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Bibliographic Review

Genetic improvement and quality parameters of sorghum silage (*Sorghum bicolor* L. Moench) in relation to maize silage (*Zea mays* L.)

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Abstract

The aim of this review was to report studies on genetic improvement of sorghum (*Sorghum bicolor* L. Moench), intended for obtaining genotypes with better forage characteristics for silage production. Among the forages destined to silage production, the sorghum constitutes a good alternative, with production superior to 20 t ha^{-1} of dry biomass. The main advantage of using sorghum is the possibility of producing higher biomass volume and better quality silage, with digestible fibers of great animal consumption and performance, in areas where cultivation restrictions for maize and others forages are risky and/or impossible. One of the limitations of using sorghum on animal nutrition is the tannin concentration in the grain, relating negatively with dry mass digestibility. By means of genetic improvement, such situation, through the knowledge of genetic inheritance of this characteristic, enabled 95% of the national sorghum to be devoid from tannin in the grains. As for the bromatological composition of silage, the sorghum presents fiber levels on neutral detergent varying from 52% to 56% against 45% to 64% in maize, in acid detergent from 32% to 35% against 28% to 35% in maize, and dry matter digestibility in vitro from 52% to 56% against 54% to 78% in maize, evidencing strong similarities regarding these parameters. The genetic improvement has made the sorghum cultivation an alternative to the maize replacement for animal nutrition.

Key words: animal performance, fiber in acid detergent, fiber in neutral detergent, biomass production, tannins

Mejora genética y parámetros de calidad del silaje de sorgo (*Sorghum bicolor* L. Moench) en comparación con el ensilaje de maíz (*Zea mays* L.)

Resumen

El objetivo de esta revisión fue reportar artículos a respecto de la mejora genética del sorgo (*Sorghum bicolor* L. Moench) con el fin de la obtención de genotipos con las mejores características de forraje para ensilado. Entre las forrajee destinados a la producción de ensilaje el sorgo constituye una buena alternativa con productividad superior a 20 t ha^{-1} de biomasa seca. Lo más destacado en el uso de sorgo es la posibilidad de producir mayor volumen de biomasa y ensilaje de mejor calidad, con fibras digeribles de alto consumo y rendimiento animal en las zonas de restricción de cultivo de maíz y/o otros forrajes se convierte en imposible o de riesgo. Uno de los limitadores del sorgo en la alimentación animal es la concentración de taninos condensados en el grano por se relacionaren negativamente con la digestibilidad de la materia seca. Por medio del mejoramiento esta situación, a través del conocimiento de la herencia genética de esta característica, permitió actualmente en 95% del sorgo nacional no tener el tanino en el grano. Cuanto a la composición bromatológica del ensilaje, el sorgo presenta fibra detergente neutro que van de 52% a 56% contra 45% a 64% en el maíz, fibra detergente ácida de 32% a 35% contra 28% a 35% en el maíz y digestibilidad in vitro de la materia seca de 52% a 56% contra 54% a 78% en el maíz, que muestran fuertes similitudes en estos parámetros. El mejoramiento genético tornó la cultura del sorgo forrajero en una opción alternativa para reemplazar el maíz en la alimentación animal.

Palabras clave: rendimiento animal, fibra detergente ácido, fibra detergente neutro, producción de biomasa, taninos

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Melhoramento genético e parâmetros de qualidade da silagem de sorgo (*Sorghum bicolor* L. Moench) em relação à silagem de milho (*Zea mays* L.)

