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Impact of castor bean cake fertilizer as side-dressing on cauliflower yield and quality in organic farming systems

Joara Secchi Candian[1], Pâmela Gomes Nakada-Freitas[2], Andre Luiz Biscaia Ribeiro da Silva[3], Antonio Ismael Inácio Cardoso*[4]

[1]Bejo Seeds Inc, 1972 Silver Spur Pl, Oceano, CA, USA, 93445
[2]São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Department of Crop Science, Dracena, Brazil
[3]Auburn University, 101 Funchess Hall, Auburn University, Auburn, AL, USA, 36849
[4]São Paulo State University (Unesp), School of Agriculture, Department of Crop Science, Botucatu, Brazil

***Corresponding author:** antonio-ismael.cardoso@unesp.br

Abstract

The significance of organic production has grown significantly in the past decade. Therefore, research on organic fertilizer, mainly as side-dress, has gained more importance. Castor bean cake is a fertilizer rich in nitrogen and organic matter. This cake has been used as an organic fertilizer once it has higher mineralization rate compared to other sources such as as sugarcane bagasse and cattle manure. We studied rate and application time of castor bean cake on the production, physicochemical characteristics, macronutrient contents, and accumulation of cauliflower in an organic system. Ten treatments were studied, in a 3 x 3 + 1 factorial design, with three rates of castor bean cake (1290, 2580 and 3870 kg ha^{-1}) combined with three application times as side-dress (single application at 30 or 45 days after transplanting (DAT) and split application at 30 and 45 DAT), as well as a control (without fertilizer). The experimental design was randomized blocks with four replications. This study measured cycle, leaf number, inflorescence diameter, height, fresh and dry biomass, vegetative part (stem and leaves) fresh and dry biomass, pH, titratable acidity (TA), ascorbic acid (AA), soluble solids (SS), maturation index/ratio, reducing sugar contents (RSC), protein, macronutrient content, and accumulation in inflorescence. The maximum inflorescence fresh biomass was highest at 3015 kg ha^{-1}, while the maximum height and diameter were at 3785 and 3335 kg ha^{-1}, respectively. The highest rates of castor bean cake increased TA, while it decreased RSC, AA, and inflorescence ratio. The decreasing order of accumulated nutrients on inflorescence was K>N>P≈Ca>Mg>S, with maximums of 1.48; 1.03; 0.15; 0.14; 0.08 and 0.06 g inflorescence^{-1}, respectively. The rates of 3000 to 3800 kg ha^{-1} of castor bean cake increased production regardless time of application. Time factor had low influence on the physicochemical characteristics, macronutrient contents, and accumulations in inflorescence. Growers are recommended to apply 3 to 4 t ha^{-1} of castor bean cake.

Keywords: *Brassica oleracea* var. *botrytis*, organic fertilizer, nutrition, physical-chemistry analysis, nitrogen.

Introduction

Vegetables are produced in different agroecosystems, and the conventional cultivation system is still predominant. Recently, production area of organic system has significantly increased. Among the vegetables produced in the organic system, brassicas are the largest group in Brazil, and cauliflower is an important crop of this group. Filgueira (2008), Magro et al. (2010), and Candian et al. (2015) reported the excellent response of brassica to organic fertilization. According to Souza and Rezende (2014), cauliflower is the most demanding brassica in soils rich in organic matter compared to cabbage and broccoli.

Cauliflower plants accumulate mainly nitrogen and potassium. Therefore, it is necessary to synchronize applications with nutrient demands during its growth cycle, which usually increases in the reproductive phase. According to Filgueira (2008), nitrogen split promotes the development of the cauliflower plant when applied after transplantation, favoring productivity. However, very high nitrogen rates stimulate excessive leaf growth and reduced inflorescence dry biomass (Din et al., 2007; Kano et al., 2007).

