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Production potential of *Sorghum bicolor* (L.) Moench crop in the Brazilian semiarid: review

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Abstract. Sorghum is a crop that has high adaptability to adverse edaphoclimatic conditions, maintaining a high productive performance, serving as a food source for animal humans, as well as raw material for ethanol production. In the semi-arid region, this crop is even more important, especially as an alternative in complementing the food diet, mainly animal, bringing cost reduction in the livestock sector, and favorably contributes to the balance of grain regulatory stocks and promoting balance in production. Thus, contributing to the sustainable growth of livestock in this region. However, evidence indicates a reduction in planted area in recent harvests due to an evident reduction in sorghum crop production performance under the edaphoclimatic conditions of that region, discouraging large-scale production. In this context, overcoming these obstacles has been the use of cultivars adapted to the edaphoclimatic conditions of these regions, as well as some modifications in crop planning and crop management. This review aimed to explore the general characteristics, classification of sorghum types, socioeconomic importance, ecophysiology, edaphology, phytosanitary agents and yield potential of sorghum cultivars currently available for cultivation in the Brazilian semiarid region. Sorghum cultivation in Brazil has shown a high productive potential, not only for its adaptive ability in different environmental conditions, but for its ease of mechanization from sowing to harvest.

Keywords: adaptability, diet, sorghum

Potencial produtivo da cultura do *Sorghum bicolor* (L.) Moench no semiárido brasileiro: revisão

Resumo. O sorgo é uma cultura que apresenta elevada capacidade de adaptação a condições edafoclimáticas adversas, mantendo um alto desempenho produtivo, servindo como fonte alimentar para humanos e animais, assim como matéria prima para a produção de etanol. Na região do semiárido, esta cultura tem uma importância ainda maior, sobretudo como alternativa na complementação da dieta alimentar, principalmente animal, trazendo redução de custos no setor pecuário, além de contribuir favoravelmente

para o equilíbrio dos estoques reguladores de grãos e promovendo equilíbrio na produção de volumosos, contribuindo assim para o crescimento sustentável da pecuária nessa região. No entanto, evidências indicam uma redução na área plantada nas últimas safras devido a uma diminuição do desempenho produtivo da cultura do sorgo nas condições edafoclimáticas da região, desestimulando a sua produção em grande escala. Nesse contexto, a superação destes obstáculos tem sido a utilização de cultivares adaptadas às condições edafoclimáticas dessas regiões, bem como algumas modificações no planejamento do cultivo e no manejo da cultura. Esta revisão objetivou explorar as características gerais, classificação dos tipos de sorgo, importância socioeconômica, ecofisiologia, edafologia, agentes fitossanitários e potencial produtivo de cultivares de sorgo atualmente disponível para cultivo na região Semiárida brasileira. A cultura do sorgo no Brasil vem mostrando um alto potencial produtivo, não só pela sua habilidade adaptativa em diferentes condições ambientais, mas pela sua facilidade de mecanização desde semeadura a colheita.

Palavras-chave: capacidade de adaptação, dieta alimentar, sorgo

Potencial productivo del cultivo de Sorghum bicolor (L.) Moench en el Semiárido brasileño: revisión

Resumen. El sorgo es un cultivo que tiene una alta adaptabilidad a condiciones edafoclimáticas adversas, mantiene un alto rendimiento productivo, sirve como fuente de alimento para humanos y animales, así como materia prima para la producción de etanol. En la región semiárida, este cultivo es aún más importante, especialmente como una alternativa para complementar la dieta alimentaria, principalmente animal, reduciendo los costos en el sector ganadero y contribuyendo favorablemente al equilibrio de las existencias reguladoras de granos y promoviendo el equilibrio en la producción de fibrosos, contribuyendo así al crecimiento sostenible del ganado en esta región. Sin embargo, la evidencia indica una reducción en el área plantada en las cosechas recientes debido a un descenso en el rendimiento de la producción de cultivos de sorgo en las condiciones edafoclimáticas da región, lo que desalienta la producción a gran escala. En este contexto, la superación de estos obstáculos ha sido el uso de cultivares adaptados a las condiciones edafoclimáticas de estas regiones, así como algunas modificaciones en la planificación y gestión de cultivos. Esta revisión tuvo como objetivo explorar las características generales, la clasificación de los tipos de sorgo, la importancia socioeconómica, la ecofisiología, la edafología, los agentes fitosanitarios y el potencial de rendimiento de los cultivares de sorgo actualmente disponibles para el cultivo en la región semiárida brasileña. El cultivo de sorgo en Brasil ha demostrado un alto potencial productivo, no solo por su capacidad de adaptación en diferentes condiciones ambientales, sino por su facilidad de mecanización desde la siembra hasta la cosecha.

