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Growth and composition of sugarcane and chemical attributes of the soil by fertilizing with different levels of cow manure

Geicimara Guimarães[1]*, Rogério de Paula Lana[2], Rosane Cláudia Rodrigues[3], Cristina Mattos Veloso[4], Renata de Souza Reis[5], Maria Regina de Miranda Souza[6] and Silvane de Almeida Campos[7]

[1]Graduate Program in Agroecology, Universidade Federal de Viçosa (UFV), 36570-900, Viçosa-MG, Brazil.
[2]Department of Animal Science, Universidade Federal de Viçosa (UFV), 36570-900, Viçosa-MG, Brazil.
[3]Department of Animal Science, UFMA, Chapadinha-MA, Brazil.
[4]Department of Animal Science, Universidade Federal de Viçosa (UFV), Viçosa-MG, Brazil.
[5]Department of Animal Science, UFSJ, São João Del Rei-MG, Brazil.
[6]EPAMIG, Viçosa-MG, Brazil.
[7]Department of Plant Science, UFV, Viçosa-MG, Brazil.

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Four months after planting sugarcane variety RB867515, fertilized with 0.0, 4.5, 9.0, 13.5 and 18.0 Mg ha^{-1} of cow manure, there was positive linear effect of the fertilizer on plant height and stalk diameter, quadratic positive effect on width and length of the largest leaf, and no effect on number of plants m^{-1} linear and the number of leaves plant^{-1}. At 10 months, there was quadratic positive effect of cow manure on plant height and no effect on number of plants, stalk diameter, width and length of the largest leaf and number of leaves plant^{-1}. At 12 months, there was quadratic effect on the yield of green mass with the highest value on 18 Mg ha^{-1} of cow manure, without change on chemical composition. During the cutting time, the most pronounced effect of cow manure on sugarcane was in the yield of green mass and, therefore, up to 18 Mg ha^{-1} of cow manure can be used to increase sugarcane performance, without changing chemical composition and maintaining soil fertility.

Key words: Agronomic characteristics, chemical analyses, organic fertilizer, residue, *Saccharum* spp.

INTRODUCTION

The sugarcane (*Saccharum* spp.) is one of the main crops in tropical countries and its cultivation has great

*Corresponding author. E-mail: geicimara.guimaraes@ufv.br.

prominence for several purposes, such as in the production of ethanol, sugar, brown sugar, molasses, fodder and by-products for use as fertilizer and power generation. Currently, most of the cane-producing units still use mineral fertilizers, as a source of nutrients. However, there is a concern to obtain a new product, with high benefit, for some units that use the system of organic fertilization or almost entirely organic (Anjos et al., 2007).

The organic fertilizer with cow manure is a millennial practice, having lost prestige with the introduction of mineral fertilizer, in the mid-19th century, and revived the importance, in recent decades. There is growing concern on the questions related to the need for preservation of the environment, with healthy eating and the need of adequate allocation of large quantities of manure produced in some countries (Holanda, 1990; Blaise et al., 2005; Salazar et al., 2005).

The use of organic compounds improves the physical, chemical and biological properties of the soil (Almeida Júnior et al., 2011), where the improvement of pH and nutrient levels in the soil are some benefits that provide increased sugarcane yield (Bulegon et al., 2012). Andrade (1998) stated that the use of manures can even replace the chemical fertilizer of planting. According to Anjos et al. (2007), it is feasible to replace chemical fertilizer by organic (farmyard manure), without loss of quality and yield of sugarcane.

Gana (2009) suggested that combined application of cow manure between 10 and 20 Mg ha^{-1} and 50 kg N ha^{-1} increase yield of successive cane cropping and Teshome et al. (2014) reached highest cane and sugar yields with 15 Mg ha^{-1} of compost applied before furrowing and 46 kg N ha^{-1} at 2.0-2.5 months after planting. However, according to Gana (2011), there are few works on the recommendation of cow manure in sugarcane production, and farmers are using manure without any scientific data on the most appropriate method of application.

