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Full Length Research Paper

Production and quality of forage cane based on variety, row spacing and time of harvest.

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The aim of the current study was to evaluate the productivity of biomass and the bromatologics attributes of two sugar cane varieties, distance between planting, and time of harvest. The experiment was conducted in Presidente Prudente in the state of São Paulo (Brazil). A randomized complete block design, with split sub sub-division, was used. In the plots were installed planting spacings of 1.0 and 1.5 m, in the sub-plots IAC 862480 and RB867515 varieties, and sub sub-plots to harvest three times (180, 270 and 360 days). Variety IAC862480 was higher compared to RB867515 tillering, the spacing of 1.5 m better than 1.0 m. Productivity and the percentage yield of dry matter was higher in variety RB867515 harvested 360 days after planting. Spacing of 1.0 m for variety RB867515 resulted in greater productivity compared to the other variety and spacings evaluated. Crude protein, ash, neutral detergent fiber, acid detergent fiber, total digestible nutrients and degrees Brix suffered interference of the date cutting sugarcane, with increased in the values.

Keywords: *Sccharum spp.*, animal feed, bromatology.

INTRODUCTION

Sugar cane (*Saccharum* spp.) is currently one of the most important crops to the Brazilian economy. It is the main raw material used for production of sugar and ethanol. Approximately 10% of Brazilian cane sugar is used for animal feed, generating a massive great acceptance among ranchers for presenting characteristics such as ease of cultivation, cut during the dry period, the possibility of self-storage and conservation field, besides the persistence of culture and high production per hectare.

According Siqueira et al. (2012), the realization that sugar cane could be a competitive option forage for cattle occurred recently as a result of technological developments, such as chemical hydrolysis, release of varieties suited, perfecting procedures silage, among other factors. Furthermore, the use of sugar cane as animal feed has increased due to higher productivity of biomass compared to corn silage and sorghum, which is associated with a significant supply of forage perennial grass during periods of drought in the autumn-winter of Central Brazil (Balsalobre et al., 1999).

A sugar cane crop can be comprised of numerous varieties that possess diverse characteristics. For instance, when specifically intended for animal feed, important features include the dry matter yield, quality, harvest efficiency, and bromatologic characteristics (Freitas et al., 2006). However, the choice of sugar cane variety for forage production generally consider only agronomic information (e.g. yield, drought tolerance, disease resistance, vigor of regrowth, etc.), with limited data on nutritional biomass quality (Morelli et al., 1997).

In a study by Strieder et al. (2008), another factor that may increase production of forage is the spacing between furrows. In general, the spacing between a particular culture is based on several factors, such as edaphoclimatic, cultivate, plant management, machine traffic, purpose of exploration and technological level adopted.

Graziano (1988) evaluated sugar cane planted with 0.9, 1.0, 1.1 and 1.4 m between rows and found that reducing the spacing increased productivity and ensured the rapid closure of lines, lowered the cost of herbicide and fertilizer per ton of sugar cane, lowered lodging and reduced susceptibility to erosion. However, operating costs and expenses for planting seedlings were higher since it reduces the spacing of the crop. It was also determined that spacing of 1.0 m between rows led to the best productivity and operational efficiency, as the machine traffic was better than at a spacing of 0.9 m and the yield was higher when compared to the greater spacing.

Galvani et al. (1997) studied spacing variations ranging from 0.9 to 1.9 m between rows of sugar cane in five locations, using different varieties, in plots of sugarcane third ratoon, and observed an increase in productivity due to reduced spacing, which was primarily attributed to an increase in leaf area index. However, the gain level was dependent on environmental conditions, variety and age of the stand. Furthermore, Muraro (2011) reduced cane row spacing from 1.3 m to 0.9 m, resulting in increased crop yield by nearly 16% by the first harvest, with a 22% average increase after two harvestings.

On plant cane and first ratoon, Espironelo et al. (1987) studied the interaction between variety, spacing and nitrogen and potassium fertilizer and found that, regardless of variety or fertilizer, row spacing of 1.20 m straw yielded higher per unit area than spacing of 1.50 m. However, production of stalks per meter was higher for wider spacing. In addition to the possibility of increased productivity by reducing spacing, these results show that a lower volume of plant material per meter of ridge can be obtained, promoting operational efficiency of mechanical harvesting of sugar cane.

The aim of the current study was to evaluate the yield of cane and bromatologics attributes of two varieties of sugar cane, the IAC862480 recommended feed and RB867515 for ethanol production, planted with row spacings of 1.0 and 1.5 m, and collected over three seasons after 180, 270 and 360 days after planting.