Palabra clave: adaptabilidad, dieta, sorgo

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is currently considered the fifth most important cereal in the world, followed by wheat, corn, rice and barley (Luna et al., 2018). The production of this crop in Brazil has intensified since the 1970s, and presently, as the largest producers of this grain, in decreasing order, the states of Goiás, Minas Gerais, Mato Grosso, Bahia and São Paulo, states where concentrate 89% of the grain sorghum production in the country. According to the follow-up of the Brazilian harvest (17/18 harvest), 34.3% of national production is concentrated in the state of Minas Gerais, with 210.4 thousand hectares planted, producing 732.8 thousand tons of grain, resulting in an average yield of 3,483 kg ha⁻¹ of grain (CONAB, 2018).

Sorghum can adapt to various environments, especially under water deficiency conditions. Due to this characteristic, the crop is an “extraordinary energy factory” of great utility in crop regions with irregular rainfall distribution and high air temperature (Almeida Filho et al., 2014; Griebel et al., 2019). According to

[Buso et al. \(2011\)](#) and [Vanamala et al. \(2018\)](#), sorghum is indicated as a high potential crop for use in salinized semiarid areas, due, among other things, to its tolerance to water stress through osmotic adjustments, maintaining a high energy value in its grains and, consequently, in animal feed, thus being more adapted to the environmental conditions of the semiarid than other crops, such as maize, for example.

S. bicolor presents itself as a promising alternative to complement the food supply reducing costs for food, allowing greater competitiveness to the sector. In addition, it contributes directly to the balance of energy grain regulatory stocks and is also indicated for boosting the production of roughage and consequently promoting the sustainable growth of livestock ([Alves et al., 2012](#); [Avelino et al., 2011](#); [Griebel et al., 2019](#)).

Under favorable conditions in summer and in succession plantations, the yield potential of sorghum grains can exceed 10 t ha^{-1} , so, since it presents a rustic plant, this characteristic spread its cultivation in several regions, notably in the semiarid. [Biesdorf et al. \(2018\)](#), as well as [Almeida Filho et al. \(2014\)](#) show that sorghum grown not only in the semi-arid region, but in almost all of Brazil, especially in the second crop, is made with low investment in fertilization, due to the concept established among producers that sorghum cultivation does not require larger amounts management care because it would be a plant that, due to its characteristic of rusticity, produces well under any circumstances, which understanding can lead to improper management, bringing risks to production, reducing the productive potential of the crop. In other words, in the semi-arid region, sorghum has been cultivated inappropriately, under conditions that do not allow the expression of its full genetic potential. Consequently, the discouragement of its cultivation in some regions is notorious due to the low yields achieved, evidenced by the average productivity in Brazilian crops, which is around 2.4 t ha^{-1} annually.

Thus, it is noteworthy that for the successful expansion of the crop and the increase of grain supply, besides the revision of the concepts of sorghum rusticity by the producers, it is necessary to use cultivars adapted to the semiarid production and cultivation systems ([Almeida Filho et al., 2014](#)).

In view of the above, this review aimed to explore the general characteristics, classification of sorghum types, socioeconomic importance, ecophysiology, edaphology, phytosanitary agents and productive potential of sorghum cultivars in the Brazilian semiarid region.

General characteristics of *Sorghum bicolor* (L.) Moench

Sorghum is a crop belonging to the Poaceae family, Panicoideae subfamily, Paniceae tribe, Sorghum genus, *Sorghum bicolor* species ([Figure 1](#)). The Sorghum genus is very broad and polymorphous giving it a great diversity of species, which are widespread in Africa and Asia. The origin of the species is still uncertain, and there are reports that the species originated in Africa.

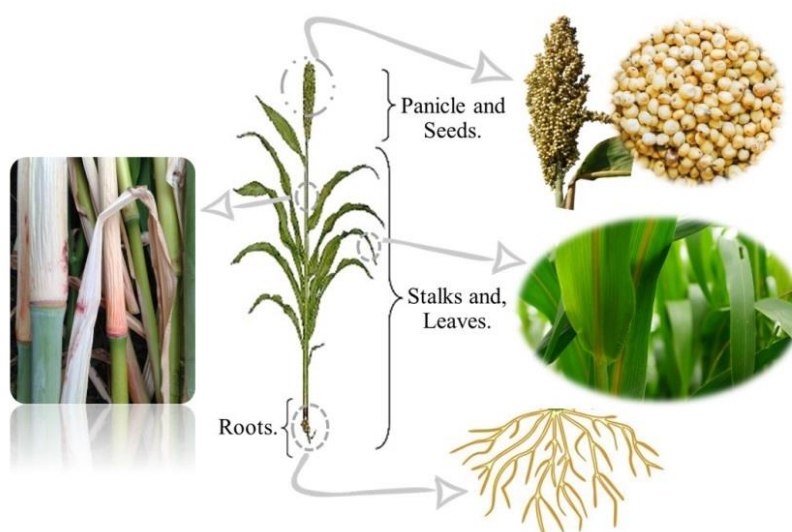


Figure 1. Representation of the vegetative and reproductive structures of sorghum (*Sorghum bicolor*) crop. Adapted from [Jafari et al. \(2017\)](#).