The purpose with this work is to evaluate the development and chemical composition of sugarcane in response to increasing levels of cow manure applied in the soil during the planting and the effect on soil fertility.

MATERIALS AND METHODS

The study was conducted in Boa Vista farm, district of Cachoeirinha, Viçosa, MG, Brazil, belonging to Universidade Federal de Viçosa. The city of Viçosa is located in the Zona da Mata region of Minas Gerais, Brazil, and its geographical coordinates has the position 20° 45' 20" South latitude and 45° 52' 40" West longitude of Greenwich and 651 m altitude. The climate is of the Cwa type (mesothermic), according to Köppen classification, with two well-defined seasons, with hot and humid summers and cold and dry winters. The average rainfall is 1341.2 mm per year. The average maximum and minimum temperatures are 26.1 and 14.0°C, respectively (UFV, 2016).

The experiment was conducted from October 2013 to October 2014. The experimental area has small slope topography and, in order to prevent influence from previous fertilization, an area with no management for over ten years in which predominated the signal grass (*Brachiaria decumbens*) was chosen. Before the implementation of the experiment, chemical analysis of the soil was performed for characterization, collection of samples from different places at random and with the same volume to obtain a composed sample of 0 to 0.2 m layer. The sample composite was placed in plastic bag, identified and forwarded to the laboratory for soil analysis, showing the following results: pH in water (1:2.5) = 6.2, P = 6.2 mg dm^{-3}, P-rem = 33.1 mg L^{-1}, K = 67 mg dm^{-3}, Ca^{+2} = 2.8 $cmol_c$ dm^{-3}, Mg^{+2} = 1.1 $cmol_c$ dm^{-3}, Al^{+3} = 0.0 $cmol_c$ dm^{-3}, H + Al = 4.13 $cmol_c$ dm^{-3}, SB (sum of bases) = 4.07 $cmol_c$ dm^{-3}, $CTC_{(t)}$ (effective cations exchange capacity) = 4.07 $cmol_c$ dm^{-3}, $CTC_{(T)}$ (cations exchange capacity at pH 7.0) = 8.2 $cmol_c$ dm^{-3}, V (percent base saturation) = 50%, m (percent aluminum saturation) = 0,0% and light sandy loam.

The limestone was spread and incorporated by plowing in August 2013 (two months before planting), based on the method of saturation by bases and recommendation for sugarcane, using the equivalent of 4 Mg ha^{-1} of dolomitic limestone (NP = 70.5%, RE = 99.1%, RPTN = 69.9%, Ca^{2+} = 211 g kg^{-1} and Mg^{2+} = 47 g kg^{-1}). Plowing was performed to approximately 0.30 m depth, and harrowing (hoeing start), ensuring the soil unpacking, the reduction of the infestation of pests in the area and the elimination of signal grass (*Brachiaria decumbens*).

The cow manure was kept heaped and covered with plastic for 60 days, and then five subsamples were collected, at random, to obtain a composite sample for chemical characterization. The manure used in the experiment came from the same place where the experiment was implemented and it presented: 2.71% N, 0.66% P, 1.68% K, 0.336% Na, 1.76% Ca, 0.75% Mg, 0.53% S, 21.06% OC, 7.77 C N^{-1}, 139 ppm Zn, 4,484 ppm Fe, 280 ppm Mn, 28 ppm Cu, 12.4 ppm B, pH = 7.9 and 42.8% humidity.

The planting furrow was performed mechanically, by occasion of the planting, in October 2013, approximately 0.30 m depth and spaced 1 m apart, removing the clods of planting furrow. The experiment was conducted in randomized complete block design, with five treatments (fertilizer levels) and four replications, totaling 20 experimental plots. The treatments consisted of applying 0.0 (control), 4.5, 9.0, 13.5 and 18.0 Mg ha^{-1} of cow manure on natural matter. Each experimental unit was 5 m long and 4 m wide, totaling an area of 20.0 m^2, consisting of four lines of plants, considering useful area (8 m^2), the two centerlines, discarding 0.50 m at each end.

