2.19 Sorghum

U Kumar, P Craufurd, CLL Gowda, A Ashok Kumar, L Claessens, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

The importance of sorghum for food and nutrition security

Sorghum [*Sorghum bicolor* (L.) Moench] is cultivated in the drier areas of Africa, Asia, the Americas and Australia. It is the fifth most important cereal after rice, wheat, maize and barley, and is the dietary staple of more than 500 million people in more than 30 countries (Ashok Kumar et al. 2011). It is grown on 42 million hectares in 98 countries of Africa, Asia, Oceania and the Americas (Table 2.19.1). Nigeria, India, the USA, Mexico, Sudan, China and Argentina are the major producers. Other sorghum-producing countries include Burkina Faso, Chad, Ethiopia, Gambia, Ghana, Mali, Mauritania, Mozambique, Niger, Senegal, Somalia, Tanzania and Yemen.

Sorghum is a staple cereal in sub-Saharan Africa, its primary center of genetic diversity. It is most extensively cultivated in zones of 600–1000 mm rainfall, although it is also important in the areas with higher rainfall (up to 1200 mm), where poor soil fertility, soil acidity and aluminum toxicity are common. Sorghum is extremely hardy and produces even under very poor soil fertility conditions (where maize fails). The crop is adapted to a wide range of temperatures, and is thus found even at high elevations in East Africa, overlapping with barley. It has good grain mold resistance and thus has a lower risk of contamination by mycotoxins. The cultivated species is diverse, with five major races identified, many of them with several subgroups. This reflects farmer selection pressure applied over millennia for adaptation to diverse production conditions, from sandy desert soils to waterlogged inland valleys, growing to maturity with only residual moisture, as well as in standing water. The grain is mostly used for food purposes, consumed in the form of flat breads and porridges (thick or thin, with or without fermentation). Sorghum grain has moderately high levels of iron (> 40 ppm) and zinc (> 30 ppm) with considerable variability in landraces (iron > 70 ppm and zinc >50 ppm) and can complement the ongoing efforts on food fortification to reduce micronutrient malnutrition globally (Ashok Kumar et al. 2012). In addition to food and feed it is used for a wide range of industrial purposes, including starch for fermentation and bio-energy. Sorghum stover is a significant source of dry season fodder for livestock, construction material and fuel for cooking.

Sweet sorghum is emerging as a multi-purpose crop. It can provide food, feed, fodder and fuel (ethanol) without significant trade-offs among any of these uses in a production cycle. ICRISAT has pioneered the sweet sorghum ethanol production technology and its commercialization (Reddy et al. 2008, 2011; Ashok Kumar et al. 2010).

Table 2.19.1. Sorghum statistics by region

Region	Average production per year ('000 Mt)	Average area (1000 ha)	Average yield (t/ha)
Year	2008	2008	2008
Eastern Africa	4.59	4.29	1.07
Middle Africa	1.24	1.48	0.83
Northern Africa	4.73	6.79	0.70
Southern Africa	0.32	0.17	1.85
Western Africa	14.32	14.86	0.96
Northern America	12.00	2.94	4.08
Central America	7.02	2.09	3.36
Caribbean	0.10	0.12	0.87
South America	5.95	1.82	3.27
Central Asia	0.02	0	4.07
Eastern Asia	2.53	0.60	4.21
Southern Asia	8.09	8.03	1.01
South-Eastern Asia	0.06	0.03	1.70
Western Asia	0.66	0.56	1.18
Eastern Europe	0	0	0
Northern Europe	0	0	0
Southern Europe	0	0	0
Western Europe	0	0	0
Australia and New Zealand	0	0	0
Melanesia	0	0	0

Source: FAOSTAT 2008

Globally, sorghum production has remained more or less stable over the past 30 years, although there are notable regional differences. Area of production has decreased overall, but has remained essentially constant during the past five years on a global basis. West Africa, which produces roughly 25% of the world's sorghum, has seen a steady increase in total production over the past 25 years. Most of the increase up to 1995 is attributed to increases in area, although productivity increases also contributed; after 1995, yield increases explain most of the rise in sorghum production in the region. Recent global trends also show both grain yield and production increases. These gains may reflect increased use of improved varieties and better crop management practices (such as fertilizer micro-dosing), as well as increased demand due to population growth and higher world prices for major cereals. The yields of post-rainy season sorghum have steadily increased in India, and are in demand for their superior grain and stover quality.

Major constraints to sorghum production include shoot fly, stem borer, head bug and aphid insect pests; grain mold and charcoal rot diseases; weed competition and the parasitic plant Striga (in Africa); and abiotic stresses such as drought (especially terminal drought), high temperatures, acid soils (resulting in high levels of aluminium saturation) and low soil fertility (in terms of both macronutrients like nitrogen and phosphorus and micronutrients such as iron and zinc).