Resumo

O objetivo desta revisão foi relatar trabalhos com melhoramento genético de sorgo (*Sorghum bicolor* L. Moench), destinados a obtenção de genótipos com melhores características forrageiras para produção de silagem. Entre as forrageiras destinadas a produção de silagens o sorgo constitui-se numa boa alternativa com produtividade superior a 20 t ha^{-1} de biomassa seca. O grande destaque na utilização do sorgo é a possibilidade de se produzir maior volume de biomassa e uma silagem de melhor qualidade com fibras digestíveis de elevado consumo e desempenho animal, em áreas de restrição ao cultivo do milho e/ou outras forrageiras se torna impossível ou de risco. Um dos limitadores do uso do sorgo na nutrição animal é a concentração de taninos condensados no grão por relacionar-se negativamente com a digestibilidade da matéria seca. Por meio do melhoramento tal situação, via conhecimento das heranças genéticas desta característica, possibilitou atualmente em 95% do sorgo nacional não possuir tanino nos grãos. Quanto à composição bromatológica de silagem, o sorgo apresenta teores de fibra em detergente neutro variando 52% a 56% contra 45% a 64% em milho, fibra em detergente ácido de 32% a 35% contra 28% a 35% em milho e digestibilidade in vitro da matéria seca de 52% a 56% contra 54% a 78% em milho, evidenciando fortes semelhanças quanto a estes parâmetros. O melhoramento genético tornou a cultura do sorgo forrajeiro em uma opção alternativa a substituição do milho na alimentação animal.

Palavras chave: desempenho animal, fibra em detergente ácido, fibra em detergente neutro, produção de biomassa, taninos

Introduction

Among the methods and nutritional strategies that help on animal production is the conservation of food in silages. According to DINIZ (2010), several species are used for silage production in Brazil, notably the maize cultivation (*Zea mays*), considered standard along with sorghum *(Sorghum bicolor)*.

The production of sorghum silage constitutes a good alternative for substituting the use of maize, presenting productivity levels superior to 20 ton ha^{-1} of dry biomass (GUARESCHI et al., 2010), tolerance to water stress, developing well in temperatures between 5 to 40ºC and lower requirement regarding soil fertility (DIAS et al., 2001).

The great advantage of using sorghum is the possibility of producing greater biomass volume, associated with better quality silage, with digestible fibers of high animal consumption and performance, in areas with cultivation restrictions for maize and/or other forages (BUSO et al., 2011).

The tolerance to water stress comes from the capacity of sorghum plants to cease the growth in dry periods, and retake the growth after drought periods, a characteristic that is absent in maize plants (COSTA et al., 2004). The root system of sorghum, when compared to maize, has greater length, is more fibrous and has greater number of root hairs, reaching 1.5 m depth and 2 m lateral extension, characteristics that are responsible to water stress tolerance (EMBRAPA, 2012). For sorghum plants to produce 1 kg of dry mass, they require 332 liters of water, whilst for maize plants it is necessary 368 liters for an equivalent production (COSTA et al., 2004).

Routinely in Brazil, the sorghum cultivation replaces maize for silage productions in areas with water restrictions, and on the second crop, which in some regions can be of high risk for the maize culture (SILVA et al., 2009). This progress in cultivations reflects the changes on the philosophy of genetic improvement programs, which formerly sought bigger plants, pest resistance, diseases, abiotic stresses and adaptability, and currently concentrate efforts on the obtaining of raw material of greater digestibility and nutritional value, matching the sorghum cultivation to maize, regarding silage production (MARTINS et al., 2003).

For the improvement of forages destined

to silage, generally the focus is the obtainment of genotypes with high yield of dry biomass, combined to the high digestibility of leaves and grains (GUARESCHI et al., 2010).

The positive factors on animal production are evident with the use of sorghum, when hybrids with the best aptitude are used for this goal. However, we observed variations on the digestibility, harming the animal performance, these causes being justified by the use of inadequate genotypes and processing for this goal (SILVA et al., 2009).

In this aspect, this bibliographic review aims to report the situation on studies with sorghum improvement destined to obtaining genotypes with better forage characteristics for silage production.

Economic importance of *sorghum*

On the 2010 crop, the sorghum production was of 55.5 million tons, representing the 5º most produced cereal in the world (FAO, 2012). Brazil, despite not being one of the biggest sorghum producers, has good representativeness in area and yield, with about 1.5 million hectares (EMBRAPA, 2011) and an estimated production of 2.064 million tons of grains (CONAB, 2012). However, we estimate that approximately 400 thousand hectares are destined to sorghum forage cultivation, with a production of 18 million tons of silage that goes for Brazilian herd nutrition (EMBRAPA, 2012). This demonstrates that approximately 1/3 of the national sorghum is destined for forage production and/or silage.