The cow manure was placed at the bottom of the planting furrow. The sugarcane was planted manually, using a variety RB867515, on 1 m spacing between rows and two rows of sugarcane per planting furrow, being stung in sizes of 0.20 m inside the planting furrow. The control of spontaneous plants was performed by hand weeding using hoes.

Four and ten months after planting, the number of plants per meter, plant height (measured from the ground to the highest leaf ligule), stalk diameter (near the surface of the soil), number of leaves per plant and length and width of the largest leaf were measured. At 12 months, the yield of whole plant (Mg ha^{-1} of green mass) was measured and samples were chopped, packed in plastic bags (500 g) and frozen for chemical composition. At this time, soil was sampled for chemical evaluation.

After thawing, the plant samples were placed in paper bags, properly identified and taken to an oven with forced ventilation of air at 55°C for 72 h, and weighted in semi analytics scale for the determination of the dry matter in the air. Then, the samples were ground and analyzed for dry matter content at 105°C, neutral detergent fiber corrected to ash and protein (NDFap), non-fibrous carbohydrates (NFC), crude protein (CP), ether extract (EE) and ashes (As), according to Detmann et al. (2012). The Brix was

Table 1. Chemical attributes of the soil after harvest of sugarcane in areas fertilized with increasing levels of cow manure[1]

Manure ($Mg\ ha^{-1}$)	pH Water	P	K		Ca	Mg	Al	H+Al
		$mg\ dm^{-3}$			$cmol_c\ dm^{-3}$			
0.0	5.6	2.5	60		1.8	1.0	0.0	3.30
4.5	5.4	2.1	67		1.9	1.0	0.0	3.96
9.0	5.6	2.5	48		1.9	1.0	0.0	3.30
13.5	5.7	4.7	63		2.3	1.2	0.0	3.14
18.0	5.8	4.7	64		2.0	1.2	0.0	3.30
Manure ($Mg\ ha^{-1}$)	**SB**	**CTC(t)**	**CTC(T)**	**V**	**m**	**MO**	**P-rem**	
	$cmol_c\ dm^{-3}$			%		$g\ kg^{-1}$	$mg\ L^{-1}$	
0.0	2.95	2.95	6.25	47	0	33.5	29.3	
4.5	3.07	3.07	7.03	44	0	42.6	27.3	
9.0	3.02	3.02	6.32	48	0	33.5	28.3	
13.5	3.66	3.66	6.80	54	0	37.3	30.5	
18.0	3.36	3.36	6.66	50	0	33.5	29.3	
Manure ($Mg\ ha^{-1}$)	**Zn**	**Fe**	**Mn**	**Cu**	**B**			
	$mg\ dm^{-3}$							
0.0	2.0	97.1	55.7	1.6	0.2			
4.5	2.2	71.2	49.5	1.6	0.4			
9.0	1.5	65.6	47.8	1.4	0.3			
13.5	2.7	100.9	68.2	1.8	0.2			
18.0	2.7	89.7	66.4	1.5	0.2			

[1]Cow manure: 2.71% N, 0.66% P, 1.68% K, 0.336% Na, 1.76% Ca, 0.75% Mg, 0.53% S, 21.06% CO, 7.77 C N^{-1}, 139.00 ppm Zn, 4,484.00 ppm Fe, 280.00 ppm Mn, 28.00 ppm Cu, 12.40 ppm B, pH = 7.90 and 42.80% humidity. Contents determined in acid extract (nitric acid with perchloric acid), in dry matter at 75 ºC. Nitrogen (N) determined by Kjeldahl method. Humidity in stove at 75 ºC. SB = sum of bases, $CTC_{(t)}$ = effective cations exchange capacity, $CTC_{(T)}$ = cations exchange capacity at pH 7.0, V = percent base saturation and m = percent aluminum saturation.

measured in samples of sugarcane juice obtained in electric mill device, using a saccharimeter (densimeter).

