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Morphoagronomic traits of BRS 610 sorghum submitted to artificial defoliation

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The objective of this study was to evaluate the agronomic traits of BRS 610 forage sorghum, based on developmental stages and defoliation levels. The experiment was conducted in a protected environment, located in União experimental farm, in Nova Xavantina-MT, in vases with 8 dm^{-3} capacity in soil classified as dystrophic red latosol. The experimental design was a randomized block, arranged in a 4 x 3 + 1 factorial, four stages of defoliation [three expanded leaves (15 days after emergence of plants - DAE), six expanded leaves (30 DAE), panicle differentiation (45 DAE), booting (60 DAE)] and three levels of defoliation [(33, 66 and 99%) and an additional treatment without defoliation], making the total of 13 treatments with three replications. BRS 610 sorghum crop was used. It was evaluated plant height, stem diameter, root dry mass and shoot dry mass. Except for plant height and stem diameter, for the other variables there were significant influences of defoliation levels. To root mass and shoot dry mass it was verified that less intense defoliation and the early stages affect less those variables. To root dry mass, reductions are evident up to 66.36% when the plants are submitted to total leaves removal at the stage of panicle differentiation. The production of shoot dry mass of the BRS 610 sorghum is affected when submitted to any level and defoliation stage.

Key words: Forage, silage, *Sorghum bicolor* (L.) Moench.

INTRODUCTION

Brazil stands out in the global agribusiness landscape among the largest producers of grain and cattle. According to USDA (2012), the cattle herd in Brazil has about 198 million animals, being the country with the second largest herd in the world, whereas the grasses represent an important role in cattle feeding. The grasses (*Poaceae*), for presenting low production cost and high production yields, constitute 99% of the diet of the Brazilian beef herd (Castro et al., 2008). However, the current situation of production processes in beef and dairy cattle in Brazil have made the competitive market with high production costs, according to Machado et al. (2012), there is a need for quantitative and qualitative increase of food for the animals, especially during periods

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Table 1. Chemical composition of the dystrophic red latosol (0 to 0.20 m) soil before setting up the experiment at União experimental farm, Nova Xavantina, MT, Brazil.

pH $CaCl_2$	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^{+}+Al^{3+}$	SB	CEC	P	K	OM	V
	cmol$_c$ dm^{-3}						mg dm^{-3}		g kg^{-1}	%
5.40	1.14	0.60	0.00	2.90	1.90	4.80	42.00	65.00	6.40	39.70

H + Al, Potential acidity; SB, sum of bases; CEC, cation exchange capacity at pH 7.0; OM, organic matter; V, base saturation.

of pastures shortage. An efficient way to decrease the production cost of beef and dairy livestock is to reduce the feeding costs. In this context, forage production has emerged as a viable alternative for food production. Among the forages, the sorghum [*Sorghum bicolor* (L.) *Moench*] stands due to its higher tolerance to drought because of its abundant and deep root system. However, defoliating insect attacks can cause reduction in biomass productivity, since it reduces the leaf area (Zuffo et al., 2015).

The main defoliating pests are greenbug (*Schizaphis graminum*), corn aphid (Rhopalosiphum maidis), the fall armyworm (*Spodoptera frugiperd*) Lesser Cornstalk Borer (*Elasmopalpus lignosellus*) (Waquil, 2008). According to Fonseca et al. (2013), the defoliating insects can cause damage to the sorghum crop up to 58% in the dry mass production, with complete defoliation when carried out in the reproductive stage.

Therefore, the damages caused in the leaves can promote reduction in growth in the whole plant, because the leaves are responsible for performing photosynthesis and producing photoassimilates for the whole plant. The active leaf area, photosynthetic ability of leaves to form photoassimilates and conservation of the photosynthetic apparatus is of fundamental importance for the production of a plant (Magalhães et al., 2002).

As controlling measures of defoliating insects, producers have used chemical applications. However, this measure must be used with caution, because according to Barros et al. (2002), besides increasing the production costs, these products promote environmental damage. Therefore, the evaluation of artificial defoliation at different times is necessary to obtain information about the crops tolerance when submitted to defoliation levels and times. Given the above, the objective of this study was to evaluate the agronomic characteristics of BRS 610 forage sorghum on developmental stages and defoliation levels.

MATERIALS AND METHODS

The experiment was conducted at União experimental farm, located in Nova Xavantina-MT (14° 50 '41 "S, 52° 22' 49"W, with an average altitude of 290 m) during the period June to August 2013, in a protected environment at 50% brightness. The soil used in the experiment was collected in a soybean production area in the layer of 0 to 0.20 m. As a result of soil analysis, the following physical characteristics were verified: 500, 100 and 400 g kg^{-1} of sand, silt and clay, respectively. The chemical composition of the soil of the experimental area is shown in Table 1.