MATERIALS AND METHODS

The experiment was conducted under field conditions, in paddy plant cane, at the experimental field of Universidade do Oeste Paulista (Unoeste), located at 51° 26' 00" longitude and 22° 07' 30" latitude at an altitude of 433 meters, in the city of Presidente Prudente-SP, from November 2007 to December 2008. Figure 1 presents the daily maximum and minimum temperatures and rainfall occurring during the conduct of the experiment.

The soil of the study area has been characterized by Embrapa (2006) as typic dystrophic Argisoil (*Rhodustults-PVd*) and is wavy with good drainage. Samples were collected to characterize the soil's chemistry and the grain sizes at the 0-20 and 20-40 cm layers. The respective results as follows: pH 5.9 and 5.2 ($CaCl_2$ 1 mol L^{-1}); 18 and 11 g dm^{-3} of OM; 16 and 7 mg dm^{-3} of P_{resin}; 2.7 and 3.6 $cmol_c$ dm^{-3} of H+Al; 0.1 and 0.1 $cmol_c$ dm^{-3} of K; 3.8 and 2.0 $cmol_c$ dm^{-3} of Ca; 1.2 and 6.0 $cmol_c$ dm^{-3} of Mg; 5.2 and 2.7 $cmol_c$ dm^{-3} of SB (sum of bases); 6.9 and 6.3 $cmol_c$ dm^{-3} of CEC (cation exchange capacity); 74 and 43% base saturation (V); 740 and 760 g kg^{-1} sand; 80 and 30 g kg^{-1} silt; and 180 and 210 g kg^{-1} clay.

Was conducted soil tillage with plowing and harrowing for incorporating lime and gypsum (Raij et al., 1997), and systematization of the land. The experiment was initiated on 09/11/2007 using sugar cane seedlings previously selected in terms of physiological and sanitary quality. The furrows were opened with tractor with 25-30 cm deep, with spacing of 1.0 m and 1.5 m between rows, according to the experimental design. This operation were applied 400 kg ha^{-1} of fertilizer NPK 04-30-10 (Raij et al., 1997) and 400 g active ingredient (ai) ha^{-1} of the insecticide Fipronil, incorporated into the soil at the bottom of the grooves. The sugar cane seedlings previously topped and tailed and

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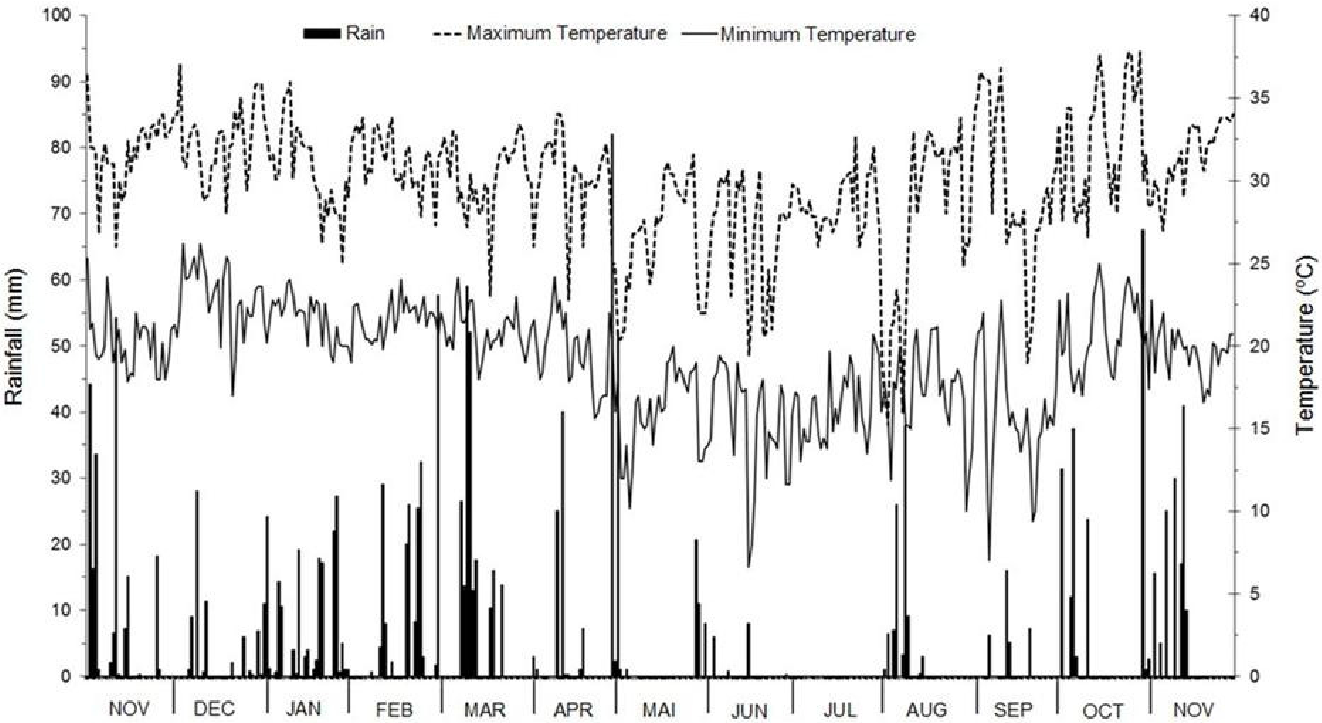