Nitrogen is an easily lost nutrient in the soil, either by volatilization or leaching. It is indicated to supply nitrogen along with the application of materials rich in organic matter, as they can store it longer in the soil (Kiehl, 2010). According to Colombari et al. (2018), a part of the nitrogen should be provided before planting and the remainder distributed after planting along the cycle as side-dress fertilization, one or more times, coinciding with the higher demand of culture.

Organic fertilizers have several benefits, such as increased water retention and penetration capacity, increased pH and cation exchange capacity (CEC), as well as being a source of nutrients (Magro et al., 2010), favoring productivity of various vegetables, including brassicas (Diniz et al. 2008; Steiner et al., 2009; Candian et al., 2015).

Castor bean cake has been tested as an organic source of fertilization, as it has a high mineralization rate when compared to other sources such as sugarcane bagasse and cattle manure, besides being rich in organic matter and nitrogen (Severino et al., 2005). Other advantages of castor

bean cake are the low variation in its composition and the capacity to increase microbial activity in the soil where it is incorporated (Severino et al., 2005).
Besides being beneficial to the environment, organic fertilization can influence characteristics related to food quality, making them often healthier and tastier. However, little has been studied on how these fertilizers can favor the production and quality of brassicas and most of them are related to use of organic fertilizers before planting. However, for most species of vegetables, including the brassicas, there are few recommendations and works regarding the organic fertilization in top dressing. Among the options of organic fertilization adopted by vegetable producers, we have the castor bean cake (Silva et al., 2016). Thus, the objective of this study was to verify the effects of side-dress fertilization with castor bean cake on the production, physicochemical characteristics, macronutrient contents, and accumulation in cauliflower in an organic system.

Results and Discussion

Yield and physical characteristics of inflorescence

The growth cycle (DAT) was not affected by the factors studied as well as the number of leaves, with a general average of 73.3 DAT (CV = 2.1%) and 18.4 leaves per plant (CV = 4.3%), respectively. Kano et al. (2010) also observed no difference in growth cycle of Teresópolis Gigante cultivar at different rate of inorganic N (urea). This cultivar is one of the latest among those recommended for fall/winter cultivation in the state of São Paulo with an average cycle of 126 DAT.
The application time and the rate x application time interaction were not significant (F-test) for the fresh biomass of the vegetative part, while the castor bean cake rates significantly influenced this characteristic. The values showed adjustment to the linear model, increasing until the highest rates tested (Figure 1). Without side-dress fertilization, the plants presented 855g plant^{-1} of fresh biomass of the vegetative part, reaching 1000g plant^{-1} in the highest rate of castor bean cake (3870 kg ha^{-1}), an increase of 15%. This result corroborated with Tempesta et al. (2019) and Sohail et al. (2018) which showed increase in the number and biomass of leaves in cauliflower. Martins et al. (2013) also reported that organic fertilizer in lettuce, include castor bean cake, increased the vegetative weight when compared to plants without fertilizer.
It was observed that there was no significant interaction between factor rates and application times, as well as the application times factor for all inflorescence characteristics that were influenced only by rates. For inflorescence fresh biomass, data were adjusted to the quadratic model (Figure 1), with a maximum estimated value of 436 g for the rate of 3015 kg ha^{-1} of castor bean cake as side-dress (equivalent to 151 kg ha^{-1} of N). There was an increase of 145 g in inflorescence biomass in relation to plants without side-dress fertilization (rate 0) (average of 291 g), an increase of about 50%.
In onion, Santos et al. (2012) did not observe significant effects on the application of castor bean cake rates in the production and classification of the bulbs, and the authors justified that the soil already had high fertility, besides using 10 t ha^{-1} of manure in the planting fertilization. On the other hand, Silva et al. (2016) observed linear increases in beet yield under higher the rate of castor bean cake as side-dress in soil deficient in organic matter. In the present study, the results show that even if the soil is initially fertile and fertilization was performed before planting, side-dress can increase yield. Application of organic compost before each crop, may cause a cumulative increase in organic matter in the soil. So, there is the release of nutrients throughout the following crops, together with fertilization performed before planting. Several authors have reported this residual effect of organic fertilization from one crop to the next one in different vegetables (Linhares et al., 2010; Lanna et al., 2018), whereas probably, occurred in the present study. However, there was a response to castor bean cake application as a side-dress.
Inflorescence diameter and height were significant only for the factor rate which fitted the quadratic model, with maximum values estimated at the rates of 3335 and 3785 kg ha^{-1} of castor bean cake as side-dress. This is equivalent to 167 and 189 kg ha^{-1} of N, respectively (Figure 2). The cauliflower diameter was increased 1.2 cm and the height 1.44 cm, compared to control without side dress.
Producers usually sell cauliflower per unit, and its diameter and height are essential visual aspect at the time of choice by the consumer. Also, the biomass of the product will affect the consumer decision, so these three physical aspects are the main during commercialization. Even without side-dress, inflorescence showed a good appearance, because the soil was rich in organic matter.
For the state of São Paulo, Brazil, the recommended application of N as side-dress is 15 to 200 kg ha^{-1} (Trani et al., 1997). In this work, we observed that the maximum yield and inflorescence sizes were obtained with rates ranging from 3000 to 3700 kg ha^{-1} of castor bean cake as side-dress, equivalent to 150 to 185 kg ha^{-1} of N. So, it is within the range recommended by these authors for inorganic fertilization.
For all characteristics related to production, the factor application times were not significant, so it is better to apply only one time to save labor. Despite some authors related difference to physical and productive characteristics in vegetables with fertilizer split (Zanão Júnior et al., 2005; Marques et al., 2011; Masaka et al., 2016; Colombari et al., 2018), high fertility soils, rich in organic matter, may be able to provide the needs in nutrients by plants. In addition, the fertilizer source type may influence the efficiency of the split (Fan et al., 2017). Besides this, organic fertilizer releases nutrient more slowly than inorganic ones, so it is necessary just one application as side dress to supply cauliflower plants during all cycle.