On the other hand, it is assumed that cultivated sorghum originated in Ethiopia or Sudan due to the great diversity of these sites. There are indications that people near the Niger River could have domesticated and there is archaeological evidence in Ethiopia of domestication around the year 3000 BC (Dar et al., 2018; Fornasieiri Filho & Fornasieiri, 2009).

The root system of the species consists of silica in the endodermis, high pericyclic lignification rates and large amount of absorbent hair. The stem is divided into nodes and internodes (internodes) presenting leaves throughout the plant, its inflorescence is panicle type and its fruit is caryopsis or dry grain, characteristic of grasses. The plants can reach 1 to 4 meters in height, their ear is of the fertile sessile type, accompanied by two pedunculate sterile spikelets that characterize the genus (Dar et al., 2018; Fornasieiri Filho & Fornasieiri, 2009).

Silva et al. (2017) aiming at verifying the morpho agronomic characteristics that could be used as selection criteria for high yield and early sorghum strains, observed the morpho agronomic characteristics according to the minimum sorghum descriptors proposed by the Ministry of Agriculture, Livestock and Supply, Brasil (1997) and noted a significant effect ($P < 0.01$) for all characteristics evaluated, allowing to infer the existence of genetic variability in the population (Table 1).

Table 1. Summary of the joint analysis of variance for the traits evaluated in 160 grain sorghum in Sete Lagoas, 2015. Adapted from Silva et al. (2017).

Trait	Cve (%)	CVg (%)	CVt	h2 (%)	Mean	P value
WL	18.88	11.62	0.78	54.93	7.07	<0.01
LL	8.66	9.36	1.08	70.02	60.56	<0.01
SEP	45.13	33.64	0.75	52.64	9.52	<0.01
SD	19.36	13.17	0.68	48.06	18.11	<0.01
SQ	36.76	21.21	0.58	39.96	8.78	<0.01
LMPR	24.44	12.44	0.97	65.37	7.06	<0.01
LPBP	29.81	19.13	0.78	55.07	2.48	<0.01
ANT	35.98	18.16	0.61	42.61	2.34	<0.01
HELM	31.71	28.71	0.8	56	1.19	<0.01
RUS	33.85	22.4	0.66	46.68	1.84	<0.01
PH	6.39	26.53	4.15	97.18	109.35	<0.01
FLO	6.66	5.54	0.83	58.05	75.95	<0.01
STA	21.12	16.82	0.8	55.94	32.42	<0.01
MOIG	10.09	6.57	0.65	45.87	12.56	<0.01
PW	56.64	47.7	0.84	58.65	854.83	<0.01
YIE	41.14	54.28	1.32	77.69	2757.95	<0.01
WTG	24.24	14.77	0.61	42.62	17.01	<0.01
PHI	19.97	18.8	0.94	63.94	0.56	<0.01

WL: width of the third leaf blade from the flag leaf; LF: length of the third leaf blade from the flag leaf; SEP: shape and extension of the peduncle; SD: stem diameter; SQ: stem quality; LMPR: length of the main panicle rachis; LPBP: length of the primary branch of the panicle; ANT: anthracnose (*Colletotrichum sublineolum*); HEL: helminthosporiosis (*Exserohilum turcicum*); RUS: rust (*Puccinia purpurea*); PH: plant height; FLO: flowering; STA: number of plants per experimental plot; MOIG: moisture of grains; PW: panicle weight; YIE: grain yield; WTG: weight of thousand grains; PHI: panicle harvest index; Cve: experimental coefficient; CVg: coefficient of genetic variation; and, CVr: relative coefficient of variation.

In order to clarify the phenotypic interrelationships between the various morpho agronomic characteristics evaluated Karla et al. (2017) used two-dimensional correlation network to detect complex phenotypic patterns, difficult to evaluate with other techniques (Figure 2). In the correlation network, significant correlation values by the t-test were highlighted with bold edges, where negative correlations were expressed in red lines and positive correlations in green lines.

The efficiency of this innovative technique was reported by Ursem et al. (2008), DiLeo et al. (2011) and Silva et al. (2016), showing that sorghum plants susceptible to diseases such as helminthosporium and anthracnose reduced the photosynthetic leaf area and, consequently, the life cycle of the sorghum genotypes studied.

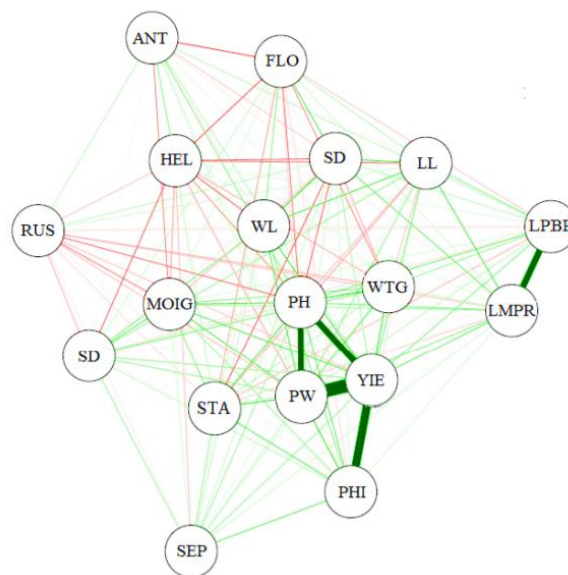


Figure 2. Phenotypic correlation network among traits evaluated in 160 grain sorghum lines.