Opportunities for the future include developing hybrids to increase yields for a wider range of production systems in Africa, building on successes in India, Mali and elsewhere; and exploiting photoperiod sensitivity and temperature insensitivity to adapt to variable climates and developing new, improved plant types for 'dual purpose' sorghums for grain, feed and fodder uses that would increase the value of the crop. These new sorghum types would strengthen the integration of animal husbandry with crop production, resulting in higher and more stable incomes while improving soil health through increased organic matter cycling. The availability of the full genome sequence and other genetic and genomic tools will enable efficient use of the crop's rich genetic diversity for the improvement of sorghum and other cereals.

Sorghum has been an important staple in the semi-arid tropics of Asia and Africa for centuries. It is still the principal sources of energy, protein, vitamins and minerals for millions of the poorest peoplein these regions. While total food consumption of all cereals has risen considerably during the past 35 years, world food consumption of sorghum has remained stagnant, mainly because, although nutritionally sorghum compares well with other grains, it is regarded in many countries as an inferior grain. Per caput consumption of sorghum is high in countries or areas where climate does not allow the economic production of other cereals and where per caput incomes are relatively low. These include especially the countries bordering the southern fringes of the Sahara, including Ethiopia and Somalia, where the national average per caput consumption of sorghum can reach up to 100 kg per year. Other countries with significant per caput consumption include Botswana, Lesotho, Yemen and certain provinces in China and states in India (per caput consumption is up to 75 kg per year).

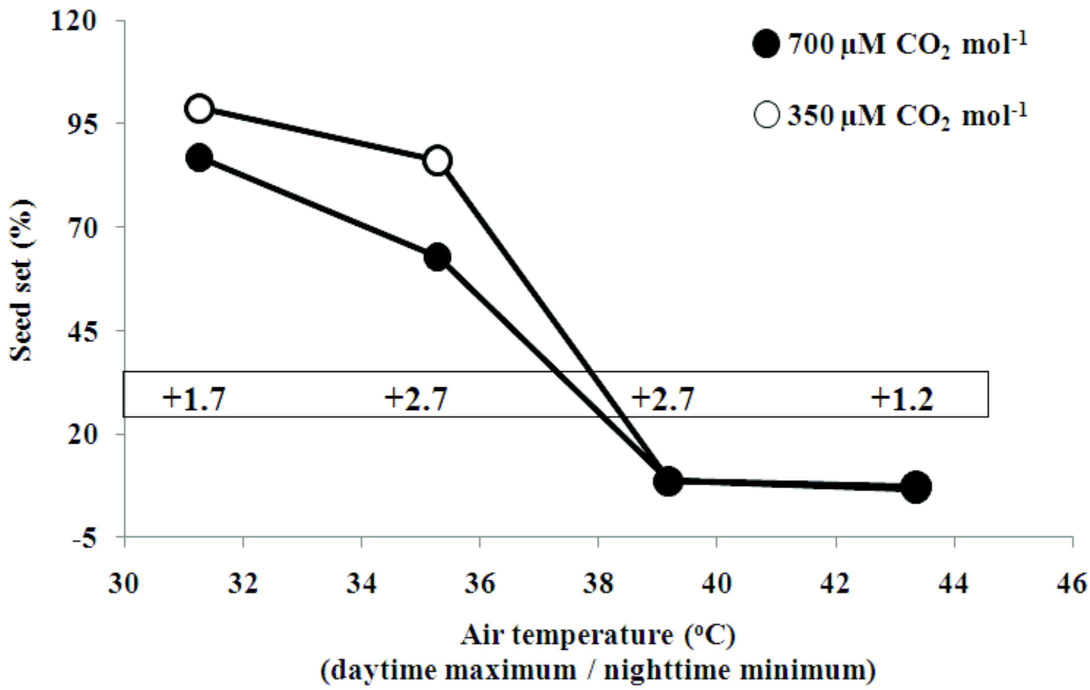
Grain use for animal feed has been a dynamic element in the stimulation of global sorghum consumption. The demand for sorghum for feed purposes has been the main driving force in raising global production and international trade since the early 1960s. The demand is heavily concentrated in the developed countries, where animal feed accounts for about 97 percent of total use, and in some higher-income developing countries, especially in Latin America where 80 percent of all sorghum is utilized as animal feed. The United States, Mexico and Japan are the main consuming countries, followed by Argentina, the former Soviet Union and Venezuela. These countries together account for over 80 percent of world use of sorghum as animal feed

Biological vulnerability to climate change

Sorghum is one of the major rainfed crops for food and fodder in tropics and subtropics of the world. These regions are already towards the higher side of the tolerant range of temperature. Thus, a small change in climate could reduce the production of the crop drastically.