Physicochemical characteristics of inflorescence

For the soluble solids content (SS) and the percentage of protein, the factors castor beans cake rates and application times, and the interaction between them were not significant. The average percentage of protein was 1.44% (CV = 7.5%) and SS was 7.99° Brix (CV = 4.7%). Kano et al. (2010) also observed no difference in SS when studying N (urea) rates as side-dress, with an average of 6.95° Brix, lower than the present research. In beet, also no difference was observed in soluble solids content with increasing rates of cattle manure (Marques et al., 2010).
Among the evaluated characteristics, only the pH presented significant interaction for the factor rates and application times (Table 3). Although the difference was minimal (0.25), only at the smallest rate (1290 kg ha^{-1} castor bean cake).

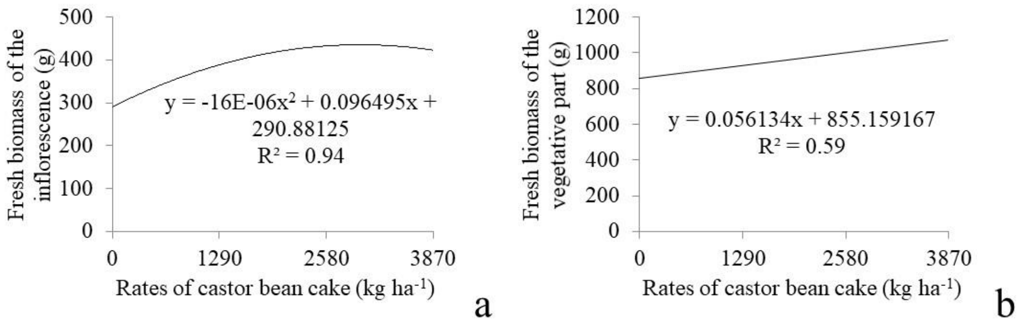

Figure 1. Fresh biomass of the inflorescence (a) and vegetative part (b) of cauliflower plant in function of castor bean cake rates as side-dress. Botucatu, SP, 2016.

