Influence of inter row spacing and plant densities in cultivate of sorghum on cutting management

Mikael Neumann[1], João Restle[2], José Laerte Nörnberg[3], Rodrigo Oliboni[4], Luiz Giovani de Pellegrini[5], Marcos Ventura Faria[1], Fabiano Marafon[6]

Abstract

The cultivation of sorghum in management of cutting is little studied, considering its importance of use in the feeding of ruminants. This work aimed to evaluate the associative effect of spacing between rows(30, 50 and 70 cm), plant densities (300, 450 and 700 thousand plant ha^{-1}) and periods (50, 85 and 125 days of plant) of the productive and qualitative potential of cultivated forage sorghum, on cutting management. The forage production increased linearly with the increase in inter row spacing independent on the plant densities, in the proportion of 103.9 kg ha^{-1} of dry matter (DM) for each increase of 10 cm in inter row spacing. No significant interaction (P>0.05) was observed between spacing between rows and plant densities for FND, FAD and LIG of sorghum plant on cutting management, just as no significant interaction (P>0,05) was observed between period of utilization of sorghum matched with the factors spacing between rows and plant densities for FND and LIG of sorghum plant. The FND and LIG contents decreased linearly with the increase of spacing between rows, independent on plant densities on the proportion of 0.34% and 0.32% of DM for every increase of 10 cm in inter row spacing. The change of 30 to 70 cm caused larger dry matter production, without changing plant structural composition, just as reduced the ADL and NDF values. The plant densities did not affected the production plant composition and nutritional value of sorghum plant on court regiment.

Key Words: plant densities**;** acid detergent fiber; neutral detergent fiber; lignin; dry matter production

Introduction

The restriction of the nutrient consumption is the main factor capable of limiting the production of animals in pasture, mainly in tropical regions, where there are significant changes in the composition and availability of forages over the year. The forage potential of a plant is related to its productive capacity and its nutritional value to animal feeding (TOMICH et al., 2004). Most of the tropical forage grasses present high potential of production per unit of area, considering that the geographic distribution of these plants is determined by interactions between climate and soil factors. According to NASCIMENTO (1997), the appropriate management of the pastures enables a maximization of animal production per area, trough great combination of forage yield and efficient conversion of the produced biomass in animal product, emphasizing, though, that the forage yield is function of the conditions of the soil, climate, species characteristics and their management, while the conversion of the biomass in animal product is function of its nutritive value, consumption and genetic potential of the animal.

The use of cultivated pasture is indicated to reduce the effect of the periods of food scarcity of the animals in pasture, however its composition and productivity are influenced by biotic factors (NASCIMENTO and GUIMARÃES, 1997). Cultivated pastures with summery cycle (C_4) have been used to maximize the production of meat and milk per hectare, considering that, among them, the consumption of sorghum (*Sorghum bicolor* x *Sorghum sudanense*) have gained evidence in the last years, mainly in regions where the period of drought

Received on: 10 feb. 2010. Accepted for publication on: 03 jun. 2010.

1 Agronomic engineer, Dr., Researcher from NUPRAN (Núcleo de Produção Animal – Nucleus of Animal production), Professor of the Master's degree course in Agronomy from UNICENTRO – Rua Simeão Camargo Varela de Sá, 03, 85.040-080, Guarapuava, PR. E-mail: mikaelneumann@hotmail.com e mfaria@unicentro.br

2 Agronomic Engineer, Ph.D., Professor of the Post-graduation course in Animal Husbandry from UFG, Researcher from the CNPq. email: jorestle@terra.com.br

3 Veterinarian, Dr., Professor of the post-graduation course in Food Technology of UFSM. email: jlnornbergi@bol.com.br

4 Agronomic Engineer, Master in Agronomy at UNICENTRO. E mail: roliboni@hotmail.com

5 Veterinarian, Dr., Professor of the Department of Veterinary Medicine from Unicentro. email: depellegrini@yahoo.com.br

6 Student of Veterinary Medicine, trainee of the Animal Husbandry Nucleus from UNICENTRO email: Fabiano_marafon@hotmail.com

occur with frequency, limiting the production of forage. According to NEUMANN et al. (2005a), the sorghum culture is an excellent alternative to the cattle breeder minimize the problems which come from the seasonality of the production of forage in the period of food scarcity, besides it can enable the production and providence of good quality food aiming to maximize the animal performance, either in order to produce milk or meat. On the other side, the economical situation challenges the production system of the meat and milk farms to produce forage in quantity, quality and low cost available over the year (MELLO et al., 2003).