The region climate is Aw according to Köppen global climatic classification, with two well defined seasons, with a drought season from May to September and a rainy one from October to April. Climatic data were collected at the meteorological station of the National Institute of Meteorology - INMET and are in Figure 1.

The experimental design was a randomized block, arranged in a 4 × 3 + 1 factorial, four stages of defoliation [three expanded leaves (15 days after emergence of plants - DAE), six expanded leaves (30 DAE), panicle differentiation (45 DAE), booting (60 DAE)] and three levels of defoliation [(33, 66 and 99%) and an additional treatment without defoliation], making the total of 13 treatments with three replications. Defoliation was characterized by randomly removal of the leaves in the plant with the assistance of scissors.

Sorghum was grown in vases with a capacity of 8 dm^{-3}. Ten seeds were sown per pot, with subsequent removal of material leaving only one, with seeding depth of 1 to 2 cm. The fertilization was performed as indicated by Malavolta (1980), in which was applied 3 g of lime and 10 g of the formulated N-P_2O_5-K_2O (02-20-20) per vase. At 30 DAE was applied by coverage 2 g of urea. During the experiment, daily irrigation was made to restore the evapotranspired water and maintain the soil field capacity.

During the plant development, it was used the following management: (i) two applications of insecticide, thiamethoxam + lambda-cyhalothrin (Platinum Neo®) at a dose of 200 mL p. c. ha^{-1}, applied at 20 and 45 DAE; ii) an application of pyraclostrobin fungicide + epoxyconazole (Opera®) at a dose of 500 mL p. c. ha^{-1}, applied at 40 DAE. The weed plants were manually removed to eliminate the competition effect. For the application it was used a CO_2 backpack sprayer pressurized with CO_2 coupled to a bar with four spray nozzles XR 110.02, applying spray volume equivalent to 200 L h^{-1}.

In the forage cut-off point that is characterized by a 'pasty' grain texture that was at 100 days after sowing, it was determined: i) plant height (cm) - determined from the soil surface to the apex bunch with assistance of a millimeter ruler in the main tiller. ii) stem diameter (mm) - measured in the lap height of the ground surface of the plant with readings by digital caliper Clarke®; iii) was also performed root dry mass (g) and total plant dry mass (g), with assistance of forced air circulation stove at 60°C for 72 h until constant weight, and then vegetable residues were weighted on a precision scale (0.001 g).

After collecting and tabulating the data, the analysis of variance of the obtained data was performed in all evaluated parameters. The comparison of defoliation treatments and comparison of each average treatment defoliation versus additional treatment (control), was made by Scott-Knott test at 5% probability. To perform the analysis the statistical program Sisvar was used (Ferreira, 2011).

RESULTS AND DISCUSSION

Except for plant height and stem diameter, for the other parameters there were significant influences of defoliation

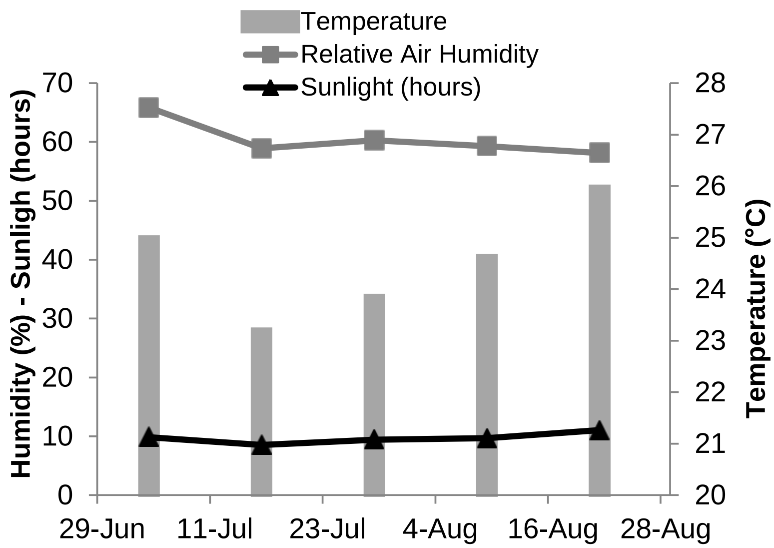

Figure 1. Mean temperature, relative air humidity and sunlight hours during the experiment period (data from INMET – Nova Xavantina Station, MT, Brazil).

Table 2. Variance analysis for plant height (PH), stem diameter (SD), root dry mass (RDM) and total plant dry mass (TPDM) data, obtained in the experiment according to stages and levels of defoliation in BRS 610 sorghum crop. Nova Xavantina - MT, Brazil, 2013.