Brazil has an enormous potential of expanding the areas for sorghum cultivation, if it is considered only the semiarid regions, tillage that are not cultivated after the normal summer crop and/or places with water restriction on the different regions of the country. If there was a planning for these areas for sorghum cultivation, there would be millions of tons of grains or silage more, available for animal nutrition (DINIZ, 2010).

Another accurate information is that Pernambuco alone has one million hectares of potential area for sorghum cultivation, being a much promising state for sorghum cultivation growth, in spite of its water conditions (BRASIL, 2009).

According to CONAB (2012), in Parana it is cultivated approximately 9 million hectares for grain production on the first crop. From this total, about 4.5 million hectares are fit to maize cultivation in second crops, according to maps of agricultural zoning (IAPAR, 2013). According to CONAB (2012), approximately 2 million hectares are used for second crop maize, constituting the most expressive culture in this period. It is evident that without handling the area with second crop maize, there is still 2 million hectares that are being underutilized, and that could perfectly fit to sorghum cultivation, evidencing that Parana has enormous potential for sorghum culture, aimed for animal nutrition. With the optimization of agricultural areas in Parana it would be possible to triplicate the national area of sorghum crops, without intervening in areas destined for the cultivation of other cereals, Brazil being a possible power in sorghum cultivation (DINIZ, 2010).

Morphological and physiological characteristics of *sorghum*

There is evidence that the sorghum is originated from tropical regions, more precisely the African continent, on the proximities of Ethiopia, distinguished for being a plant of C4 metabolism, of short days and autogamous, with better yield performance in temperatures superior to 20ºC. Such characteristics greatly explain its behavior regarding tolerance to water restrictions (EMBRAPA, 2012).

According to SIMON (2006), sorghum genotypes are divided in four types: low-sized grain; forage for large-sized silage or saccharine; forage for grazing, cut or haying and broomcorn. For this author, the great difference between these sorghum types is on the productions of leaves, stems and panicles, influencing the biomass productivity, fermentative pattern and finally the nutritional value.

The grain sorghum cultivars, when used for silage making, present low productivity of dry biomass. The forage cultivars grow up until 3 m height, producing elevated quantity of dry biomass, but with great proportion of stems and leaves in the silage. Thus, by the means of improvement programs, currently, for silage making, there are hybrids of double purpose, with approximately 2 m height, that perform a large dry biomass productivity, with good grain participation and digestibility of the fiber fraction of the plant (SILVA et al., 2009).

The biomass productivity of sorghum is related to the plant size, since higher rates are reached with bigger plants, but this reflects on the decrease of panicle production and increased stem participation on the resultant silage. It is known that the digestibility of the plant parts influences the total digestibility of the silage, the panicles being the most digestible portion (MACHADO et al., 2011). According to RODRIGUEZ (2002), there is great variation between hybrids provided by seed companies, which opens the possibility of improving the quality of sorghum silage through the selection of hybrids that better relate the plant parts associated with higher digestibility.

The root system of sorghum plants presents elevated specific length, capable of exploring great soil volume per unit of metabolic expenditure, improving the efficiency of water and nutrient absorption per unit of waste energy. This reflects its root system, which, differently from maize, for instance, has silica in the endoderm, great quantity of root hairs and higher lignification (DINIZ, 2010). The plant stem is divided into nodes and internodes with leaves all over the plant's dimension. One particular characteristic is its inflorescence, which consists of one panicle, the fruit being a caryopsis or grain (EMBRAPA, 2012).

The sorghum presents potential agronomic characteristics; for instance, it is a great green mass producer (64 t ha^{-1}), grains (3.3 t ha^{-1}), leaves (18 t ha^{-1}) and stems (46 t ha^{-1}), elevated content of total sugar (49.1%), demonstrating to be an excellent food source, with silage potential to serve on cattle feed (SOUZA et al., 2005).

The sorghum comprises annual and perennial species, with height varying from 1 to 4 m and with a tillering characteristic (absent on maize), and one panicle per tiller (DINIZ, 2010). According to SILVA et al. (2009), the sorghum has elevated production capacity with rates superior to 20 ton ha^{-1} of dry biomass, added to the regrowth capacity after cut, enabling the use of grazing without the need of culture implantation procedures. To these authors, the tillering capacity is influenced by the plant population, so that the lower the population, the higher the number of tillers.