Optimum temperature for reproductive growth of sorghum plants is 25 to 28 °C (Maiti 1996). High temperature (HT) stress during reproductive processes can affect the crop substantially as the reproductive processes are more sensitive to HT stress compared to vegetative processes of development (Downes 1972, Craufurd et al. 1998, Hammer and Broad 2003, Prasad et al. 2006). Growth temperatures of 40/30 °C (day/night) delay panicle exsertion by about 30 days, while panicle exsertion is completely inhibited at growth temperature of 44/34 °C (Prasad et al. 2006). As temperature increases from 32/22 to 36/26 °C, panicle length and panicle diameter decreases significantly. Beyond 36/26 °C, panicle length and panicle diameter decreases linearly. High temperatures (33/28 °C) at later stages of panicle development and at flowering induce floret and early embryo abortion, which result in lower grain yield compared to 27/22 °C (Downes 1972). Pollen viability decreases above 36/26 °C (Prasad et al. 2006). Increases in temperature from 32/22 to 36/26 °C decrease pollen germination by 26% at ambient CO_2 (350µmol mol^{-1}) and by 48% at elevated CO_2 (700µmol mol^{-1}) whereas, at elevated CO_2 pollen germination decreases by 9% at 32/22 °C and 36% at 36/26 °C (Prasad et al. 2006, see Figure 2.19.1). Prasad et al. (2008) suggested that the preflowering phase (10 d before flowering) is highly sensitive to HT stress (40/30 °C) as the phase coincides with microsporogenesis. The effect of temperature, CO_2 and their interaction were found to be significant on pollen germination.

Figure 2.19.1. Effect of temperature on seed-set in sorghum at two levels of CO_2. The difference in tissue temperature between ambient and high CO_2 is also shown.



Redrawn from Prasad et al., 2006.

Increase in temperature from 25 to 33.5 °C increases the rate of seed growth, which decreases both seed size and seed yield (Chaudhury and Wardlaw 1978). Similarly, Kiniry and Musser (1988) also reported increased grain growth rate and reduced grain filling duration from 22.5 to 30 °C, which resulted in lower yields.

A simulation study from India reported the sensitivity of increasing temperature and impact of the A2a emissions scenario and HADCM3 global climate model outputs for 2020, 2050 and 2080 compared to the baseline conditions (1961–1990) (Srivastava et al. 2010). The study found that a 1 °C increase in average air temperature could decrease the yield of sorghum from 4 to 8% in the rainy season in sorghum-growing regions of India. Winter sorghum suffered yield losses of 8–15% with a 2 °C rise in temperature. Results of the simulations using the A2a scenario and the HADCM3 global climate model for 2020, 2050 and 2080 indicated yield decreases of 3–76% for the rainy season and 7–32% for the winter crop (Srivastava et al. 2010).

Mastrorilli et al. (1995) observed the impact of water stress at critical stages of sorghum and reported that water stress at flowering reduces seed numbers significantly per paniculum and also reduces grain yield compared to the plants in well-watered conditions, while water stress at seed setting and seed ripening does not show any significant difference. Water stress at flowering reduces final biomass by 52%, number of seed per panicle by 58%, and grain yield by 61%.

Simulated changes in yields of sorghum are presented in Table 2.19.2 where yields of the crop in 2000 are compared to 2050 with climate change and without climate change (without CO_2 fertilization in both the conditions). Two climate change models, the CSIRO (Commonwealth Scientific and Industrial Research Organization, Australia) model and the NCAR (National Center for Atmospheric Research, US) model for 2050 were used to simulated yield impacts. Both the scenarios project increase in temperature and precipitation by 2050. Yields of sorghum are projected to increase by 106% by 2050 globally in the 'no climate change' situation. Sorghum showed a global decline in yield in both the climate change scenarios. Increases in yields of both model runs in some regions were not large enough to compensate for the global yield reduction.

Table 2.19.2. Simulated impact of climate change on sorghum production

Crops/Scenarios	South Asia	East Asia	Europe And Central Asia	Latin America And The Caribbean	Middle east and north Africa	Sub-Saharan Africa	Developed countries	Developing countries	World
2000 (mmt)	8.4	3.1	0.1	11.4	1.0	19.0	16.9	43.0	59.9
2050 No CC (mmt)	9.6	3.4	0.4	28.0	1.1	60.1	20.9	102.6	123.5
2050 no CC (% change)	13.9	11.6	180.9	145.3	12.2	216.9	23.6	138.7	106.2
CSIRO (% change)	-19.6	1.4	-2.7	2.3	0.3	-2.3	-3.1	-2.5	-2.6
NCAR (% change)	-12.2	6.7	-10.4	4.3	0.7	-3.0	-7.3	-1.5	-2.5

Source: Nelson et al., 2009

Socioeconomic vulnerability to climate change

Sorghum, like millet, groundnut and pigeonpea, is typically part of mixed cropping systems in the Semi-Arid Tropics (SAT) and it is rarely grown as a monocrop over large areas. There is little information available as to how changes in the production and productivity of sorghum may affect households in the SAT.

The SAT contains about 160 million rural poor, of whom 100 are in India. Poverty is declining in rural India, but not elsewhere. Rural households are predominantly net buyers of food, so any reduction in production and/or increases in price affect them proportionately more, women headed households especially (Walker 2010). In India the sorghum, millet, groundnut and pigeonpea area now accounts for about 30% of the cropped area and about 20% of the value of production, so the net effects on vulnerability in India as a whole are less than 50 years ago (Walker 2010). In India agriculture still accounts for about 40% of per capita income in rural areas, and in the SAT of sub-Saharan Africa, it will account for considerably more than this. Most rural households are still substantially reliant on rainfed agriculture for their livelihoods, and their resilience is generally low.

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