Figure 1. Daily maximum and minimum temperatures and precipitation from November/2007 to November/2008, in the Experimental Farm by UNOESTE, Presidente Prudente-SP, Brazil.

husked ears were planted in such a way to have 18 viable buds per meter of furrow, the seedlings being sectioned stalks with 3-4 buds and manually covered with 10-15 cm of soil.

The experimental design was a randomized complete block design with four replicates. Treatments were arranged in split-splitplots as follows: the plots were installed spacing between rows of crops of 1.0 m and 1.5 m, the splitplots varieties IAC862480 (forage) and RB867515 (sugarcane), and split-splitplots three cutting times (180, 270 and 360 days after planting). The split-splitplots consisted of six rows of crops with 6 m long, and the floor area of the same was formed by the four central rows by 4 m long, 1 m discarding tillage as margin at the longitudinal edges.

Weed control was accomplished by spraying the tebuthiuron herbicide from a tractor at a dose of 1.0 kg ai ha^{-1} pre-emergence. Thirty-eight days after planting (DAP), post-emergence herbicide was applied at 2.3 kg ai ha^{-1} of MSMA (monosodium methyl arsenate), which was directly sprayed between rows of crops. At 42 DAP, became fertilization with 50 kg N ha^{-1} (urea) and 80 kg ha^{-1} K_2O (potassium chloride), according to Raij et al. (1997).

Counts were performed based on the number of stems (tillers) per meter at 180, 270 and 360 days after planting at three random points from 2 m contiguous row crop, the floor split-splitplots area. Manual harvest was performed at 180, 270 and 360 days after planting, and emerge without dawn and without removing the straw culms, three sub-samples of 2 m contiguous row crop at random points in the useful split-splitplots area. There was weighing all aerial parts of the samples cane (stem + leaves + pointers) to determine the mass productivity of green matter (GM) and dry matter (DM).

Immediately after cutting, were randomly collected 20 stems with leaves and pointers, which had portions of broth extracted between the seventh and ninth internode for determining the Brix through refractometer field Instrutherm RT-30-ATC Model. Then, 20 stem such beams were weighed and submitted to chopping and emerges without detrash, using forage stationary machine in such a way to obtain particles between 1 and 2 cm. Fresh samples were then collected and prepared for measurement of dry matter (DM) using oven drying under forced aeration at 60°C until a constant weight was observed. After drying, the samples were ground and passed through a 1 mm sieve. Crude protein (CP), ether extract (EE), mineral matter (MM), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and total digestible nutrients (TDN) were quantified according to methods previously described by Silva and Queiroz (2002).

The results were subjected to analysis of variance, followed by Tukey's test. Statistical significance was defined as $p<0.05$.

Table 1. Tillering, mass productivity of green matter (GM) content (%) and yield of dry matter (DM) of shoots total plant cane (stem + leaves + pointers), due to row spacing, variety and time trimming.