Sorghum plants normally have phenolic compounds as protection mechanisms against birds and pathogens, which may or may not occur (EMBRAPA, 2012). The most common phenolic compounds are condensed tannins, which can reduce the digestibility of the grains and are able to be genetically controlled (MAGALHAES et al., 2000), facilitating improvement works.

Genetic improvement of *sorghum*

The genetic improvement of plants is based on the obtaining of adequate germplasm and generation of variability (BORÉM, 1998). In the past, the quality of silage was not one of the main priorities of sorghum improvement, in a way that the breeding companies produced hybrids and directed some assessments regarding bromatological characteristics of the genotype in order to verify the aptitude for silage. Currently, the sorghum cultivation nationwide is being the focus of genetic improvement researches aimed to the generation of double purpose hybrids (grains and silage), where it is related phytotechnical factors of a sorghum cultivar with the resultant silage quality (EMBRAPA, 2012). VIANA and NOCE (2004) cite that one factor to be considered in a good sorghum cultivar for silage is the number of panicles, since it is highly related to the quality.

Initially, improvement programs of sorghum sought tall-sized cultivars and elevated concentration of sugar, focusing only on green matter production, resulting in low grain participation, a scenario that in the past few years has suffered an inversion and, currently, the aim has become shorter plants with better relation between stem, leaves and panicles, for silage matters (MARTINS et al., 2003). In other cultures such as maize, the use of short-sized plants results in the reduction of dry matter productivity, which in the case of sorghum is offset by the possibility of bigger population, incrementing the grain participation on the final mass, allied to the lower possibility of plant lodging, being the priorities of improvement programs (FERNANDES e LEITE, 2004). The studies with bigger population densities are supported because the improvement is destining efforts for the obtaining of genotypes that have more upright plants, shorter size and high prolificacy, reducing then the risk of productivity decrease and plant lodging (MARTINS et al., 2003).

One of the factors that the improvement needs to balance in sorghum cultivars is the tannin concentration in the grain. There are reports that, if ingested in big doses (6 to 12% in the dry matter), it can result in decrease of dry matter consumption and the digestibility of crude protein, harming the animal performance (FRUTOS et al., 2002). This sorghum characteristic constitutes a protection against pathogens, pests, birds and other organisms, but these phenolic compounds are antinutritional when provided to animals, being unfit for silage and grain hybrids (MAGALHAES et al., 2000). According to RODRIGUES et al. (1998), two dominant genes (B1 and B2) determine the tannin presence in the grain of sorghum plants. The tannins are a problem because they contain high molecular weight and affinity for proteins and for formulating strong hydrogen bonds; however, they can be managed with improvement techniques, in order to eliminate this characteristic (MAGALHAES et al., 2000).

Bromatological characteristics of *sorghum* silage

For silage matters, it is recommended short-sized (1.7 m) sorghum plants of double purpose, with grain participation around 40 to 50% in the total dry matter, and this objective is facilitated when we have hybrids of early maturity with reduced size, helping the growth on plant population, elevating productivity and silage quality (FERNANDES and LEITE, 2004).

When it comes to bromatological characteristics of any forage, the comparison pattern is the maize culture. In this context, conducted studies show that the nutritional value of sorghum can reach 85 to 92% of the maize, depending on the cut process, storage and the utilized genotype (RODRIGUEZ, 2002).

The dry matter intake can be determined by the cut season, when MACHADO et al. (2011) found greater consumption when the plants were ensiled on the stage between farinaceous to hard dough, which corresponds to levels from 30 to 40% of dry matter, when compared to the milky stage, with levels of dry matter inferior to 29%. We must pay attention to the losses on feces in the case of silage with elevated proportion of hard grains on the final mass, from the fact that some sorghum hybrids differ as for the stage of dry matter accumulation, ideal for silage (MOLINA et al., 2002; RODRIGUEZ, 2002).