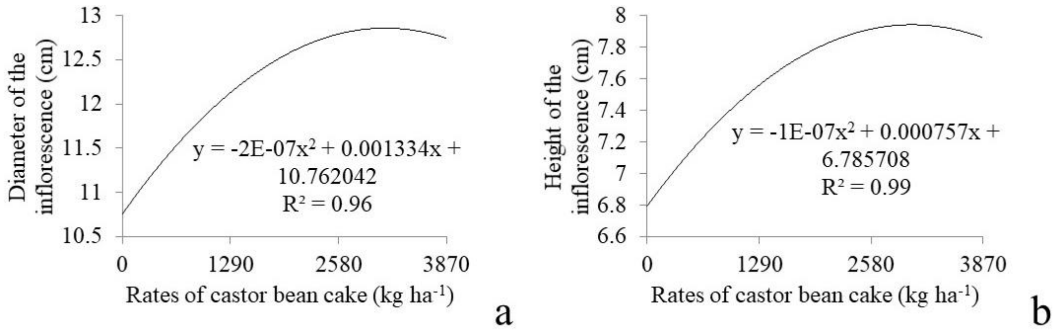

Figure 2. Diameter (a) and height of cauliflower inflorescence (b) in function of castor bean cake rates as side dress. Botucatu, SP, 2016.

The pH was higher when fertilization was split twice, at 30 and 45 DAT, compared to only one application at 30 or 45 DAT. For the other rates, there was no difference between the application times (Table 5). For rates of castor bean cake (Figure 3), a different effect was observed for each application time. When the rates were divided in two times (30 and 45 DAT), the pH of inflorescence was not affected by the rate (average of 6.99). For the early single application (30 DAT), we observed a decrease in pH with an increased rate, while application time at 45 DAT resulted in a quadratic equation, with an estimated minimum of 6.88 at 1762 kg ha^{-1} (Figure 3). However, although significant, the differences were less than 0.3 units of pH. Kano et al. (2010) reported a small linear increase in inflorescence pH values of inflorescence in the highest nitrogen rates: pH of 6.99 and 7.10 for control (without N) and the highest rate (225 kg ha^{-1}), respectively.

For reducing sugars, ascorbic acid, titratable acidity, and maturation index, only the factor castor bean cake rate was significant.

The titratable acidity (TA) was increased with higher rates of castor bean cake application. Consequently, with the stable soluble solids (SS) content, the maturation index (SS/TA) decreased (Figure 4). Blanco and Folegatti (2008) observed that increasing rates of nitrogen did not affect the soluble solids and titratable acidity values in tomato. Marques et al. (2010), studied rates of cattle manure in sugar beet and observed that, although it did not influence the pH and soluble solids, it increased the values of ascorbic acid and titratable acidity.

The content of reducing sugars decreased linearly from 3.27% in the absence of side-dress to 2.96% at the maximum castor bean cake rate, while ascorbic acid decreased from 96 to 90 mg 100mL^{-1}.

Studying rates of N, Kano et al. (2010) observed no difference in ascorbic acid content, with an average of 48.7 mg 100 mL^{-1}, which was about half of the values found in this research.

The values of soluble solids, reducing sugars, protein, and ascorbic acid are the main attributes responsible for improving taste and food quality. In this research, it was observed that the increase of the castor bean cake rates had little influence, implying that, under these conditions, the increase of the fertilized quantity may have little effect on the quality of the inflorescences. However, although small, some differences were significant.

Dry biomass, macronutrient contents and accumulations in inflorescence

The interaction between the studied factors was not significant for dry biomass, contents, and accumulations of all macronutrients in the inflorescence. For the inflorescence dry biomass, the application time factor was also not significant, while for the castor bean cake rates, the values were adjusted to the quadratic model (Figure 5) with maximum amount (38.1 g per inflorescence) estimated at the rate of 3699 kg ha^{-1} of castor bean cake (185 kg ha^{-1} N) as side-dress. We obtained 24.4 g and 38.1 g of dry biomass per inflorescence for the control without side dress and the treatment with maximum dry biomass, an increase of 56%, similar to the increase in inflorescence fresh biomass (50%).