Classification of types of sorghum

Sorghum species are classified into five groups: graniferous; fodder for silage and/or saccharin; forage for grazing/cutting; green/hay/mulch, broom sorghum and biomass sorghum.

The graniferous type is the one with the highest economic expression, being one of the most important cereals in the world, being suitable for human and animal food ([Richards & Hicks, 2007](#)). In terms of production, it has a small size, with a maximum height of 1.7 m, with compact grain panicle at the upper end, these characteristics give it adaptation to mechanical harvesting ([EMBRAPA, 2009](#); [IPA, 2015](#)).

The group of sorghum is widely cultivated in the United States, replacing sugar as a sweetener, in industries, besides being used in the production of alcohol; its main purpose in the country is the production of syrup. reach a height of over 2.0 m, with a sweet and succulent stem resembling that of sugarcane, the panicle is opened, and with a grain yield of approximately 2.5 t ha⁻¹ ([Silva et al., 2019](#); [Teixeira et al., 2017](#)) ([Figure 3](#)).

In the Northeast, it can be used as fodder sorghum in the form of silage and cut ([Whitfield et al., 2012](#)) as well as an alternative source of renewable energy as the generation and consumption of renewable energy accounts for 41% of the total Brazilian energy matrix ([Ministry of Mines and Energy, 2016](#)).

In this context, saccharin sorghum is an ideal option to increase bioenergy production and reduce idleness of industries during the sugar cane off-season. Saccharin sorghum is a C4 plant and has high biomass production, which reinforces its viability for the use of bioenergy. It has a short cycle (about 120 days) and its stems are juicy and have fermentable sugars, allowing ethanol production ([Regassa & Wortmann, 2014](#)).

According to [EMBRAPA \(2009\)](#) and [IPA \(2015\)](#) the forage type can become a major crop for the livestock sector, due to its characteristics associated with its high production potential, good adaptation to mechanization, recognized qualification as a source of energy for the animal, great versatility (i.e., for hay, silage and direct grazing) and adaptation to drier regions such as Agreste and Sertão de Pernambuco. It is tall, over 2.0 m high, with many leaves, open panicles and few seeds.

According to [Calviño & Messing \(2012\)](#) forage sorghum can regenerate, that is, after the harvest of the first crop, the plant keeps its root system alive, which enables regeneration when there are ideal conditions for its development. Thus, regrowth can also be used to produce biomass, which can reduce planting costs and, consequently, the final cost per unit of biomass produced as well as environmental gain.

Sorghum broom has large size, with generally thin stalks and panicles with special characteristics in the form of broom, for this reason, is widely used in the manufacture of brooms and brushes, with high expression for the region of Rio Grande do Sul ([EMBRAPA, 2009](#); [IPA, 2015](#)).