The sorghums used in cutting and/or pasture management are interspecific hybrids obtained trough crossing between Sudan Grass (*Sorghum sudanensis*) and the sorghum genotypes (*Sorghum bicolor*). The product of this breeding is characterized by giving high speed of growth, good capacity of tillering, high production of dry matter and resistance to drought. Forage sorghum in cutting or pasture management have become a viable alternative, due to the globalization of the economy and the necessities of management and production of pasture with great productive potential (CHIELLE et al., 2000).

Thus, among the several factors which contribute to good forage and/or cutting sorghum productivity, the search for the best arrangement in the sorghum plant distribution is of major importance. For COELHO et al. (2002), the seeding density may range in function of the size and the architecture of the forage plant, of the tolerance to tillering and the purpose of which the planting is destined, i.e., the seeding density is related to the cultivar, water and nutrient availability to the sorghum. The larger the availability of these factors, the higher the recommended density, considering that, normally, in smaller sorghum cultivars with more erect leaves, it is used higher densities and narrower spacing, aiming at an increase in productivity.

According to RESENDE et al. (2003), the increase of the number of plants per unit of area may be performed trough the reduction of the spacing between seeding lines. In the evaluation of the effects of the population of plants over the morphologic and agronomic characteristics of pearl millet (*Pennisetum glaucum*), MOREIRA et al. (2003) concluded that the larger plant population provide a larger degree of tillering, due to the smaller diameter of the plant stalk, characteristic undesired when the objective is to produce forages with quality and in quantity.

GONTIJO NETO et al. (2006) recommend in the sorghum culture cutting the spacing between lines ranging from 0.30 to 0.60 m and the population between 200 and 300 thousand plants ha^{-1}, while, for pasture or haymaking, they recommend spacing between lines inferior then 0.30 m with population ranging between 200 and 300 thousand plants ha^{-1}. For EVANGELISTA (1995), in a general way, a good density must range from 10 to 20 plants/m^2 between the different tropical forages used in the form of cutting and/or pasture. In this context, for REZENDE et al. (2003), the definition of the best arrangement of plants in the area also must be determined trough the choice of the cultivar, due to the morphological characteristics of each material and that the appropriated choice of seeding density and spacing between lines is established in function of several situations in the culture management.

The objective of the work was to evaluate the associative effect between spacing between planting lines, plant density and period of evaluation during the vegetative cycle of the culture, over the productive and qualitative vegetative performance of the forage sorghum, managed in cuttings.

Material and methods

The experiment was conducted in the Federal University of Santa Maria (UFSM), located in the Depressão Central of Rio Grande do Sul, with altitude of 95 m, at 29º 43' of South latitude and 53º 42' of West longitude. The soil of the area used for the cultivation belongs to the mapping unit of São Pedro, classified as Argiloso Vermelho Distrófico Arênico[1]. The climate of the region is Cfa (Subtropical humid), according to the classification of Köppen, with average annual rainfall of 1769 mm, average annual temperature of 19.2 °C in July and maximum average of 24.7 °C in January, insolation of 2212 annual hours and air relative humidity of 82% (MORENO, 1961).

The soil of the experimental area presented the following chemical characteristics: pH in water: 4.8; P: 19.3 mg L^{-1}; K: 79.0 mg L^{-1}; MO: 3.1%;

1 According to the Brazilian soil classification

Al: 2.2 $cmol_c$ L^{-1}; Ca: 7.9 $cmol_c$ L^{-1}; Mg: 4.0 $cmol_c$ L^{-1}; effective CTC efetiva: 14.2 $cmol_c$ L^{-1}; and base saturation: 63%. In Table 1 it is presented the average values of rainfall, temperature and normal insolation occurred in the period of conduction of the experiment.