For most of the macronutrient contents (except Ca and S), there was no difference among treatments. The lack of variation in this experiment might be due to the soil rich in organic matter. Besides the base organic fertilization carried out in large quantities and located in the holes, which favors greater nutrient availability to plants until the end of the cycle.

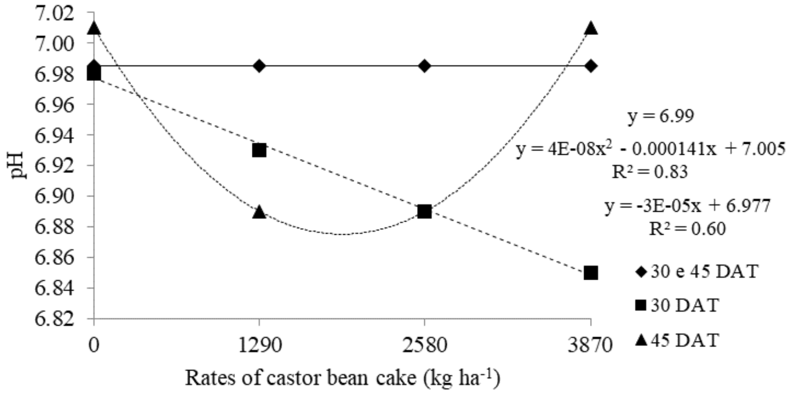

Figure 3. pH of cauliflower inflorescence in function of castor bean cake rates as side-dress for each application time. Botucatu, SP, 2016.

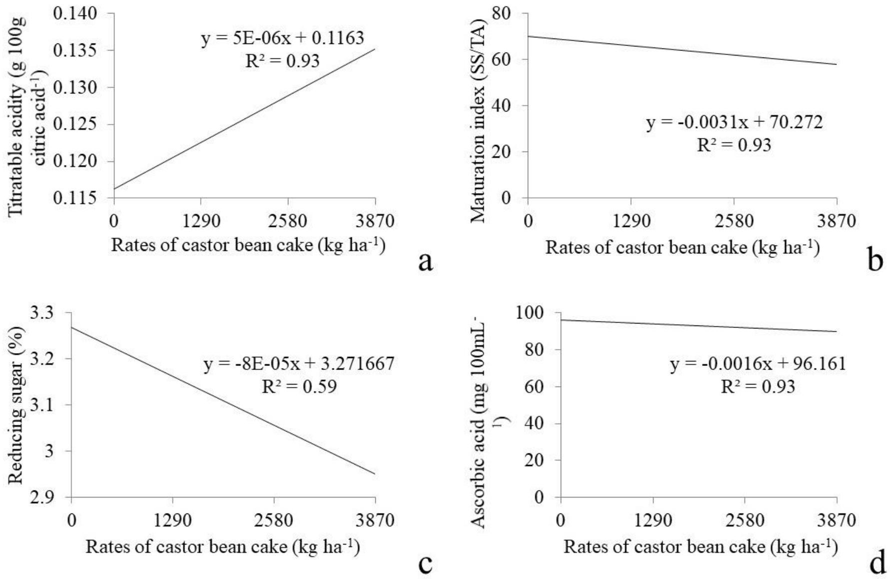

Figure 4. Titratable acidity (a), maturation index (b), reducing sugars (c), and ascorbic acid (d) of cauliflower inflorescence in function of castor bean cake rates as side-dress. Botucatu, SP, 2016.