MACHADO et al. (2011) observed a variation on the percentage of leaves, stems and panicles as the maturation advances, with green mass reduction and dry mass increase. These same authors ensiled sorghum plants in the milky, soft and farinaceous stages, observing a linear reduction on leaf (19,5 to 16%) and stem (53 to 38%) participation, as the stages of soft dough to farinaceous advanced, with respective increase on panicle participation (27 to 45%), reflecting in greater yield of total dry matter for all assessed hybrids. In similar studies, FARIA JUNIOR (2008), working with different sorghum hybrids and harvest seasons, found that with the advance of the maturity there was also a reduction on the leaf and stem participation, but increase on panicle participation.

It is noteworthy the aspects related to the quality of the produced silage, in order to assess the optimal time of harvest. In this context, FARIA JUNIOR (2008), working with eight stages of harvest, found that there is a decrease in the fiber content in neutral and acid detergent, cellulose and hemicelluloses as the harvest advanced until the farinaceous grain stage. This fact was attributed to the increment on the grain percentage in the mass as the plants grew, since it is a highly digestible portion and which reached levels of 50% on the total dry matter; the same was not observed for the lignin content, which increased with maturity, causing digestibility reduction of dry matter *in vitro*, in the range of likely two percentage units; however it was attributed that the better harvest and silage moment of the plants is in the stage of farinaceous grains, which corresponds to approximately 30 to 35% of dry matter. MACHADO et al. (2011) found similar behavior for fiber in acid and neutral detergent as the maturation stages advanced, and varied behavior for dry matter digestibility, explaining the response through the variation in the proportion of plant parts of each genotype and the nutritional differences of the different fractions; however, the best moment for silage was in farinaceous grains.

When comparing maize and sorghum silages, DIAS et al. (2001) found similar pH values, in the range of 3.9 for both, being within the adequate standards for silages with good fermentation. As for the fiber levels in neutral detergent, it was significantly more elevated in sorghum silage, with 75% against 68% with maize, which caused a tendency for greater consumption of dry matter and higher milk production in animals fed by maize silages. It is noteworthy that the sorghum plants were ensiled in the milky stage of grains. These results are different from those obtained by MACHADO et al. (2011), who worked with different sorghum hybrids, harvested in the farinaceous stage, verifying a variability between them for fiber levels in neutral detergent (52 to 56%), for fiber levels in acid detergent (32 to 35%) and dry matter digestibility *in vitro* (52 to 56%).

Variations on the fibrous portion of the plant are results that serve as an indicative of the existence of variability between sorghum genotypes, guiding the genetic improvement to work in way of selecting superior genotypes. Working with different maize hybrids for silage purposes, GRALAK (2011) found a variation of 28 to 35% of fiber in neutral detergent, 45 to 64% of fiber in acid detergent and 54 to 78% on the dry matter digestibility *in vitro*, values that match the ones cited above for sorghum culture. This allows us to infer that the maize and sorghum crops are similar regarding bromatological characteristics and that sorghum, with the aid of genetic improvement, has a potential to produce silage of similar quality to the silage with maize plants.

According to RODRIGUEZ (2002), several studies have been comparing the performance of animals fed with sorghum and maize silage, observing that for the modern hybrids of both species the results related to the apparent digestibility of the dry biomass are similar.

The qualitative similarity between maize and sorghum is reinforced when comparing the grain composition, since ANTUNES et al. (2007), assessing the composition of sorghum grains, found variations on the crude protein levels from 9.8 to 18%, on starch from 62 to 79%, on ether extract from 1.7 to 3.6%, besides the presence of total phenols above 0.75% in some genotypes, which can be characterized as sorghum with tannin. CASTRO et al. (2009), working with composition of maize grains, found average levels of crude protein of 9%, 80% starch, 5% ether extract and absence of phenol; however, these characteristics are similar to the composition of sorghum grains. The results related to the grain composition reinforce the possibility of using sorghum in equivalence to maize for animal nutrition.

The use of sorghum in substitution to maize is justified by several factors, such as the 20% lower cost for silage, the 92% nutritional value of maize silage, the equivalent consumption of 90% of maize silage, the great energetic source and the regrowth rate with production of 60% from the production of the first cut (RODRIGUEZ, 2002).