Cause of variation	DF	Mean square			
		PH	**SD**	**RDM**	**TPDM**
		cm	**mm**	**g**	
Blocks	2	26.69	14.11	1.16	112.17
Defoliation (D)	2	2329.77^{ns}	0.34^{ns}	448.76**	5409.22**
Stage (S)	3	1697.65^{ns}	3.65^{ns}	422.87**	8387.76**
D x S	6	534.07^{ns}	0.72^{ns}	81.93*	442.39^{ns}
Factorial *vs* aditional	1	5166.72^{ns}	0.51^{ns}	31166.30**	3512.45**
Treatments	12	1676.97^{ns}	1.37^{ns}	302.80**	4979.01**
Residue	-	933.55	2.21	25.25	231.44^{ns}
CV	-	21.25	8.26	14.49	16.07

** and * , Significant at 1 and 5% of probability, respectivelly, for the F test. ^{ns}, non significant; DF, degree of freedom; CV, coeficient of variation.

levels (Table 2). It is also noted that the root and shoot dry mass were significantly influenced (p<0.01) by defoliation stages. Interaction between both factors were detected only to the root dry mass, therefore, for the other parameters it was held an isolated analysis of the factors (Tables 3 and 4). For the plant height and stem diameter there were no statistical differences between the evaluated factors. By relating the treatments with the control one, it was also noticed that there is no statistical difference of the averages. These results support those seen by Karam et al. (2010), who verified that the defoliation levels and stages do not affect the height of corn plants (*Zea mays* L.). Fonseca et al. (2013) did not observe influence of these factors on the heights of grain sorghum (cv. BRS 506), however, to stem diameter total, the removal of the leaves resulted in the stem diameter reduction.

Based on the growth variables (plant height and stem diameter), it was observed that plants can tolerate the stress, regardless of the level and stage of defoliation (Tables 3 and 4). This fact is probably related to stem photoassimilates, as emphasized in literature by Alvim et al. (2010) and Sangoi et al. (2012). For Sangoi et al. (2001), hybrids that have the characteristic to redirect stem sugars to another part of the plant, have greater agronomic stability, which may have occurred in this

Table 3. Plant height (cm) for the experiment of levels and stages of defoliation on BRSS 610 sorghum crop. Nova Xavantina – MT, Brazil, 2013.

Defoliation stages	Defoliation level (%)			
	33	66	99	Mean
Three expanded leaves	176.00	144.33	115.33	145.22[A]
Six expanded leaves	134.66	117.33	108.00	120.00[A]
Panicle differentiation	159.33	164.66	122.66	148.88[A]
Booting	149.66	150.66	143.00	147.77[A]
Mean	154.91[a]	144.25[a]	122.25[a]	140.47

Means followed by the same lowercase letter in line and capital letter in column are from the same group according to Scott Knott test at 5% of probability. Mean of the control without defoliation: 183.66 cm.

Table 4. Stem diameter (mm) for the experiment of levels and stages of defoliation on BRSS 610 sorghum crop. Nova Xavantina – MT, Brazil, 2013.

Defoliation stage	Defoliation level (%)			
	33	66	99	Mean
Three expanded leaves	18.62	18.16	18.26	18.35[A]
Six expanded leaves	18.33	18.35	18.20	18.29[A]
Panicle differentiation	18.30	18.00	18.40	18.23[A]
Booting	16.10	17.16	17.79	17.02[A]
Mean	17.84[a]	17.92[a]	18.16[a]	17.97

Means followed by the same lowercase letter in line and capital letter in column are from the same group according to Scott Knott test at 5% of probability. Mean of the control without defoliation: 18.40 mm.

Table 5. Root dry mass (g) for the experiment of levels and stages of defoliation on BRSS 610 sorghum crop. Nova Xavantina – MT, Brazil, 2013.

Defoliation stage	Defoliation level (%)			
	33	66	99	Mean
Three expanded leaves	46.00[Aa]	41.33[Aa]*	41.98[Aa]*	43.10*
Six expanded leaves	33.18[Ba]*	25.21[Ba]*	23.93[Ba]*	27.41*
Panicle differentiation	35.48[Ba]*	37.94[Aa]*	17.49[Bb]*	32.05*
Booting	40.94[Aa]*	31.64[Bb]*	23.59[Bb]*	32.05*
Mean	38.90*	34.03	26.74	33.22

Means followed by the same lowercase letter in line and capital letter in column are from the same group according to Scott Knott test at 5% of probability. *Means statistically different from control mean without defoliation (52.00 g), according to Scott Knott test at 5% of probability.

experiment. Although no statistical difference for plant height was observed, when we compared the means, it is possible to observe that the lower level of defoliation has less effect in this variable (Table 3). This trend can be confirmed when analyzing the root and shoot dry mass (Tables 5 and 6).