To find out the result of the rates of manure on the growth parameters of the sugarcane, the experimental data were subjected to ANOVA and regression analysis through Minitab (Ryan and Joiner, 1994). The chemical attributes of the soil and chemical composition of the sugarcane were obtained in pooled samples, reporting solely the mean per treatment for the chemical attributes of the soil and mean, standard deviation and coefficient of variation for the chemical composition of the sugarcane.

RESULTS AND DISCUSSION

The gradual increase of cow manure allowed smaller reduction in the content of P relative in the initial condition of soil, but it did not change, noticeably, the remaining parameters (Table 1). It is worth mentioning that although it has been used up to level 18 Mg ha^{-1} of cow manure, dry matter content was low (57.2%), contributing with 10.3 Mg ha^{-1} of dry matter.

The agricultural use of organic wastes, such as livestock manure, is an advantageous feature. It provides agronomic benefits, such as raising the pH of the soil (Silva et al., 2001), reducing potential acidity and increasing the availability of macronutrients (Berton et al., 1997), in addition to the final provision with less impact on the environment (Freitas et al., 2012). In this study, the pH showed slight increase with increase in the level of cow manure.

Oliveira et al. (2007) pointed that the sugarcane, producing large amount of mass, extracts from the soil and accumulate large amount of nutrients. In the present study, the reduction of the levels of phosphorus in the soil became more apparent after the first cut of the cane, especially by using 0.0, 4.5 and 9.0 Mg ha^{-1} of cow manure (Table 1).

According to Malavolta et al. (2002), chemically, the organic fertilizing is important source of nutrients, especially N, P, K and micronutrients, being the only form of N storage, which does not volatilize, and is responsible for 80% of the total phosphorus found in the soil. It is observed that the crops in general present as a rule high nitrogen and potassium requirements in addition to copper and molybdenum; however, the requirement order of other nutrients may vary between cultures and even cultivate/hybrid. In general, the decreasing standard order of crop extraction is as follows: macronutrients: N > K > Ca > Mg > P ↔ S; and micronutrients: Cl > Fe > Mn > Zn > B > Cu > Mo.

Four months after sugarcane planting, there was no

Table 2. Growth parameters of the sugarcane at four months as a function of organic fertilizing with cow manure

Item	Cow manure (Mg ha^{-1})					SE	Significance	RE
	0.0	4.5	9.0	13.5	18.0			
Plants m^{-1} linear	6.73	8.35	8.63	8.80	8.63	0.92	0.198	
Height of plant, m	0.254	0.308	0.381	0.357	0.464	0.022	0.001	1
Stalk diameter, mm	14.9	17.6	19.7	18.5	21.9	0.82	0.001	2
Leaf wide, mm	26.5	31.9	33.9	32.8	36.8	2.16	0.054	3
Leaf length, m	1.01	1.17	1.35	1.31	1.40	0.043	0.001	4
Number of leaves $plant^{-1}$	6.56	6.69	6.81	6.88	6.56	0.15	0.198	

Means followed by same letters in the same row do not differ among them, by Tukey test, at 5% probability. SE = standard error of mean; Signif. = significance by F test; RE = regression equation: [1] $0.259 + 0.0104x$, $r^2 = 0.88$; [2] $15.6 + 0.33x$, $r^2 = 0.82$; [3] $27.2 + 0.858x - 0.0214x^2$, $R^2 = 0.85$; [4] $1.02 + 0.0429x - 0.00127x^2$, $R^2 = 0.93$.

effect ($P > 0.05$) of the increasing level of cow manure only on the number of plants m^{-1} linear and the number of leaves $plant^{-1}$ (Table 2). There was increase in linear effect ($P < 0.01$) of the level of cow manure on the height of the plant and the stalk diameter, in which the level of 18 Mg ha^{-1} (moisture content = 42.8%) provided values 83 and 47% higher, respectively, than the control treatment (Table 2 and Figure 1).