Aims of the genetic improvement of *sorghum* for silage

Advances on sorghum improvement were possible since 1954, with the use of cytoplasmic-genetic male sterility, allowing the exploration of heterosis with the hybridization process (BORÉM, 1998). The cytoplasmic-genetic sterility is a product of the combination of Milo cytoplasm and Kafir genes, where the hybrids are product of the crossing of one sterile-male lineage and one of fertile pollination (PARRELLA and SHAFFERT, 2012). The maintenance of the male-sterile lineage A1 occurs by the crossing of A1 plants with an isogenic lineage of normal cytoplasm denominated maintainer B. The hybrid is the result from the crossing A1xB with a restorer lineage of fertile pollination C, (A1+B x C) (DURÃES, 2011), constituting an unanimous technology among researchers from various countries.

Pioneering researches on sorghum improvement were conducted in the United States, mainly based on the selection of mutations and natural crosses, providing basis for other improvement programs throughout the world, and from that moment each country focused on the improvement according to their necessities and issues to be overcome (EMBRAPA, 2012).

A great progress on forage sorghum development was the discovery of mutant plants that present modified lignin and cellulose levels. These sorghum mutants are called brown midrib sorghum and are being widely used for the production of forage hybrids, through the incorporation of genes that confer higher digestibility with procedures of genetic improvement (DURÃES, 2011).

At Embrapa, classic and molecular studies are being developed in order to generate genotypes with better profile to produce forage and biofuels (EMBRAPA, 2012). The use of genomic techniques and mapping and analysis of gene expression of lignin levels is a new focus on sorghum improvement studies. These studies found great variability on lignin levels (2 to 12%), and they already identified homologous of the main genes responsible for the synthesis of these compounds, and with the use of the PCR technique (polymerase chain reaction), it is possible to study in real-time the expression levels of these genes (DAMASCENO and PARRELLA, 2011).

Sorghum plants carriers of the *bmr* genes are characterized by having a phenotype with brown pigments on the stem and midrib of the leaves, and present lower lignin levels (HALPIN et al., 1998). AGUILAR et al. (2012), working with genotypes of normal type sorghum and mutants carriers of the *bmr*-6 gene, where most of the mutant isogenic genotypes showed lower lignin levels in the whole plant. This bromatological improvement is attributed by these researchers to the action of the *bmr*-6 gene, which inhibits the activity of the CAD (cinnamyl alcohol dehydrogenase) enzyme, involved in the lignin synthesis.

One of the main complicating factors of

genetic improvement on the silage production of sorghum is undoubtedly the presence of secondary compounds, with emphasis to the tannins in the grain. Many studies are focused to the negative effects of tannins, related to lower nitrogen use, resulting in lower protein digestion and also reducing the palatability of the food (CABRAL FILHO, 2003). According to TEIXEIRA (2001), the damaging factor is related to the tannin concentration, where levels above 0.8% can decrease the amino acid digestibility, such as the methionine, being an issue for monogastrics and young ruminants. The genetic inheritances of this characteristic are known and it is clear that it has high heritability, significant heterosis and strong evidences of control by the dominant genes B1 and B2. According to RODRIGUES et al. (1998), in Brazil the improvement programs seek to identify on the parental the absence of tannins to generate base populations. These authors, aiming to estimate the combinatory capacity of sorghum lineages, conducted a diallel with lineages with and without tannins, observing that all resultant hybrids of lineages with tannin x lineages without tannin presented tannin levels above 0.8%, being framed in the group of genotypes with tannin in the grain.

It is evident that, in order to obtain sorghum populations without tannin in the grains, we must direct the selection over the populations with absence of this polyphenol (DINIZ, 2010). Over the past few years, the improvement programs have been increasing efforts on the production of sorghum genotypes without tannin in the grains, and since 2002 more than 90% of the national sorghum does not have this polyphenol (EMBRAPA, 2012). The efficiency of sorghum hybrids without tannin in the grains was demonstrated by IGARASI et al. (2008), providing silages of wet grains of maize and sorghum, in comparative, as the nutrition for feedlot steers, verifying a similar productive performance between these two silages.