Treatment	Nº tillers m^{-1}	GM	DM	DM
Spacing		Mg ha^{-1}	%	Mg ha^{-1}
1.0 m	11.62 ^{ns}	128 a	27.5 ^{ns}	35 a
1.5 m	13.18 ^{ns}	104 b	27.9 ^{ns}	29 b
Variety				
IAC 862480	13.10 ^{ns}	107 b	26.5 b	28 b
RB 867515	11.70 ^{ns}	124 a	28.8 a	36 a
Cut Time				
180 days	14.41 a	117 ab	23.5 b	28 b
270 days	10.95 b	107 b	29.1 a	31 b
360 days	11.84 b	123 a	30.4 a	38 a
Causes of variation	--------------------- F calculated ----------------------			
Spacing (A)	ns	**	ns	**
Variety (B)	ns	*	*	*
Cut time (C)	**	*	**	**
A x B	ns	ns	ns	ns
A x C	*	ns	ns	ns
B x C	**	*	*	**
A x B x C	ns	ns	ns	ns
CV $_{plots}$ (%)	08.2	09.0	5.7	10.6
CV $_{splitplots}$ (%)	16.6	12.5	7.6	17.8
CV $_{split-splitplots}$ (%)	06.5	12.9	7.0	14.4

The following averages for the same letter in the line do not differ by the Tukey test at 5% of probability. **significant at the 5% and 1% level of probability, respectively. ns: not significant.

RESULTS AND DISCUSSION

The results of tillering, yield of green matter (GM) and dry matter (DM) of shoots (leaves + stem + pointers), the two varieties used in the experiment, at spacings of 1.0 and 1.5 m, cut to 180, 270 and 360 days after sowing, are shown in Table 1. A higher tillering at 180 days after planting, with further decrease, which is consistent with the physiology of the plant, because after 180 days there is a reduction and stoppage of tillering, when the plant starts vegetative growth (Segato et al., 2006). Figure 2 illustrates the greater tillering observed at 10 days for the two varieties used in the experiment, and the tillering variety IAC862480 top, there being no statistical difference between varieties in other cutting times.

In Figure 2a, it can be seen that the tillering is greater in the 1.5 m spacing, compared with the spacing 1.0 m, probably due to sunlight for longer penetrate the base of the stem, favoring the larger tillering.

Green matter productivity, percentage and yield of DM at 180, 270 and 360 days are summarized in Figure 3. The variety IAC862480 showed no significant difference in green matter yield over the three harvests, while the variety RB867515 higher productivity at 360 days. The same result was observed for the percentage of dry matter of the two varieties at the three harvest periods. As for dry matter yield, there was no statistical difference between harvests at 270 and 360 days for both two varieties. However, yield was still higher compared to harvest at 180 days.

With regards to spacing of the crop, higher yields of stems + leaves + pointers were obtained with 1.0 m between rows for both varieties included in the study (Table 1). The variety RB867515 was superior in productivity compared to forage biomass IAC862480. At 360 days, productivity of MS and MV was higher than the two previous harvests. As for the interaction, there was a significant response in all parameters studied for the split variety x harvest time (Table 1).

Galvani et al. (1997), studying spacings ranging from 0.9 to 1.9 m in five locations, plots with different varieties and different ages (plant cane the third ratoon), show an increase in productivity due to the reduction of the spacing, and concluded that the main factor that explains the better performance of the crop was the elevation of leaf area index in the reduced spacing. However, the authors observed that gain of productivity was dependent on several factors, including environmental conditions, variety and age of the plants.

Table 2. Brix, ether extract (EE), mineral matter (MM), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), non-nitrogen extract (NNE) and total digestible nutrients (TDN) by aerial total part of the plant cane (stem + leaves + pointers), due to row spacing, variety and harvest time.

Treatment	°BrixX	EEX	MMX	CFX	NDFX	ADFX	CPX	NNEX	TDNX
Spacing		----------	----------	----------	(%)	----------	----------		
1,0 m	17.7 ns	0.63 ns	2.4 ns	26.4 ns	53.7 ns	31.4 ns	3.7 ns	66.9 ns	62.3 ns
1,5 m	18.6 ns	0.65 ns	2.8 ns	26.5 ns	54.0 ns	31.7 ns	3.7 ns	66.7 ns	62.0 ns
Variety									
IAC 862480	17.7 ns	0.64 ns	2.6 ns	26.1 ns	53.8 ns	31.2 ns	3.7 ns	67.1 ns	63.4 ns
RB 867515	18.6 ns	0.64 ns	2.6 ns	26.8 ns	54.0 ns	31.9 ns	3.6 ns	66.4 ns	62.0 ns
Cut Time									
180 days	15.7 b	0.61 ns	2.8 a	28.0 a	51.9 b	29.7 b	3.0 c	66.8 ns	60.3 b
270 days	15.7 b	0.63 ns	2.1 b	26.7 b	54.7 a	31.4 c	4.5 a	66.3 ns	61.2 b
360 days	23.1 a	0.68 ns	2.9 a	24.5 c	54.9 a	33.5 a	3.6 b	67.2 ns	64.8 a
Causes of variation	----------	----------	----------	F calculated	----------	----------	----------		
Spacing (A)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Variety (B)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cut time (C)	**	ns	**	**	**	**	**	ns	**
A x B	ns	ns	ns	ns	ns	ns	ns	ns	ns
A x C	ns	ns	ns	ns	ns	ns	ns	ns	ns
B x C	ns	ns	ns	ns	ns	ns	ns	ns	ns
A x B x C	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV $_{plots}$ (%)	8.4	21.0	24.0	6.6	4.6	6.4	09.5	5.7	7.9
CV $_{splitplots}$ (%)	7.0	21.5	22.6	6.2	4.4	6.8	15.6	3.6	4.2
CV $_{split-splitplots}$ (%)	7.4	18.3	24.2	8.2	5.4	4.7	10.3	5.0	4.5