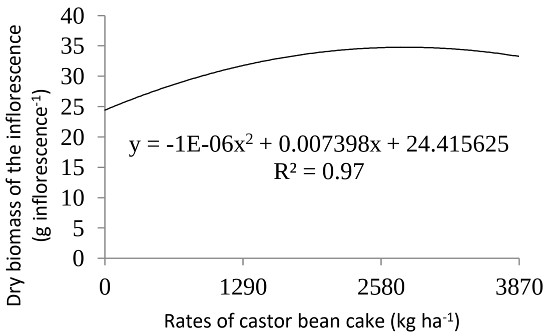

Figure 5. Dry biomass of cauliflower inflorescence in function of castor bean cake rates as side-dress. Botucatu, SP, 2016.

For Ca content, the factor rate was significant, fitting the quadratic model, and the lowest estimated value was 4.1 g kg^{-1} for the rate of 2195 kg ha^{-1} of castor bean cake (Figure 6). Ca content variation may have been due to the dilution effect because inflorescence dry biomass had the inverse effect. The biomass increased up to a specific rate and reduction in higher rates of castor bean cake. This situation can be explained because Ca has low mobility in the plant, accumulating preferentially in the leaves. So, the higher the inflorescence dry biomass, the lower the Ca content. This dilution effect has also been reported by Sánchez et al. (2001) and Alves et al. (2011) for nitrogen and phosphorus.

Only for S contents, the application time was significant, with higher value (1.97 g kg^{-1}) when the castor bean cake was applied at 30 DAT (Table 4).

Table 1. Soil chemical analyses.

$pH_{(CaCl2)}$	P_{resin}	Organic matter	V	H + Al	K	Ca	Mg	SB	CTC
	mg dm^{-3}	g dm^{-3}	%			mmol$_c$ dm^{-3}			
5.8	28	31	82	19	4	60	25	89	108

Table 2. Castor bean cake chemical analyses.

pH	C/N	N	P_2O_5	K_2O	Ca	Mg	S	$U_{65°C}$	Organic matter	Total Carbon	Na	Cu	Fe	Mn	Zn
							%						mg kg-1		
7.7	7/1	5.8	1.1	0.9	1.3	0.5	0.4	8	75	42	347	44	1624	97	119

Table 3. pH values of cauliflower inflorescence in function of application times in each rate of castor bean cake as side-dress. Botucatu, SP, 2016.

	Rate		
Application Time	1290	2580	3870
DAT		kg ha^{-1}*	
30 and 45	7.10 a	6.82 a	7.01 a
30	6.87 b	6.89 a	6.87 a
45	6.85 b	6.93 a	7.00 a

*Averages followed by the same letter in the columns do not differ from each other by the Tukey's test ($p < 0.05$).

The cauliflower hybrid Verona was grown in substrate and showed contents of N (28.07 g kg^{-1}) and Mg (2.04 g kg^{-1}) compared to this research. However, the contents of P, K and S were higher, with values of 6.18; 53.24 and 9.85 g kg^{-1} and lower for Ca, 1.67 g kg^{-1} (Alves et al., 2011). Genotype and cultivation environment, together with soil fertility and fertilization, have a significant influence on nutrient absorption and may be responsible for promoting differences between different authors.

Regarding the accumulation of macronutrients in inflorescence, no significant interaction was observed for factor rates and application times. However, there was a significant effect of castor bean cake rates for all nutrients accumulation evaluated and no significant effect on the application times factor.

Nitrogen, calcium, and magnesium accumulation showed a linear increase, and the values reached 1.00; 0.14 and 0.08 g $plant^{-1}$ at the maximum rate, respectively (Figure 7). The phosphorus, potassium, and sulfur contents were fitted to the quadratic model, and values increased until the rates of 2417, 2500, and 2167 kg ha^{-1} of castor bean cake when they accumulated a maximum of 0.15; 1.48 and 0.06 g $plant^{-1}$, respectively, decreasing the accumulation from these rates (Figure 7), similar to inflorescence dry matter.

The decreasing order of accumulated nutrients was K>N>P≈Ca>Mg>S. The amounts accumulated in inflorescences are exported and represent an essential component of soil nutrient loss, which should be returned in the fertilization programs. Considering the population of 31250 plants ha^{-1}, it would export about 46; 32; 4.7; 4; 2.5 and 1.9 kg ha^{-1} of K, N, P, Ca, Mg, S to inflorescences, respectively.