The present research work evaluated the vegetative performance of the sorghum in cutting, under three spacing between planting lines (30, 50 and 70 cm), associated to three population densities (300, 450 and 600 thousand plants ha^{-1}) in evaluation periods during the culture cycle (50, 85 and 125 days after planting).

The sorghum hybrid used was AG-2501C (*Sorghum bicolor* x *Sorghum sudanense*), characterized as of the forage type and indicated to system of use in cutting and/or pasture. It was planted in November 11th under system of conventional planting, over the cultural residues of the pasture of annual ryegrass (*Lolium multiflorum*) dried with Glifosate. The planting was manual, with base fertilization inline in the proportion of 300 kg ha^{-1} of fertilizer in the NPK formulation (10-18-20) in approximated depth of 8 cm, which was followed by seeding with approximated depth of 1 cm. The experimental parcels had total individual area of 35 m^2 (5 x 7 m) and useful area of 24 m^2 (4 x 6 m). The sorghum seeds were treated before the planting with the insecticide Tiodicarb.

The adjustment of the plant population was manual, performed 15 days after planting, determining population of 300, 450, 600 thousand plants ha^{-1}, according to the evaluated treatments. The control of undesired plants was performed 20 days after the planting trough hoeing and nitrogen fertilization of the cover was performed in the proportion of 225 kg ha^{-1} of urea (100 kg ha^{-1} of N), divided in three applications (52, 84 and 110 days after the planting period).

The vegetative performance of the sorghum was evaluated when the plants of each parcel presented average height of 95 cm ± 5 cm, trough manual harvest, with average cutting height of the plants at 20 cm of the soil, in the following days: Dec 29th (1st harvest: 50 days after planting), Feb 2nd (2nd harvest: 85 days after planting) and Mar 14th (3rd harvest: 125 days after planting).

After the cutting and weight of the plants of each parcel to determine the production of green matter, samples composed by entire plants and their structural compounds stem and leaves were collected to weight and pre-drying in forced air oven at 55 °C for 72 hours and/or until it achieved constant weight, to determine the content of partially dry matter, being later crushed in mill of the type Miley, with a 1 mm mesh sieve.

In the pre-dried samples of the entire plant it was effected the determination of the content of crude protein (CP), of fiber in the acid detergent (FAD) and of lignin (LIG), according to AOAC (1995). The content of fiber in neutral detergent (FND) was determined according to a technique described by VAN SOEST et al. (1991), using thermostable α amilase. The obtained results were corrected to total dry matter.

The experiment was conducted in accordance with the completely randomized design with four replications, in which each replication was a sample of plants of linear 48 m of planting line, using sub-plot parcels, in a factorial scheme 3 x 3 x 3, being three planting spaces, three population densities and thee evaluation periods during the vegetative cycle of the culture.

The data collected for each variable were

Table 1. Average values of rainfall, temperature and insolation in normal conditions and conditions occurred during the period of conduction and management of the forage sorghum in courts.

Month/Year	Rainfall (mm)		Temperature (°C)		Insolation (hours)	
	Normal	Occurred	Normal	Occurred	Normal	Occurred
November	132.2	99.5	21	21.7	223.3	247.2
December	133.5	114.3	22.7	23.1	244.7	231.0
January	145.1	110.7	24.6	25.1	225.2	251.5
February	130.2	141.9	24.0	23.7	196.7	199.4
March	151.7	82.4	22.2	24.6	197.5	227.7

Source: Data of the Meteorological Station of the Department of Crop Science from UFSM, Santa Maria – RS.

submitted to the analysis of variance, trough the statistic program SAS (1993) and the differenced between the averages were analyzed by the Tukey test at the level of significance of 5%. The data was also submitted to the analysis of polynomial regression, considering the variable period of evaluation (until 125 days), trough the procedure "proc reg" of the program SAS (1993).

Results and discussion

There was no significant effect of the interaction between the spacing between lines and the population density, as well as there was no statistic difference (P>0,05) between the period of use of sorghum, combined with the factors spacing between lines and population density to the distribution of production of dry matter (PDM) and to the participation of leaves in the physical composition of the plant in cutting management, respectively (Tables 2 and 5).