There was quadratic effect ($P = 0.05$) of the increasing level of cow manure on the width of the largest leaf (Table 2 and Figure 1), with maximum value estimated by the model using 20 Mg ha^{-1} of manure. The highest value was observed in the level of 18 Mg ha^{-1} of cow manure (38.9% higher than the control treatment), while the lowest value for the level 0 Mg ha^{-1}, and levels of 4.5, 9.0 and 13.5 Mg ha^{-1} showed intermediate values.

There was quadratic effect ($P < 0.01$) of the increasing level of cow manure on the length of the largest leaf (Table 2 and Figure 1), with maximum value estimated by the model using 16.9 Mg ha^{-1} of manure. The highest value was observed to be in the level of 18 Mg ha^{-1} of cow manure (38.6% higher than the control treatment), while the lowest value for the level 0 Mg ha^{-1}, and levels of 4.5, 9.0 and 13.5 Mg ha^{-1} showed intermediate values.

With the results presented at four months after planting, there was benefit of using cow manure for most of the evaluated parameters. These results are in agreement with those obtained by Freitas et al. (2012), on sorghum, who reported that doses of organic fertilizer applied in the furrow planting provided statistical difference only on initial assessments, when the number of leaves issued by plants was greater in treatments receiving higher levels of organic fertilizer.

At ten months, there was quadratic effect ($P < 0.01$) of increasing level of cow manure on the height of the plants (Table 3 and Figure 2), with maximum value estimated by the model using 16.8 Mg ha^{-1} of manure. The lowest value was observed for the level 0 Mg ha^{-1} of cow manure, while the highest value for the level of 18 Mg ha^{-1} (30.6% higher than the control treatment), and levels of 4.5, 9.0 and 13.5 Mg ha^{-1} showed intermediate values. There was no effect ($P > 0.05$) of the increasing level of cow manure on the number of plants, stalk diameter, width and length of the largest leaf and number of leaves $plant^{-1}$ (Table 3). This is in agreement with those obtained by Freitas et al. (2012), who observed statistical difference only in initial assessments of organic fertilizer on the culture of sorghum. According to Santos et al. (2011) study on grasses, it was indicated that the number of leaves $plant^{-1}$ is constant for a given species or cultivar, with little influence by environmental factors, which explains the behavior for this variable. Oliveira et al. (2011), in turn, reported that the stalk diameter depends on the genetic characteristics of the variety, the number of tillers, the spacing used, leaf area and the environmental conditions.

There was quadratic effect ($P < 0.05$) of the increasing level of cow manure on green mass yield at 12 months, in Mg ha^{-1} (Table 3 and Figure 2). The highest value was observed in the level of 18 Mg ha^{-1} of cow manure, while the lowest values in levels of 0 and 4.5 Mg ha^{-1}, and the levels of 9 and 13.5 Mg ha^{-1} showed intermediate values.

In this study, there was 98.8% increase in yield of green mass of sugarcane by using 18 Mg ha^{-1} of cow manure with 42.8% humidity in comparison with control treatment, showing that the cow manure was used efficiently in the production of sugarcane. This result is in agreement with Gana (2009), who found 101% increase in stalk yield at 12 months after planting sugarcane with 10 Mg ha^{-1} of air dried cattle manure when compared with no fertilization. For other side, Parente et al. (2012) found only 38.4% increase in yield of green mass of elephant grass fertilized with 20 Mg ha^{-1} of cow manure in comparison with control treatment.

According to Doorembos and Kassam (1994), the yield of sugarcane in the humid tropics, ranges between 70 and 100 Mg ha^{-1} with no irrigation and, in the dry subtropics, and between 100 and 150 Mg ha^{-1} with irrigation. In this experiment, the yield as the non-irrigated was obtained between 9 and 18 Mg ha^{-1} of cow manure.