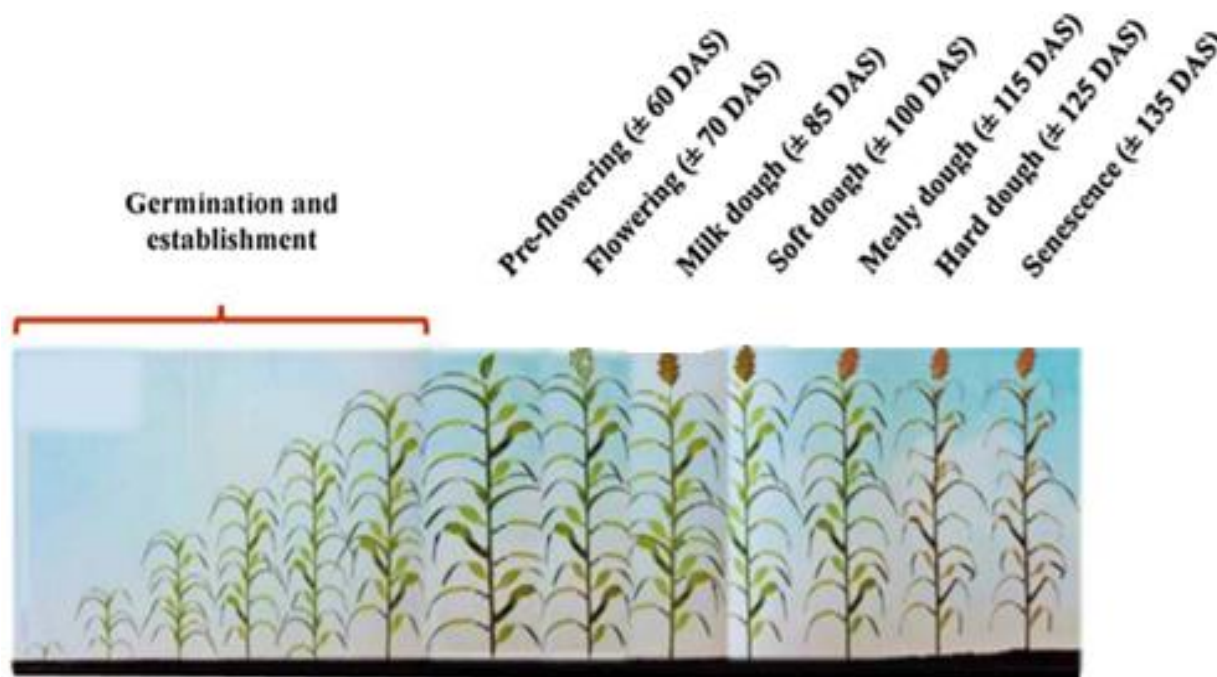


Figure 3. Phenological stage of saccharin sorghum. Adapted from [Teixeira et al. \(2017\)](#).

Among the types of sorghum with energetic characteristics, it is possible to mention besides the saccharin sorghum, the biomass sorghum. While as a sucrose saccharin sorghum is mainly used in the production of first-generation ethanol, given the high concentration of sucrose in its stem, biomass sorghum is generally used for direct burning and bioelectricity generation due to its high lignin content and good performance in combustion processes ([May et al., 2013](#)).

When compared to other bioenergy crops, sorghum biomass stands out for its short cycle and high potential for dry matter production. Eucalyptus, for example, the most common plant in Brazil for pulp and charcoal production, produces up to 20 t ha⁻¹ of dry biomass per year on average; however, it takes five years to reach an appropriate size for the cut ([Silva et al. \(2017\)](#)). On the other hand, the biomass sorghum cultivars evaluated in this study produced an average of 40 t ha⁻¹ dry mass in approximately five months. Therefore, [Pimentel et al. \(2017\)](#) reveals that in view of the high levels of productivity achieved, biomass sorghum cultivars are a promising alternative in the supply of raw materials for the bioenergy sector. This biomass can be used for direct burning in steam generation (energy production) and/or in animal feed production, papermaking and hydrolysis for alcohol generation, among others. Also, according to these authors, cultivar BD 7607 (sorghum biomass) had the highest total dry mass production (43 t ha⁻¹), being significantly higher than the others, while cultivar BRS 655 had the lowest yield: 16 t ha⁻¹. [Batista et al. \(2018\)](#) evaluating the yield potential of three sorghum agronomic groups (biomass sorghum, saccharin sorghum and forage sorghum) in two cutting seasons (crop and regrowth) concluded that the biomass sorghum cultivars (BD 7607 and BRS 716) production potential and potential characteristics for use in direct combustion and energy cogeneration, however, in regrowth, there was a significant reduction in the total biomass produced by cultivars, especially for long cycle materials, showing that the use of regrowth is not particularly advantageous for biomass sorghum long cycle materials (Figure 4).

In addition, they observed a 94% reduction in biomass production in sorghum biomass in regrowth and 87% reduction in biomass production in forage sorghum regrowth (BD 5404 and BD 1615, respectively) and a 75% reduction in biomass production in regrowth of forage sorghum for cultivars BRS 511 and BRS 655, indicating that these would be the materials that most effectively maintain their biomass yields in a second cut.