Significant differences were observed in the production of dry matter (Table 2), in an isolated way between spacing between planting lines and the periods of evaluation. The production of forage (PDM) increased linearly with the increase of the spacing between lines (PDM = 2395.9181 + 10.3929E), independent on the population density of the farming, in the proportion of 103,9 kg ha^{-1} of DM for each increase of 10 cm in the spacing between planting lines.

TOMICH et al. (2004) evaluating 23

Table 2. Distribution of dry matter production (DMP) and participation of leaves (PL) in the physical structure of the sorghum plant managed in cuttings, in function of the spacing between lines associated to the population density, in accordance with the period of evaluation.

Treatments		Evaluation in the vegetative cycle			
Spacing between lines	Plant density	1ª harvest (50 DAE)	2ª harvest (85 DAE)	3ª harvest (125 DAE)	Total DMP (kg ha^{-1})[1]
		Distribution of the DMP (% of the total)			
30 cm	300 thousand	35.6	38.2	26.2	7161
30 cm	450 thousand	33.2	43.9	22.9	7731
30 cm	600 thousand	32.7	35.6	31.7	8907
Average spacing 30 cm					**7933**
50 cm	300 thousand	24.2	41.0	34.8	9483
50 cm	450 thousand	28.1	41.7	30.3	9075
50 cm	600 thousand	35.0	39.9	25.1	8811
Average spacing 50 cm					**9123**
70 cm	300 thousand	24.3	41.6	34.1	9999
70 cm	450 thousand	23.3	40.8	35.9	9357
70 cm	600 thousand	31.2	42.3	26.6	8184
Average spacing 70 cm					**9180**
Equations of regression		DMP: -1713.338 + 119.574D – 0.679D^2 (R^2: 0.2464; CV: 27.23%; P=0.0001)[1]			
		DMP: 2395.9181 + 10.3929E (R^2:0.0353; CV:30.66; P=0.0500)[2]			
		Participation of leaves in the plant (% in the DM)			Average
30 cm	300 thousand	56.2	49.1	52.5	52.6
30 cm	450 thousand	56.1	47.9	56.1	53.4
30 cm	600 thousand	55.4	51.6	44.8	50.6
50 cm	300 thousand	56.2	47.8	56.9	53.6
50 cm	450 thousand	57.6	47.0	53.8	52.8
50 cm	600 thousand	56.0	45.2	53.8	51.7
70 cm	300 thousand	58.9	46.0	51.0	52.0
70 cm	450 thousand	57.6	47.6	52.4	52.6
70 cm	600 thousand	57.5	51.0	52.5	53.7
Equations of regression		PL: 90.112 – 0.911D + 0.0049D^2 (R^2: 0.3172; CV: 10.05%; P=0.0001)[1]			

[1] - *D = period of harvest of the forage, ranging from 50 to 125 days after planting.*

[2] - *E = spacing between planting lines, ranging from 30 to 70 cm.*

sorghum genotypes, cultivated with spacing between lines of 70 cm and populations ranging between 287.1 and 509.0 thousand plants ha^{-1}, harvested 57 days after the emergence of plants, with cutting height of 15 cm, verified PDM ranging between 3.5 and 5,8 t ha^{-1} in management of single cutting, suggesting that this variation was linked to the factors of genetic variability, distinct demands of soil fertility and availability of water, planting period, stage of plant development, successive cuttings and number of plants per unit of area. The same authors also verified that there was similarity to the data of productivity between experimental genotypes and commercial material, indicating that the management of sorghum in cutting system must comprehend distinct conditions of evaluation of the forage yield in successive cuttings, considering the stage of plant development and similar conditions of cultivation management, as an example, the height of plant cutting.

The linear increase in the PDM with the increase in the spacing between lines may be result of the genetic characteristics of the forage sorghum in cutting management, suggesting that larger spacing between lines modified the habit of erect growth of the sorghum plant, to the semi-prostrate, determining better space distribution of the tillers of the plants in the area, generating effect of anticipate cover of the soil surface and improving the use of sunlight in the production of photoassimilates.

