Sorghum - A potential crop to adapt to future climate change scenario

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Close to 1 billion people went hungry in 2010 according to the Food and Agriculture Organization (FAO) of the United Nations. In 2011, hunger plagued the Horn of Africa, hit by the worst drought in 60 years. The future is daunting too: food needs are projected to increase by 70 percent by 2050 when the global population reaches 9 billion, while climate change is projected to reduce global average yields. Climate change will affect agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts. Marginal areas, where low yields and poverty go hand in hand, may become even less-suited for agriculture as a result of land degradation through deforestation, wind and water erosion, repetitive tillage and overgrazing. Many impact studies point to severe crop yield reductions in the next decades without strong adaptation measures — particularly in Sub-Saharan Africa and South Asia, where rural households are highly dependent on agriculture and farming systems are highly sensitive to temperature increases and volatile climate. One assessment, based on a pessimistic assumption about global warming, estimates that by the 2080s world agricultural productivity will decline by 3-16 percent. The loss in Africa could be 17-28 percent (Cline 2007). While agriculture is the sector most vulnerable to climate change, it is also a major cause, directly accounting for about 14 percent of greenhouse gas emissions, or approximately 30 percent when considering land-use change, including deforestation driven by agricultural expansion for food, fiber and fuel (IPCC, 2007; Smith *et al*. 2007). And yet, agriculture can be a part of the solution: helping people to feed themselves and adapt to changing conditions while mitigating climate change.

In south Asia, the increase in average annual mean temperature is projected to be between 1.0 and 1.4 ^{0} C by 2020 and from 2.23 to 2.87 ^{0} C by 2050. With the current level of greenhouse gas emissions and the associated temperature rise (0.73°C), many areas currently suitable for sorghum in India will be lost, off course new area may be added. Increased temperatures accelerates the rate at which plants release CO_2 in the process of *respiration*, resulting in less than optimal conditions for net growth. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield. Important effects of high temperature include, decrease in pollen viability, pollen vigor resulted in spikelet sterility, decrease in seed setting, accelerated physiological development, resulting in hastened maturation and reduced yield. Heat in combination with water stress during the terminal period is a major factor contributing to sorghum production instability in these regions. Previous study have reported that under scenarios of higher temperature combining low rainfall resulted in decline of wheat and sorghum yields in sub-tropical Australia. In the absence of any adaptation or mitigation strategy, impact of climate change in terms of rise in atmospheric temperature are likely to considerable by 2020 and even greater their after. One of the important and viable strategies could be to develop the superior genetic resources with improved heat tolerance to reduce the risk of loss from heat stress injury.

The earth's climate is predicted to change through the buildup of greenhouse gases -primarily carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. The major impact of climate change due to this buildup of green house gases will be increase in atmosphere temperatures. Increased water shortages, rising sea levels (may result in more saline lands), reduced crop yields, more floods and increase in human and animal diseases are some of the serious problems being expected under climatic change scenario. Farmers can no longer rely on the rainy seasons as before. The rise in temperatures will left many boreholes dry and streams having no water. These impacts of climate change are due to the large amount of gases such as carbon dioxide and methane that are being pumped in the air by human activities and industries. It is said that in the near future, the ice on many mountains will disappear, and that many parts of the world will experience floods, droughts and forest fires, as a result of climate change. That means many people will have little food to eat and there will be no excess produce to sell in order to afford basic needs. Growing crops, that are drought and heat resistant, is one form of adapting to the impacts of climate change. Sorghum is one of the crops which have inherited its trait to adapt and grow in harsh climate from its origin. It grows in dry conditions, tolerates heat, salt and water logging, making it an ideal crop for semi-arid areas where many of the world's poor live. It is now realized that sorghum is of prime

importance for the sustainable livelihood of the rural poor farmers who cannot afford purchased inputs. Further, the urban poor consumers having limited purchasing power will benefit of nutritive millets grains are also made available as rice and wheat as low cost. Increasing industrial utilization, greater use as quality fodder and as adjunct in food and feed mixes can dramatically alter the demand of sorghum.

Sorghum [*Sorghum bicolor* (L.) Moench] ranked fifth among the world's most important crops. More than 70% of the world's total production of sorghum comes from the developing countries in Asia and Africa, where crop is grown with limited input of water and nutrients. In India, sorghum is cultivated during both kharif (rainy) and rabi (post-rainy) seasons mainly as a rainfed crop (92% of the area) with about 85% of the production concentrated in Maharashtra, Karnataka and Andhra Pradesh, all falling under warm semi-arid region. Hence, sorghum is one of the major food crops in drought prone environments, but has great potential for crop improvement for food, feed, fodder and bio fuel production ("FFFF"). In India, national productivity of sorghum is very low (880 kg/ha) as against high yield obtained in USA and China. Low productivity can be attributed to low and marginal management and rainfed cultivation. Since sorghum is grown as rainfed crop, the climate factors play a significant role in its productivity. With the threat of climate change and variability (CCV) looming large on crop productivity, the most venerable regions of the world are the tropics particularly the semi-arid regions where higher temperature and increase in rainfall variability could have substantially negative impacts (IPCC 2007). Climate change on rabi (post-rainy season) sorghum likely to reduce the yields up to 7% by 2020, up to 11% by 2050 and up to 32% by 2080. Impacts are projected to be more in south-west followed by south-central and central zones (Srivastava *et al.* 2010). Adaptation strategies like changing variety and sowing dates reduced the climate change impacts to some extent, but complete amelioration of yield loss beyond 2^0C rise may not be obtained even after doubling of rainfall in most of the sorghum growing regions.