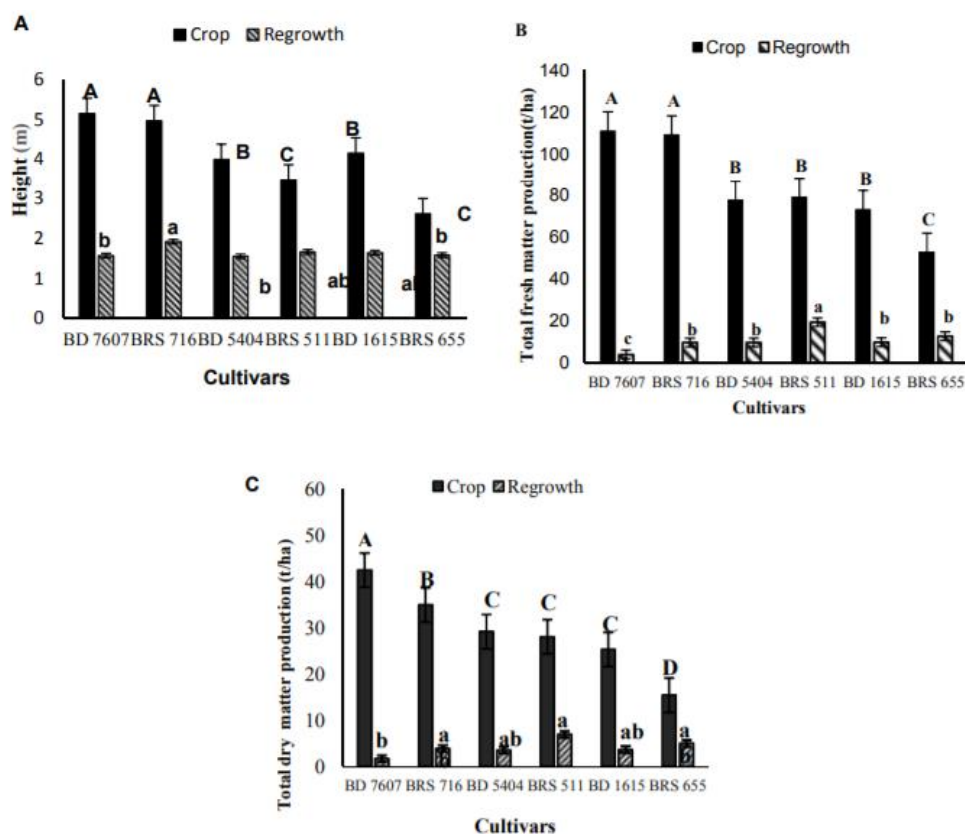


Figure 4. Effect of cutting season on cultivars: (A) plant height; (B) production of fresh matter; (C) production of dry mass. Followed by the same capital letter in the crop and the same lowercase letter in the regrowth do not differ by the test of F at the levels of 1 and 5%, respectively. Coimbra-MG, Brazil, 2015. Adapted from Batista et al. (2018).

Socio-economic importance

Sorghum is a grass originating from the arid and semi-arid regions of Africa and part of Asia and was first brought to the Americas in the 1950s. In developed countries sorghum is primarily used as animal feed, while in developing countries, is intended for human consumption. It is the main source of food in much of the countries of Africa, South Asia, and Central America and an important component of animal nutrition in the United States, Australia, and South America ([Fornasieiri Filho & Fornasieiri, 2009](#); [Ribas, 2008](#)).

The modern sorghum plant is increasingly taking on a role of extreme economic importance in the country, as the meat agro-industry is increasingly interested in increasing sorghum consumption in monogastric diets. It is even estimated that sorghum grain production could rise to five million tonnes this decade without the risk of oversupply. Since 2005, Brazil has already started to export this cereal with good financial results ([Ribas, 2008](#)). In the biofuel production sector, in countries such as China, India, USA, Iran, Italy, Spain, among others, the sorghum has been highlighting as a relevant raw material option for ethanol production, leading to the development of several research projects research with this crop in these countries ([Almodares et al., 2008](#)).

According to [Barros et al. \(2017\)](#) the replacement of varieties or species of crops with higher water demand, such as corn (*Zea mays* L.), with those with relatively low water demand, such as sorghum, are potential solutions in regions with a higher probability of rainfall deficit, as the Brazilian semiarid. However, these strategies do not guarantee a satisfactory emergence and initial development of seedlings in case of water deficit, as there are environmental and genetic limits in low water soil conditions. That is, there is a need for greater attention to the initial emergence of sorghum plants, especially in the semiarid region, and new technologies are needed to optimize the efficiency of water use in the development phase of rain fed seedlings. [Barros et al. \(2017\)](#) evaluating the effect of the application of superabsorbent polymers as seed coating or applied in the planting grooves, on the initial development of sorghum seedlings under water deficit conditions concluded that the use of this

strategy in sorghum seeds improves the vegetative development of the sorghum seeds seedlings and the survival rate with water deficit but conditioned this success primarily on an endogenous crop reduction in mortality and low natural emergence ([Figure 5](#)).

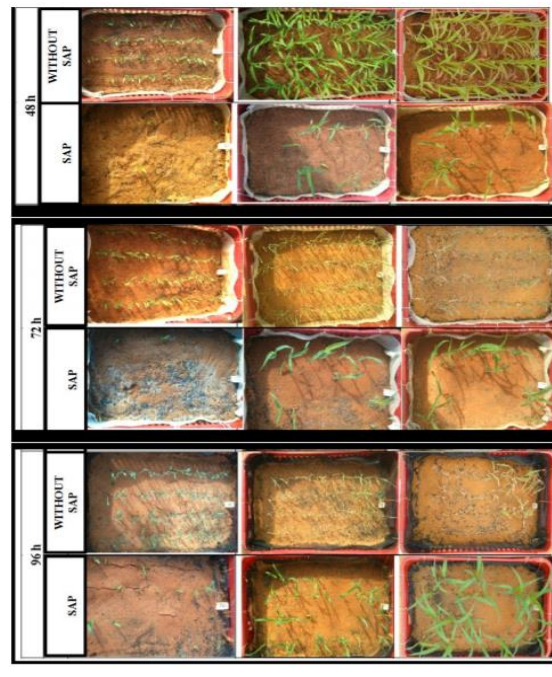


Figure 5. Sorghum seedlings at 8, 16 and 26 days after sowing (DAS) as a function of superabsorbent polymer (SAP) coating and intervals between irrigations (48, 72 and 96 hours).