The distribution of the PDM had quadratic effect ($PDM = -1713.338 + 119.574D - 0.679D^2$) during the period of utilization of sorghum in cutting management, presented the point of maximum accumulation of dry matter at 88.05 days. In a general way, under the analysis of the numeric values of the distribution of the production of sorghum forage in cutting management, independent on the spacing between lines and the plant density, 40.5% of the total dry matter produced was obtained in the second harvest comparing to the first and third harvests, both with 29.7%. The participation of leaves in the physical structure of the plant managed in cuts also has quadratic behavior, with average point of minimum participation of leaves, in the plant structure at 93 days, considering the period of utilization from 50 to 125 days after the establishment of the planting (Table 2).

NASCIMENTO and GUIMARÃES (1997) report that the small residual leaf area at the harvest of the shoot has little importance, since it presents low photosynthetic efficiency in function of the previous shading or of the advanced age. Thus, it may be advantageous the removal of practically all the leaf area by cutting or pasture, leaving the following regrowth dependent of new leaves of high photosynthetic efficiency produced quickly if the level of reserves of soluble carbohydrate in the plant crown is appropriated, even considering that remaining leaves of low photosynthetic efficiency may serve as source of mobile nutrients, as N and S trough translocation of the older leaves to the younger.

There was no significant effect of the interaction between spacing between lines and population densities for the content of dry matter (DM) and of crude protein (CP) of the sorghum plant in cutting management, as well as there was no statistical difference between period of use of sorghum, in a combined way, with the factors spacing between lines and population density (Tables 3 and 5).

The content of DM and CP did not present significant difference, in an isolated form, to the factors spacing between planting lines and population density ($P>0,05$), while for period of utilization there was difference ($P<0,05$). The content of DM of the plant increased linearly with the use of the culture of sorghum in cutting managements, in the proportion of 0.1891%, every day of advance in the period between 50 and 125 days after the establishment of the culture (Table 3). Meanwhile, for the content of CP, the behavior was quadratic, showing point of minimum concentration 94.06 days after the culture establishment.

The increase in the content of DM of the plant, according to ZAGO (1991) is a result of the participation of the fractions stem and leaves in the sorghum plant structure, in which stem is the portion which contributes the less with the increase of the content of DM, followed by leaves. The increase of the participation of leaves in the physical structure of the sorghum plant, in cutting management, was the responsible for the change in the content of DM and of the harvest at the reproductive phase, to maintain the plant in the vegetative stage and enable successive cuttings.

Table 3. Content of dry matter (DM) and crude protein (CP) of the sorghum plant managed in cuttings, in function of the spacing between lines associated to population density, according to the evaluation period.

Treatments		Evaluation in the vegetative cycle			
Spacing between lines	Plant density	1ª harvest (50 DAE)	2ª harvest (85 DAE)	3ª harvest (125 DAE)	Average
		DM (%)			
30 cm	300 thousand	10.92	16.74	24.02	17.23
30 cm	450 thousand	11.16	16.45	25.32	17.64
30 cm	600 thousand	11.76	15.01	25.12	17.29
50 cm	300 thousand	10.29	15.16	27.97	17.81
50 cm	450 thousand	11.50	16.09	23.55	17.05
50 cm	600 thousand	11.19	15.79	24.82	17.27
70 cm	300 thousand	10.87	15.74	25.64	17.41
70 cm	450 thousand	11.15	15.72	27.10	17.99
70 cm	600 thousand	11.22	15.46	23.45	16.71
Equation of regression[1]		MS = 0.9797 + 0.1892D (R^2: 0.8304; CV: 15.22%; P=0.0001)			
		CP (% in the DM)			
30 cm	300 thousand	15.65	10.98	12.30	12.98
30 cm	450 thousand	14.64	13.02	12.92	13.53
30 cm	600 thousand	13.82	12.74	11.50	12.60
50 cm	300 thousand	15.29	12.30	13.35	13.65
50 cm	450 thousand	15.73	12.65	13.83	14.07
50 cm	600 thousand	13.96	11.34	15.06	13.45
70 cm	300 thousand	16.83	12.74	12.27	13.95
70 cm	450 thousand	16.09	12.02	15.54	14.55
70 cm	600 thousand	15.44	11.72	13.63	13.60
Equation of regression		PB = 26.4105 – 0.3016D + 0.0016D^2 (R^2:0.2838; CV: 15.16%; P=0.0001)			

[1] – D = period of harvest of the forage, ranging from 50 to 125 days after planting.