As reported by Alves et al. (2011), potassium and nitrogen were the most accumulated nutrients in the inflorescence. However, Sánchez et al. (2001), Castoldi et al. (2009), and Takeishi et al. (2009) found that nitrogen was the most accumulated nutrient, followed by potassium. Differences in accumulated macronutrient orders in the works can be attributed to cultivar, environmental conditions under which plants were grown, soil fertility, and plant nutrition, as explained by Cecílio Filho and Peixoto (2013). However, the results are not so discrepant, showing that N and K are the nutrients most accumulated in cauliflower inflorescence.

At the lowest dose, N accumulation was 0.74 g $inflorescence^{-1}$, reaching 1.00 g $inflorescence^{-1}$ in the highest rate of castor bean cake with highest value. Sanchez et al. (2001), Souza et al. (2007), and Castoldi et al. (2009) observed values above 3 g $inflorescence^{-1}$. These very high values obtained by these authors may be related to the dry biomass value.

For phosphorus, there was little difference between rates, from 0.11 to 0.15 g $inflorescence^{-1}$, which is lower than those found by Alves et al. (2011) and Castoldi et al. (2009), which were 0.17 and 0.27 g $inflorescence^{-1}$, respectively. Despite the high demand for phosphate fertilization in fertilizer bulletins, this nutrient was only the third most accumulated in this research and in the experiments developed by Sánchez et al. (2001) and Takeishi et al. (2009).

For K, there was also small variation between treatments, accumulating from 1.11 to 1.48 g $inflorescence^{-1}$ (maximum value estimated for the rate 2500 kg ha^{-1} of castor bean cake). These values are similar to those related by Sánchez et al. (2001) (1.48 g $inflorescence^{-1}$), Takeishi et al. (2009) (1.15 g $inflorescence^{-1}$), and Alves et al. (2011) (1.27 g $inflorescence^{-1}$). According to Takeishi et al. (2009), K is very accumulated in leaves, and can be translocated to inflorescence, as it behaves like nitrogen due to its easy mobility in the plant.

Calcium ranked fourth among the most accumulated macronutrients in cauliflower inflorescence, with values ranging from 0.12 to 0.14 g $inflorescence^{-1}$. Higher values were observed by Takeishi et al. (2009), who found an accumulation of 0.17 g $inflorescence^{-1}$ in the hybrid Verona, and Sánchez et al. (2001) at cv. Profil (0.27 g $inflorescence^{-1}$). Takeishi et al. (2009) observed that this nutrient was the third most accumulated in whole plants, with a percentage above 90% present in leaves because calcium has low mobility in plants (Araújo et al., 2015). Moreover, in leaves there is a higher transpiratory current, causing more Ca significant accumulation than inflorescence of cauliflower (Takeishi et al., 2009; Cardoso et al., 2016).

Magnesium was the fifth most accumulated nutrient in inflorescence since its highest concentration is found in the leaves (Sánchez et al., 2001; Takeishi et al., 2009; Castoldi et al., 2009; Alves et al., 2011). This nutrient is related to enzymatic function in phosphorylative reactions and chlorophyll (Malavolta et al., 1997), acting on the photosynthesis, respiration, and synthesis processes of

Table 4. Nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur contents of cauliflower inflorescence in function of the time of application of castor bean cake as side-dress times. Botucatu, SP, 2016.

Application Time	N	P	K	Ca	Mg	S
DAT			g kg^{-1} dry biomass*			
30 and 45	28.78 a	4.40 a	45.11 a	4.22 a	2.29 a	1.73 b
30	29.11 a	4.17 a	44.78 a	4.33 a	2.20 a	1.97 a
45	26.56 a	4.13 a	42.56 a	4.11 a	2.10 a	1.72 b

*Averages followed by the same letter in the columns do not differ from each other by the Tukey's test (p <0.05).