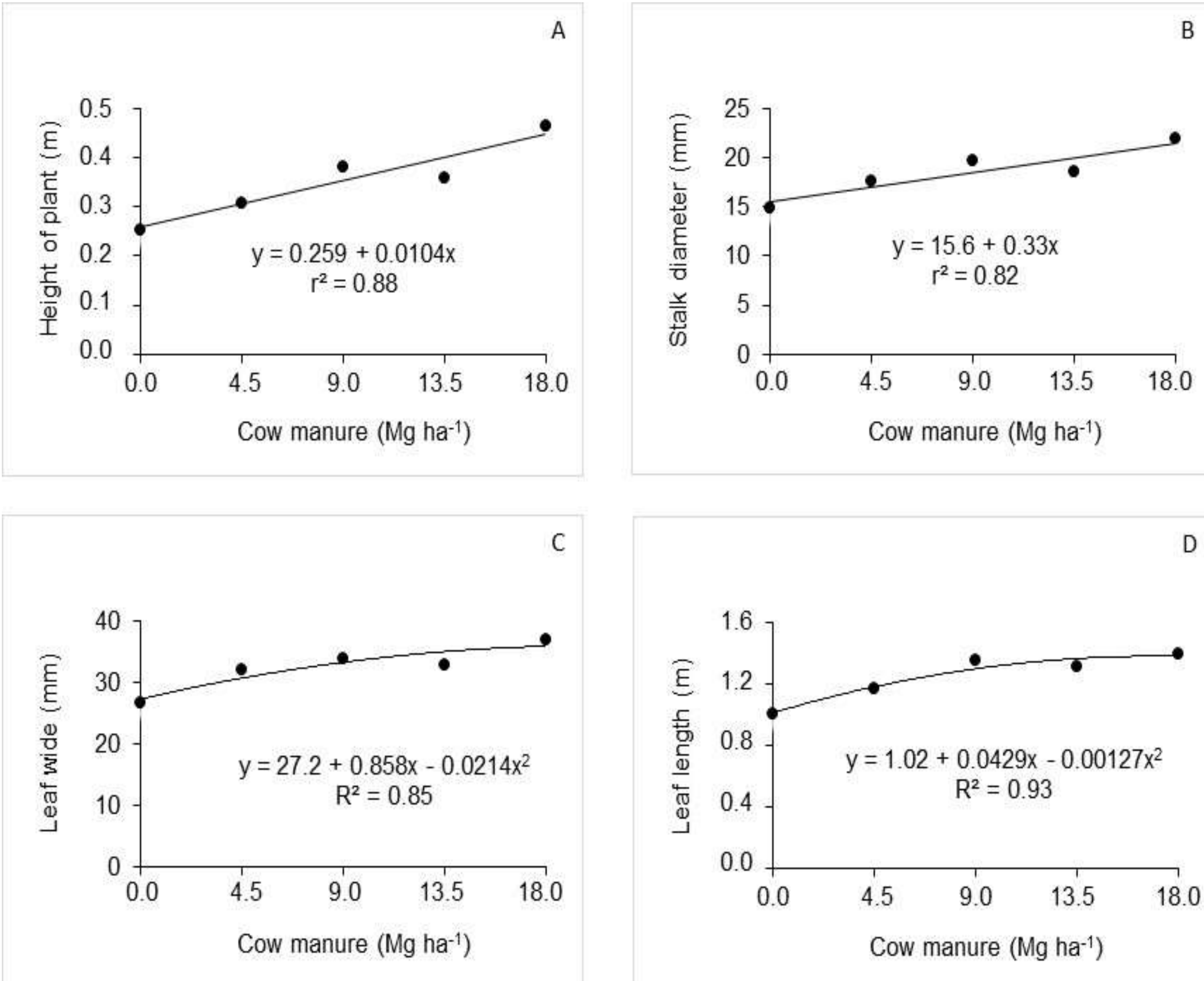

Figure 1. Growth parameters of the sugarcane at four months as a function of organic fertilizing with cow manure (A. Height of plant; B. stalk diameter; C. leaf wide; D. leaf length).

