka is the way forward for production of sorghum in Sri Lanka.

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