The following averages for the same letter in the line do not differ by the Tukey test at 5% of probability. **significant at the 5% and 1% level of probability, respectively. ns: not significant.

Muraro (2011) also noted that reducing row spacing from 1.3 m to 0.9 m resulted in increased stalk yield. However, the increase was approximately 16% in plant cane and 22% on average after two harvests, reinforcing that it is necessary to adjust the spacing depending on the variety, management, operating environment and purpose of the crop (i.e. forage production or sugar cane).

Espironelo et al. (1987) studied the interaction between variety, spacing and NK fertilizer on cane first and second cutting, and observed higher cane yield at a spacing of 1.20 m compared to 1.50 m. However, wider spacing, the mass of stems per linear meter groove was greater. In the present experiment, yield of biomass per meter of ridge was not calculated, however, there was an increase in productivity of stems + leaves + pointers after narrower spacing (Table 1), with the prospect of generating lower volume of plant material per meter groove crop destined for animal feed, favoring the operational efficiency of mechanical harvesting of the forage.

Regarding chemical analysis, no significant results for spacing and variety (Table 2), which is in line with Muraro et al. (2009), to study the bromatologic composition a variety of sugar cane planted in spacings of 0.90 m and 1.30 m, and harvested in three cutting times, found no significant effect of spacing on the bromatologic quality. However, similar to the present experiment, time of harvest of sugar cane led to significant differences in chemical composition.

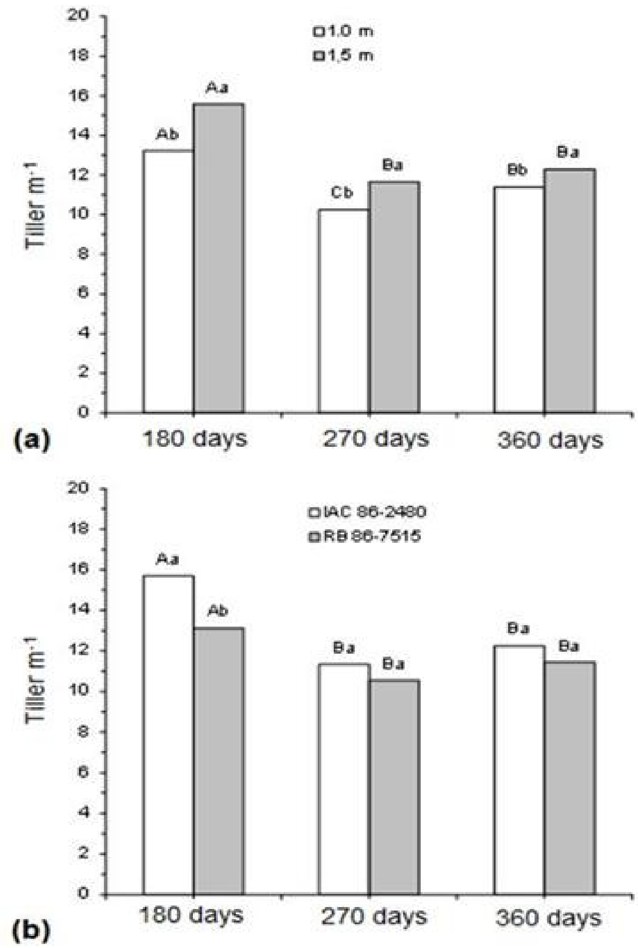

Figure 2. Tillering of sugarcane at 180, 270 and 360 days after planting, the row spacing of 1.0 m and 1.5 m (average of the two varieties) (a), and for IAC RB 862480 and 867515 (average of the two spacings) (b). Capital letters compare cutting times and lower spacing and compare varieties within each mowing season, by Tukey test at 5% probability.