Table 3. Growth parameters of sugarcane at ten months and yield at 12 months as a function of organic fertilizing with cow manure.

Item	Cow manure (Mg ha^{-1})					SE	Significance	RE
	0.0	4.5	9.0	13.5	18.0			
Plants m^{-1} linear	7.55	7.53	8.15	9.13	8.03	0.44	0.103	
Height of plant, m	1.08	1.24	1.37	1.25	1.41	0.044	0.001	1
Stalk diameter, mm	28.3	28.9	28.4	28.2	27.2	0.88	0.230	
Leaf wide, mm	47.8	50.1	51.5	50.3	50.4	2.51	0.240	
Leaf length, m	1.16	1.21	1.23	1.24	1.20	0.033	0.200	
Number of leaves plant^{-1}	6.69	6.81	6.56	6.50	6.56	0.20	0.235	
Yield of green mass, Mg ha^{-1}	57.7	50.8	75.5	83.3	114.7	11.6	0.013	2

Means followed by same letters in the same row do not differ among them, by Tukey test, at 5% probability. SE = standard error of mean; Signif. = significance by F test; RE = regression equation: [1] $1.10 + 0.0318x – 0.000947x^2$, $R^2 = 0.74$; [2] $55.6 – 0.535x + 0.2106x^2$, $r^2 = 0.95$.

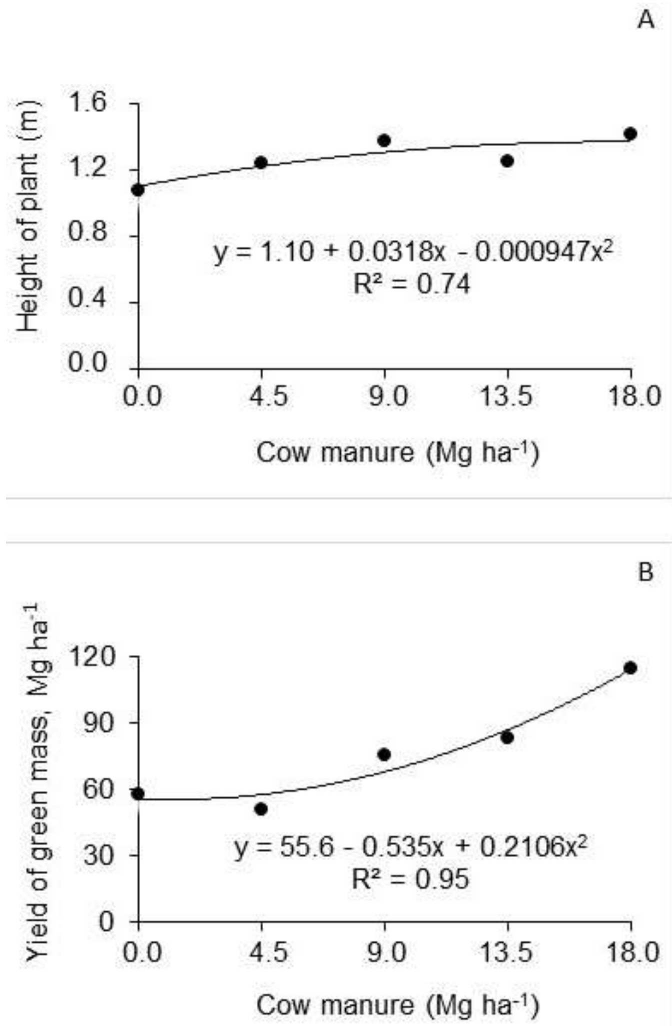

Figure 2. Height of the sugarcane plant at ten months (A) and yield of green mass at 12 months (B) as a function of organic fertilizing with cow manure.