Sorghum as food crop: Sorghum food consumption has many potential health benefits such as high anti-oxidant levels, improved cholesterol profiles of the consumer, and as a source of safe food for persons with celiac disease. Sorghum grains have high fibre content, moderate digestibility, rich mineral content compared to other cereals such as rice and wheat. Therefore, sorghum foods are recommended for diabetic and jaundice-affected persons and for fighting obesity. High tannin sorghums reduce the risk of certain types of cancer when compared to other cereals. Sorghum wax has sterols like policosanols which regulates cholesterol absorption and endogenous cholesterol synthesis.

Despite the fact that consumption of sorghum as direct food use is declining, market for processed foods such as multigrain flour, flakes, vermicelli, pasta and biscuit is surprisingly picking up in urban areas as there is increasing acceptability of sorghum if available in ready-to-eat form or as convenient foods as health and nutritional foods. In this context of increasing demand for sorghum, owing to their nutritionally rich character its value-addition has acquired a great importance which will have a striking impact on socio-economic conditions of dry-land farmers in long-run. All sorghum processed products generally have fairly strong acceptability among the consumers as revealed from the finding of consumer acceptance studies undertaken by an independent agency commodity India. These products have more nutritional value and health benefits as compared to similar products developed from wheat and rice. Since novel processing technologies in sorghum are introduced in the markets in an integrated manner to highlight them as a choice convenient and health products which is suitable for all age groups especially for those ailing from life style diseases such as diabetes.

Sorghum as source of feed and fodder: Dairy industry has been the driving force in the region of Punjab, Haryana, Uttaranchal, Uttar Pradesh, Bundhelkhand, South Rajasthan and North West Gujarat. Sorghum as a source of feed and fodder has the potential to meet the demand set by the dairy industry. Fodder availability during the lean season has enormous value for the livestock industry and farmers' livelihoods, particularly in areas with less-productive soils in north west Gujarat (saline soils) and eastern India (acidic soils). In the Eastern India, where rice is the first crop, the problem of acidity is common and there is a potential for single cut sorghum as a second crop in these rice fallows. Options to diversify fodder production on these less productive lands are important, as well for land use and income generation. In Deccan Plateau, where sorghum grain is more important, there is a need to improve the stover quality to support dairy industry. Owing to the above, the approach to meet the feed and fodder demand should be based on locally relevant traits in the plant

Sorghum as bio-fuel crop: Sorghum has a potential to emerge as one of the two big crops in the tropics" that supply biofuel such as ethanol, the demand for which "far exceeds the supply" on the world market. Further, sweet sorghum has emerged as a supplementary crop to sugarcane in dry land pockets for the production of ethanol. The advantages of the crop are it can be grown with limited water and minimal inputs and it can be harvested in four months with 2-3 irrigations. Its water requirement is one fourth of sugarcane on comparable time scale. Use of ethanol blended fuel is increasing because they reduce vehicular emission of CO_2, methane and other gases that contribute global warming. The dual-purpose nature of sweet sorghums—they produce both grain and sugar-rich stalks—offers new market opportunities for smallholder farmers and does not threaten food, feed and fodder value of sorghum. Sorghum is being cultivated since time immemorial in several countries of Asia and Africa. Incidentally, most of the landraces that are being grown in India in post-rainy season are sweet sorghums. In China, specific programs are underway to breed sweet sorghums for silage production. The emerging bio-fuel needs, therefore offer expanded markets for sweet sorghum in India, China and several African countries. Because sweet sorghum requires less water and has a higher fermentable sugar content than sugarcane, which contains more crystallizable sugars, it is better suited for ethanol production than sugarcane or other sources, and sweet sorghum ethanol is cleaner than sugarcane ethanol, when mixed with gasoline. Pilot studies in India indicated that ethanol production from sweet sorghum is cost-effective. Also, the net returns from sweet sorghum cultivation at the prevailing cost of cultivation and ethanol prices is about 10% higher than that from grain sorghum in India. In addition to this crop has a unique inbuilt ability of biological nitrification inhibition (BNI) in its root exudates through which it suppresses nitrification in soil. This indicates that sorghum can play a vital role in mitigating the impact of global warming by regulating the emission of greenhouse gases like nitrous oxide N_2O, CO_2 and methane.

One of the needs to cope with the changing climate scenario of rising temperature (hence increasing evaporation) is to improve the heat and drought tolerance of major food crops like wheat, rice and maize. The progress in these areas is generally low due the complex nature of traits associated with these stresses. Sorghum and/or millets is a group of crops which have already inherited higher tolerance to heat, drought, salinity etc. Therefore, these crops have a better chance to get adapted to these supra-optimal conditions. No doubt there is still need to improve genetic potential of sorghum for higher tolerance to these abiotic stresses. The other major challenge facing sorghum research and development workers is to provide technologies that will enable the agriculture sector to affect transformation of "subsistence farming" to a sustainable "market-oriented' enterprise successfully competing with the rest of world.

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