Saccharin sorghum is grown in 99 countries, covering an area of 44 million hectares, mainly in low fertility and semi-arid areas ([Sakellariou-Makrantonaki et al., 2007](#)). In addition, various food products and derivatives are produced with this crop ([Figure 6](#)).

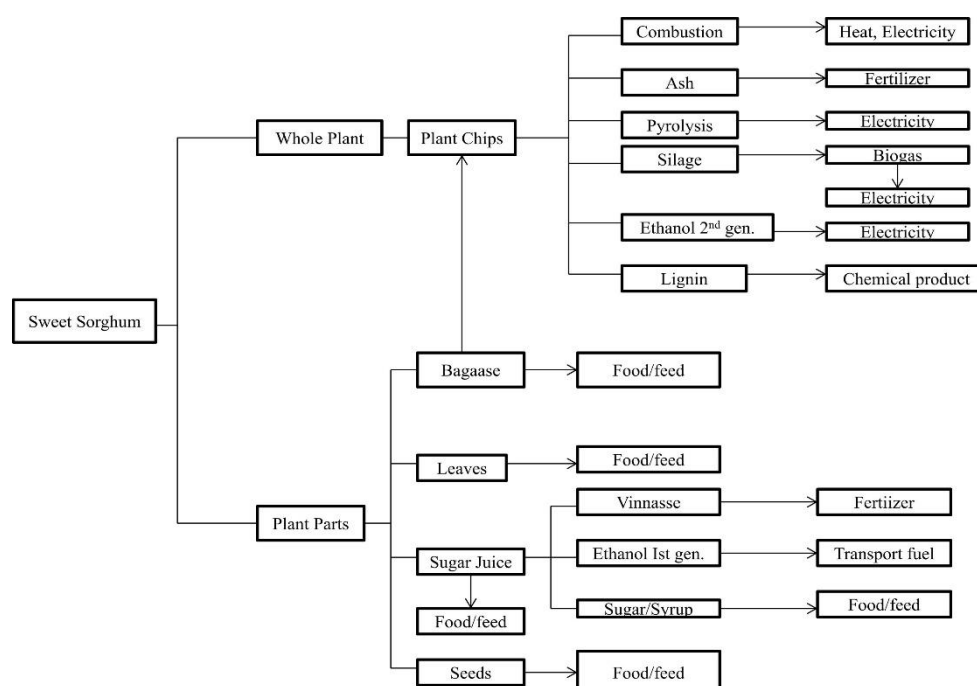


Figure 6. Flowchart of different uses and processing for the crop of saccharin sorghum (*Sorghum bicolor*). Adapted from [Dar et al. \(2018\)](#).

Ecophysiology

S. bicolor is a crop that presents C4 metabolism, short-day photoperiodic response and high photosynthetic rates ([EMBRAPA, 2019](#)). During the cycle, the growth rate of the sorghum plant depends on both the leaf area expansion rate and the photosynthetic rate per unit leaf area. Depending on the genetic material, physiologically active light intensity and leaf age, sorghum photosynthesis rates range from 30 to 100 mg CO₂ dm⁻² h⁻¹.

For genotypes adapted from sorghum and saccharin sorghum the total number of leaves in a plant ranges from 7 to 14 and can generally range from 7 to 30 leaves between groups. Sorghum stomata are smaller compared to other plants with C4 metabolism (e.g., maize), but it is estimated that sorghum leaves have 50% more stomata per unit area than maize plant ([Magalhães et al., 2009](#)).

Plant height and stem diameter characteristics are directly related to the production of green mass for saccharin sorghum cultivars, and these characteristics are highly influenced by the environmental conditions and management practices adopted ([May et al., 2013](#)).

Edaphology

According to [Aquino \(2005a\)](#), there are some particularities with regard to sorghum edaphology, being indicated for regions that present unfavorable water regime with rainfall ranging from 400 to 600 mm per year or even less. To achieve the desired success in yields, the cereal requires hot days and nights, with average air temperatures above 25° C, reaching maturity between 90 to 140 days.

Regarding the influence of air temperature on sorghum productivity, [Ribas & Machado \(2010\)](#), point out that, the average annual temperature of 18° C is considered as the lower limit for sorghum production, also based on the need for the temperature exceeds 18 °C on a daily average during the flowering phase. Thus, the ideal and favorable conditions for the establishment of the crop as a function of air temperature should vary between 26 and 30° C.

Regarding soil characteristics, sorghum can be satisfactorily cultivated in soils ranging from loamy to slightly sandy, being considered tolerant to various conditions. Although it can adapt to sandy and low fertility soils, the cereal grows best in well-prepared soils, with pH between 5.5 and 6.5, rich in organic matter (MO) and without excess moisture ([Landau & Sans, 2009](#)).

Plant pathogens

According to [EMBRAPA \(2009\)](#) even with all their productivity and performance under various conditions to which they are exposed, sorghum species and cultivars need care when they are sent to the field, care mainly taken by the producer, who needs be alert to the occurrence of pests and diseases from sorghum implantation to postharvest, since in this time interval between sowing and harvesting, there are numerous species of pathogens and insects that can be associated with the crop, and cause damage that will be expressed in economic damage.