NEUMANN et al. (2005b) evaluating sorghum AG-2501C, in system of continuous pasture, for three periods of 28 days each report that the average values of DM and CP, respectively, of 9.9 and 5.8% (1st period), of 13.5 and 5.2% (2nd period) and of 16.7 and 5.5% (3rd period) in stem and of 16.7 and 14.2% (1st period), of 15.2 and 13.1% (2nd period) and of 16.9 and 14.0% (3rd period) in leaves were values different from those found in the present work, justified in function of the system of plant harvest management. AITA (1995), when studying different pastures of hot season, verified that the contents of CP of the sorghum plant did not range according to the evaluation period, remaining constant with small variation among periods, while the content of CP in the stems decreased with the advance in the phenological stage.

FRIZZO (2001) reported that the reduction in the nutritive value of the forage with the advance of the plant cycle is due to the increase of structural carbohydrates and lignin in the sustaining tissues of plant, as well as to the reduction of the relation leaf:stem and to the increase in the percentage of senescent material in the plant, which present low digestibility.

The content of fiber in neutral detergent (FND), fiber in acid detergent (FAD) and lignin(LIG) of the sorghum plant in cutting management did not show significant effect of interaction (P>0,05) between spacing between lines and population density, as well as there was no statistical difference (P>0,05) between period of utilization of sorghum, in a combined way, with the factors spacing between lines and population density, for the contents of FND and LIG (Tables 4 and 5). For the content of FAD, it was observed significant differences between the spacing between the planting lines and the periods of evaluation.

ALVAREZ et al. (2005) evaluated the behavior of hybrids of maize for the silage of different

leaf architectures, submitted to two spacing between lines and two densities of plants, in two agricultural years, and verified that the increase on the plant density to 75.000 plants ha^{-1} provided reduction in the contents of FND, being this behavior attributed possibly to the formation of a more fibrous stem, analyzed in lower plant density (50.000 plant ha^{-1}).

The contents of FND and LIG of the plant increased linearly with the use of the sorghum culture in cutting management, in the proportion of 0.0343 and 0.0022%, respectively, at each advance day in the period of utilization between 50 and 125 days after the culture establishment. Significant differences were also observed in the FND and LIG of the plant (Table 4), in an isolated way, between spacing between planting lines. The content of FND and LIG decreased linearly with the increase in the spacing between lines, independent on the population density, respectively, in the proportion of 0.34 and 0.32% in the DM for each increase of 10 cm in the spacing between planting lines.

There was statistic difference (P>0,05) between period of utilization and spacing between lines to the content of fiber in acid detergent (FAD) of the sorghum plant in cutting management (Tables 4 and 5). The sorghum plant, with the advance in the period of utilization, changed the contents of FAD in function of the spacing between planting lines, show points of maximum concentration of FAD at 74.39; 81.56 and 96.23 days, respectively, in the spacing 30, 50 and 70 cm.

In the overall data analysis of the production of dry matter, the participation of leaves in the plant structure and the contents of FND and LIG of the sorghum plant, managed in cuttings, one may suggest the possibility of obtaining more constancy of quality in the cultivation with spacing between lines of 70 cm, independent on the population density. The present work shows that more researches should be directed to the area of crop science, since the data in the literature concerning the qualitative behavior of forage sorghum, in cutting management, are scarce, which do not make it possible to establish a reliable method of culture management aiming to ally maximum production of dry matter, fast capacity of regrowth after cuts and good forage nutritive values.

Conclusions

The seed density did not affect the production, physical compositions and the nutritive value of the sorghum plant in cutting management. The contents of dry matter and crude protein did not change in function of the associative cultural management between spacing between planting lines and population density. The change in the spacing from 30 to 70 cm provided higher DM production and increase in the participation of leaves in the physical composition of the plant, as well as reduced the values of FND and LIG.

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