According to EMBRAPA (2012), the sorghum improvement of double purpose in the Brazilian program follows a selection criteria, such as dry biomass production and percentage of panicles on the ensiled mass and not susceptible to the photoperiod, constituting new directions on sorghum improvement for silage.

DURÃES (2011) points out that, besides these characteristics on the selection of cultivars for silage purposes, the national improvement programs also invest in genotypes resistant to diseases such as anthracnose, helminthosporiose, blight, cercosporiose and mildew, defoliating pests, and also tolerant to plant lodging.

The plant population also constitutes one of the aims of improvement programs, with constant search for genotypes that support higher population densities and shorter spacing (RODRIGUEZ, 2002). Presently, the recommendations for forage sorghum planting vary from 100 to 200 thousand plants per hectare, associated with spacing varying from 50 to 70 cm between rows, since the recommendation is directly related to the plant size (EMBRAPA, 2012).

TOMICH et al. (2004), in studies with segregating genotypes of sorghum, aiming a selection to great populations, considered the parameters of relation between leaf/stem and plant height. These authors verified that the closer to 1 the relation leaf/stem got, the plants tended to have shorter size and greater dry matter production, constituting an indicative of tolerance to higher populations, which must be taken as selection criteria of genotypes. TOMICH et al. (2004) also found that a high relation between leaf and stem is correlated with high panicle proportion and low stem proportion on the ensiled mass. It is common to observe great variability of plant size in modern genotypes of sorghum, varying from 1.0 to 2.8 meters; however it is noteworthy that plants of shorter size present high correlation with dry biomass production and greater panicle proportion, being commonly preferred in the moment of selection (RODRIGUEZ, 2002; TOMICH et al., 2004).

Another important point on sorghum cultivation is the intolerance to herbicides, which generates a study field for breeders and phyto-technicians. In Brazil, it has been used in great proportions the mixture atrazine plus metolachlor in post emergence of maize and sorghum crops, for controlling unwanted plants (ARCHANGELO et al., 2002), which in conditions of high soil humidity end up interfering significantly on the final population of sorghum plants.

The tests of tolerance to herbicides are often conducted in the final stage of improvement programs. In studies conducted by ARCHANGELO et al. (2002), they assessed the phytotoxicity of the herbicide atrazine plus metolachlor in sorghum genotypes, by testing under several doses, with and without mineral oil on different stages, evidencing that there is no negative effect until the dosage of 6.0 l ha^{-1} from the moment the plants have four leaves. However, it is not recommended the use of mineral oil, because it provided a drastic phytotoxic effect, with yield reduction of the sorghum plants, independent from the phenological stage of the crop.

The use of the group of herbicides inhibitors of the ALS enzyme (Acetyl Lactate Synthase) on sorghum was made possible since 2004 by researchers of the United States; this was only possible by the identification of wild genotypes carriers of the resistance genes, which were used for developing hybrids resistant to this herbicide group (ROSO and VIDAL, 2011). The developing of hybrids resistant to the herbicides inhibitors of the ALS has enabled the use of this group for controlling various unwanted plants on the post emergence of sorghum cultivation.

Working with sorghum hybrids resistant to herbicides inhibitors of the ALS, TUINSTRA et al. (2009) obtained efficient control of grasses with the use of nicosulfuron plus rimsulfuron, and the control of round leaves was more effective when using methyl metsulfuron plus atrazine, and no toxicity was found in the sorghum plants. The inheritance related to herbicide resistance seems to be dominant because when they conducted the crossing of wild resistant genotypes with susceptible, all progenies were tolerant to the application of herbicide (TUINSTRA et al., 2009).

Conclusion

The developing of sorghum cultivars, adequate to the silage process, is currently present on the planning of genetic improvement programs of plants, and may contribute more and more on the progress of nutritional characteristics of sorghum silages, being able to make this culture a great source of food for ruminants. The improvement solved big issues of sorghum cultivation, such as the presence of tannin in the grains, and enhanced the use of this cereal on the feeding of ruminants and monogastric animals. The sorghum has potential to occupy great idle areas in Brazil that present water restrictions.

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