In both variables (root and shoot dry mass) it is noticed similar behavior, when less severe defoliation and early stages affected less the root (Table 5) and shoot parts (Table 6) dry mass. Also, when the treatment without defoliation is compared with others, no statistical differences were observed, except for the level of defoliation of 33% in the three expanded leaves stage. For root dry mass, up to 66.36% of reduction is achieved when plants are submitted to total defoliation in panicle defoliation stage (Table 5). After defoliation, roots has lower priority in photoassimilates distribution and the plant tends to translocate the greatest amount for leaf growth, in order to restore leaves photosynthetic potential (Fulkerson and Donaghy, 2001).

The roots depend on the leaves photoassimilates to grow, so with the defoliation the production of photoassimiates is lower and less amounts are directed to the roots. The roots are heterotrophic and, according

Table 6. Total plant dry mass (g) for the experiment of levels and stages of defoliation on BRSS 610 sorghum crop. Nova Xavantina – MT, Brazil, 2013.

Defoliation stage	Defoliation level (%)			
	33	66	99	Mean
Three expanded leaves	160.03	100.15*	95.73*	118.63 A*
Six expanded leaves	123.14*	110.49*	94.30*	109.31 A*
Panicle differentiation	83.72*	69.32*	46.97*	66.67 B*
Booting	74.19*	62.37*	35.03*	57.20 B*
Mean	110.27*	85.58*	68.01*	87.95*

Means followed by the same lowercase letter in line and capital letter in column are from the same group according to Scott Knott test at 5% of probability. *Means statistically different from control mean without defoliation (175.27 g), according to Scott Knott test at 5% of probability.

Table 7. Percentual of variation in plant total dry mass compared to the control without defoliation in BRS 610 sorghum crop submitted to 33, 66 and 99% of defoliation levels and four defoliation stages, grown in a greenhouse. Nova Xavantina – MT, Brazil, 2013.

Defolation stage	Defoliation level (%)		
	33	66	99
Three expanded leaves	- 8.69	- 42.85*	- 45.38*
Six expanded leaves	- 29.74*	- 36.96*	- 46.19*
Panicle differentiation	-52.23*	- 60.44*	- 73.20*
Booting	- 57.67*	- 64.41*	- 80.01*

*Means statistically different from control mean without defoliation, according to Table 6.

to Nielsen et al. (1999), are highly dependent on the synthetized photoassimilates to grow. About 60% of the carbon assimilated by the leaves is consumed by the roots, to provide the root system needs (Moreira and Silqueira, 2001).

According to Richards (1993) the root system growth is stopped when 40 to 50% of the shoot part is removed. Thus, the root system reduction with the defoliation level increase can be assigned to the roots carbon remobilization, directed to the shoot part. This results in lower root system as defoliation and carbon distribution increases.

On the other hand, the variable root dry mass has a great importance because it is through the root system that plants absorb nutrients and water to photosynthesis, and according to Taiz and Zeiger (2009), the reduction in this variable has a strong influence on plant development. Defoliation carried out at all stages and defoliation levels led to biomass reduction, as can be seen in the percentage variation of total plant dry mass data for stages and defoliation levels, compared to the control (Table 7). However, the defoliation held at the three expanded leaves stage and at 33% level did not differ from the control.

It is known that the leaves of plant structures that are able to intercept solar radiation and transform it into photoassimilates for the plant and throughout the photosynthetic apparatus contained in the leaves, are able to perform photosynthesis (Diogo et al., 1997). Thus, Carvalho (2002) demonstrated that the main physiological adaptation of plants after the leaves loss is the carbon translocate to the expansion areas, to provide the formation of new leaves. However, these physiological changes affect plant development, as demonstrated in this study. It is possible to observe that the presence of the leaves has fundamental importance for the photoassimilates production of the plant, in a satisfactory amount so the growth of roots and shoot parts is possible.

In this context, Magalhães et al. (2008) emphasize that photosynthesis provides about 90 to 95% of the plant dry mass, thus, the plant depends on the leaf that has all the photosynthetic apparatus and the growth rate depends on the expansion of leaf area and the rate of photosynthesis per unit of area. Therefore, it is a parameter of great importance when emphasize the sorghum growth analysis, therefore, a greater leaf area contributes to greater assimilation of nutrients that will be transported to the panicles (Castro et al., 2008).

The reduction in shoot dry mass for all stages and defoliation levels reflects the lower root dry mass and although with no statistical difference, a lower mean was observed. Therefore, the associations of these factors resulted in the decrease of biomass production of BRS

610 sorghum. Despite the forage sorghum good capacity of regrowth, in the conditions of this study it was not observed. In this context, further studies under different field conditions should be performed in order to get more information on this topic. Based on the results and according to the evaluated agronomic traits, the sorghum plant height and stem diameter are not influenced by stage and levels of defoliation. The shoot dry mass production of the BRS 610 sorghum is affected when submitted to any stage and level of defoliation.

Conflict of Interest

The authors have not declared any conflict of interest.

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