Gava et al. (2011) found average yield of stalks, of three genotypes of sugarcane, of 132 Mg ha-1 for irrigated by drip and 106 Mg ha^{-1} for no irrigation management, in the first production cycle. In this experiment, the yieldsuch as these was obtained only with 18 Mg ha^{-1} of cow manure, with no irrigation. According to Oliveira et al. (2007), it is not likely to get yield up to 150 Mg ha^{-1}, while the P extracted with resin is less than 6 mg dm^{-3}, as was the case of this experiment (Table 1).

The chemical composition of sugarcane at 12 months as a function of the organic fertilizing with cow manure in the planting is presented in Table 4. Change of composition was not observed for different levels of fertilizer, with coefficient of variation less than 10% except for ether extract and ashes, due to the low levels and greater variability normally observed with these analyses.

The average dry matter (DM) and neutral detergentfiber (NDF), obtained in the present study at 365 days, were 31.2 and 46%, respectively (Table 4). Azevedo et al. (2003) showed for sugarcane variety RB867515, at 426 and 549 days, values of 27.1 and 30.6% DM and 50.1 and 47.8% NDF, respectively. The average values obtained in this study for DM and NDF, at 365 days, were close to those reported by those authors, showing that the composition of the sugarcane varies little after the ideal point suitable for cutting.

The NDF $Brix^{-1}$ ratio in sugarcane depends on the environment in which the culture is growing, variety and age of cut, where higher values of NDF are registered under irrigation (Macêdo et al., 2012) or in the rainy season, due to the vegetative growth of plants (Muraro et al., 2009). Highest values of Brix, in turn, occur with increasing age of the plant and the dry season, as it reduces plant growth and sucrose accumulation occurs (Muraro et al., 2009). Macêdo et al. (2012) achieved NDF $Brix^{-1}$ ratio of 2.41 for the variety RB867515 on non-irrigated land, similar to the average value of 2.42 calculated in this study to this same variety, based on the average data of NDFap and Brix as presented in Table 4.

Muraro et al. (2009) verified the age effect of cutting on Brix, with values of 6.3, 10.2 and 16.9 for sugarcane variety RB72454 at 180, 240 and 420 days, respectively, in 0.9 m spacing. The Brix obtained in this study ranged from 18 to 22 for the variety RB867515 with no irrigation (Table 4). According to Amaral and Bernardes (2011), values equal or greater than 18% Brix is recommended for cutting sugarcane for animal feeding, where value of Brix in addition to 40 units characterize the approach to the TDN content of sugarcane, which in this study would be 58 to 62%.

Conclusions

The cow manure improves several growth parameters of the sugarcane crop at four months, being more evident in the height of the plant and the stalk diameter. Level up to 18 Mg ha^{-1} of cow manure increases the yield of green mass of sugarcane variety RB867515 with no irrigation 12 months after planting, without changing chemical composition and maintaining soil fertility.

Conflict of Interests

The authors have not declared any conflict of interests.

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Table 4. Composition of the sugarcane at 12 months as a function of organic fertilizing with cow manure.

Cow manure (Mg ha^{-1})	DM (%)	NDFap in DM (%)	NFC in DM (%)	CP in DM (%)	EE in DM (%)	As in DM (%)	Brix (%)
0.0	30.5	43.6	50.4	1.98	1.23	2.74	19.0
4.5	32.8	48.1	46.8	2.13	0.72	2.25	18.0
9.0	31.6	49.3	45.9	1.76	0.83	2.21	18.0
13.5	30.0	44.2	50.2	1.92	1.01	2.72	18.0
18.0	30.9	44.6	50.9	1.74	0.61	2.19	22.0
Mean	31.2	46.0	48.8	1.90	0.88	2.42	19.0
SD	1.10	2.60	2.30	0.16	0.24	0.28	1.20
CV	3.50	5.60	4.70	8.50	27.7	11.7	6.30

DM = Dry matter, NDFap = neutral detergent fiber corrected for ashes and protein, NFC = non-fiber carbohydrates, CP = crude protein, EE = ether extract, As = ashes, SD = standard deviation and CV = coefficient of variation (%).

publication of this study.

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