Specifically, time of harvest significantly influenced values measured for Brix, MM, CF, NDF, ADF, CP and TDN (Table 2). At 360 days, showed a higher content of Brix, around 23º Brix, a little higher than that found by Muraro et al. (2009) and Shigaki et al. (2003), which is mainly due to the large temperature and water stress suffered during the experiment, because the sucrose accumulation that occurs when vegetative growth is interrupted.

The values of mineral matter interference experienced at the time of cutting and are within the values compiled by Nussio et al. (2006) ranging from 0.81 to 6.42%. Similarly, the values of PB were also influenced by mowing season, averaging 3.7% over the three harvesting periods, which is consistent with the 3.2% and 3.3% values previously reported by Andrade et al. (2004) and Mello et al. (2006), respectively. The highest content of CP is observed at 270 days, which is mainly due to higher amount of green leaves and young present in sugar cane (Muraro et al., 2009).

Levels of cell wall components NDF and ADF also suffered interference depending on the time of harvest, increasing with the cutting age, which indicates that there was no dilution of cell wall components with aging. This was not consistent with a previous report by Muraro et al.

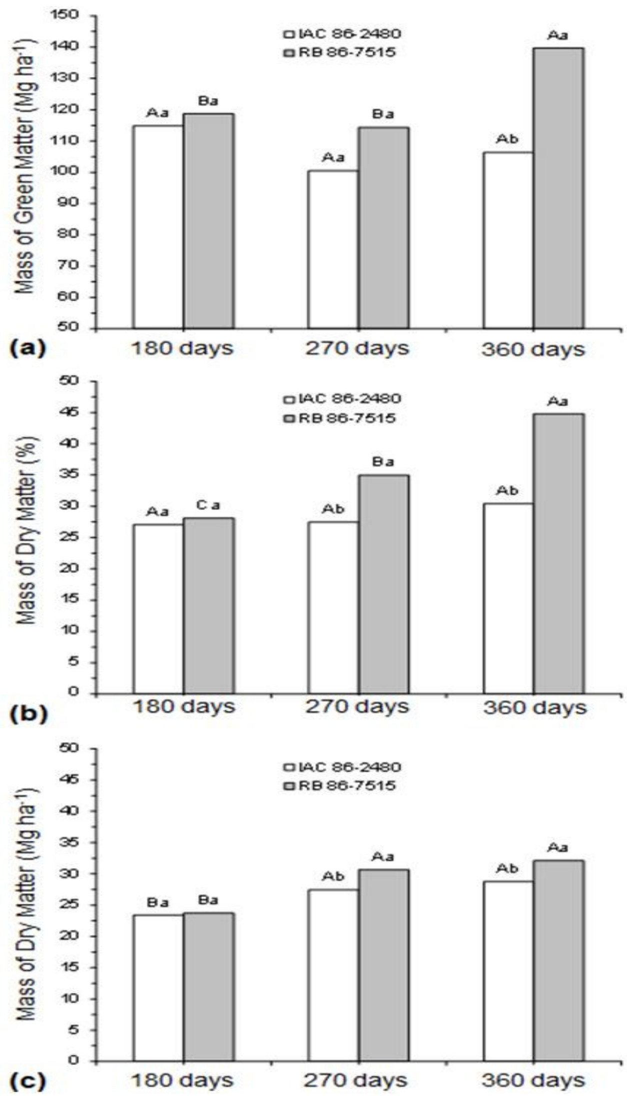

Figure 3. Productivity of green matter of shoot total plant cane (stem + leaves + pointers) (a), percentage of dry matter (b) and dry matter yield (c) at 180, 270 and 360 days after planting, to varieties IAC862480 and RB867515 (average of the two spacings). Capital letters compare cutting times and lower the varieties within each mowing season, by Tukey test at 5% probability.

(2009), but may have been due to the varieties still suffer greater maturity if the final age cutoff was high. However, values of NDF and ADF were slightly above average advocated for animal feed, around 52%, not compromising forage intake by ruminants.

CONCLUSIONS

The variety IAC862480 was superior in tillering when compared to RB867515, and the spacing 1.5 m being greater than 1.0 m. Productivity and the percentage of MS were higher in variety RB867515 when cut 360 days after planting. Spacing of 1.0 m and variety RB867515 were more productive compared to the other variety spacing studied. Crude protein, ash, neutral detergent fiber, acid detergent fiber, total digestible nutrients and ºBrix suffered interference of the date cutting sugarcane, with increased in the values.

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