Thus, there is a need on the part of the producer to periodically monitor the crop so that when registering and identifying harmful species in the production area can be adopted control measures. In addition to the identification and control of organisms harmful to the crop in the area, the plant should also be evaluated for vigor, susceptibility of the species or cultivar, soil moisture, developmental stage, abundance of natural enemies in the implanted area, among others aspects that are extremely important ([EMBRAPA, 2009](#)).

According to [EMBRAPA \(2010\)](#) there is a great diversity of pest organisms that plague sorghum crop, the most common are soil pests such as elasm caterpillar (*Elasmopalpus lignosellus*), screw caterpillar (*Agrothis ipsylon*) and ants. Other pests and diseases vary according to the specific parts of the plant and may present representatives that attack from roots, seeds and seedlings as well as products after harvest in storage. In the aerial part, stands out the cartridge caterpillar (*Spodoptera frugiperda*). Two aphid species also attack sorghum, namely the maize aphid (*Rhopalosiphum maidis*) and the green or wheat aphid (*Schizaphis graminum*), where the green aphid is of major economic importance. Another important pest is also sorghum flies, where they lay their eggs inside the flowers, and the larvae, when hatched, feed on the grains that are in the process of forming, resulting in hatching panicles and decreased production.

Among the main diseases that attack sorghum in Brazil are: seed rot and seedling diseases caused by anthracnose or sugar disease (Ergot), which can affect germination, early development and reduce stand; leaf diseases such as anthracnose, rust, sugarcane mosaic virus, sorghum mildew is of great importance for crop. It may also have stem diseases such as red stem rot and root diseases caused by nematodes and phytopathogenic fungi such as *Rhizoctonia solani*, *Rhizopus* spp., *Pythium aphanidermatum*, *Sclerotium rolfsii* ([EMBRAPA, 2010](#)).

Productive potential in the semiarid region

The use of sorghum for silage is justified by its satisfactory agronomic characteristics. Its main differentials consist of large forage production, high tolerance to water deficit and high air temperatures, ability to exploit a larger volume of soil, as it has an abundant and deep root system. Another very positive feature is the possibility of cultivating regrowth, with yields that can reach 60% of their potential in the first cut when properly managed ([Rosa et al., 2004](#)).

Due to the dense root structure, sorghum is able to decompress the soil and move nutrients in different layers, being considered an important crop for biomass production in no-tillage and crop rotation system ([Landau & Sans, 2009](#)) provided better crop yields. This forage plant has high levels of soluble carbohydrates and crude protein in some varieties ([Oliveira et al., 2006](#)).

Works developed by [Parrella et al. \(2010\)](#) reported that it was evaluated the performance of 25 cultivars of sorghum in different environments, aiming at ethanol production and concluded that it is possible to produce between 40 and 70 liters of biofuel per ton of biomass. Thus, based on current prices, it becomes feasible to use saccharin sorghum to produce ethanol (C₂H₅OH) in cogeneration plants.

Through genetic improvement of cultivars, sorghum has the potential to produce 80 t ha⁻¹ of biomass, 5,500 L ha⁻¹ of 1st generation ethanol and 3,000 L ha⁻¹ of 2nd generation ethanol (cellulosic ethanol). Satisfactory results such as these reinforce the idea that saccharin sorghum is an important alternative to complement sugarcane in ethanol production and thus collaborate to optimize the use of machinery, equipment and labor in the sugarcane industry. In addition to contributing to increasing the efficiency of the plants and reducing production costs ([Miranda et al., 2012](#)).

The same structure for sugarcane harvesting, milling and processing can be used in analogous processes for sorghum. Bagasse, as a byproduct, could be used for electricity cogeneration, second generation ethanol production and animal fodder, contributing to a positive energy balance. That is, sorghum is a complementary alternative to the sugar-energy industries, allowing the plants to operate all year round. During the off-season sugar cane sorghum provides raw material for industries, which increases working days, optimizes mill operation and amortizes fixed costs ([Parrella et al., 2014](#)).

Due to the exposed characteristics of forage sorghum, for the implantation of the crop it should be observed which variety expresses the best adaptation to the conditions that will be imposed to it to obtain better yields, being able to surpass 60 t ha⁻¹ of green mass in the summer plantations. The yield potential of sorghum grains normally exceeds 10 t ha⁻¹ under favorable summer conditions and 7.0 t ha⁻¹ under favorable second crop conditions ([Coelho et al., 2002](#)).

Final considerations

Sorghum cultivation in Brazil has been showing a high productive potential, not only for its adaptive ability in different environmental conditions, but also for its ease of mechanization from sowing to harvest, but also for presenting a wide range of sowing times and continuous production throughout provided that favorable conditions are available. For its productive value, and for presenting energy biomass content for satisfactory biodiesel production, its cultivation should be more valued and encouraging in all regions of the country.

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