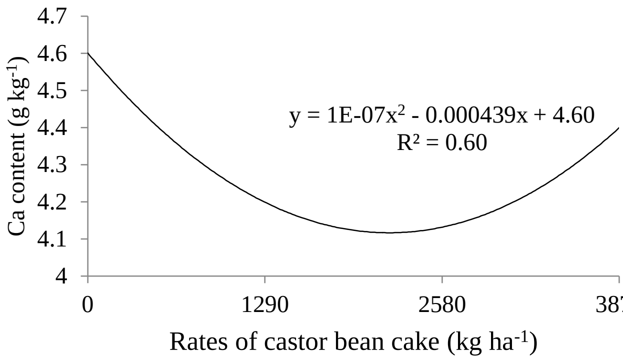

Figure 6. Cauliflower inflorescence calcium content in function of castor bean cake rates as side-dress. Botucatu, SP, 2016.

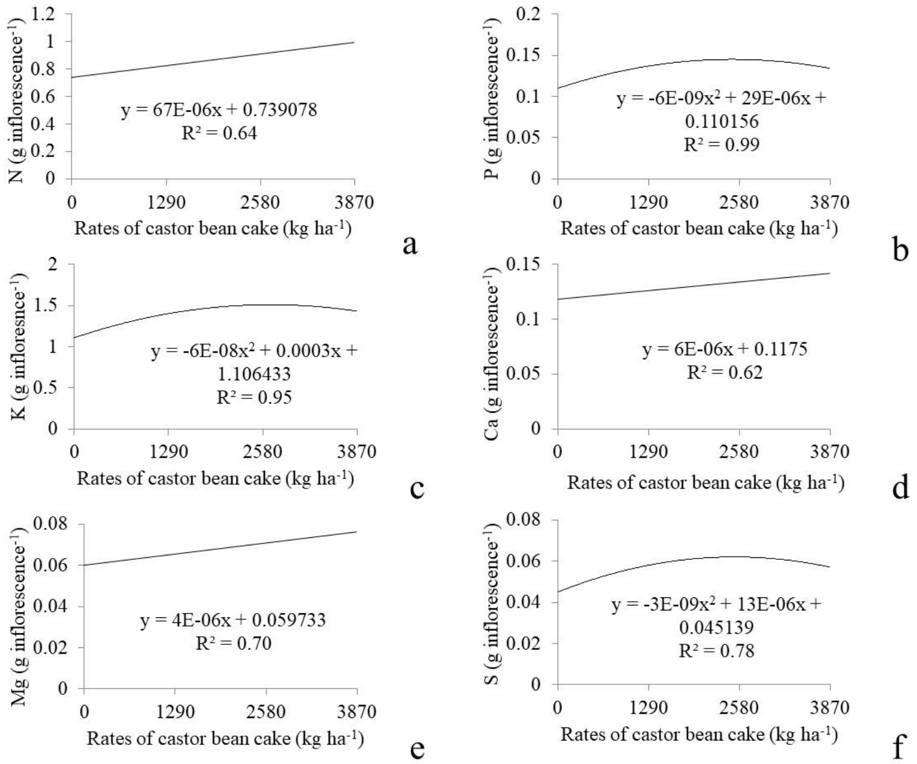

Figure 7. Accumulation of nitrogen (N) (a), phosphorus (P) (b), potassium (K) (c), calcium (Ca) (d), magnesium (Mg) (e), and sulfur (S) (f) in cauliflower inflorescence in function of castor bean cake rates. Botucatu, SP, 2016.

organic compounds. In inflorescence, magnesium accumulation occurs in the last three weeks before harvest (Takeishi et al., 2009). Values were increasing with rates, from 0.0597 to 0.0752 g per inflorescence^{-1} (Figure 8).

Sulfur accumulation adjusted to the quadratic model, ranging from 0.05 to 0.06 g inflorescence^{-1} for the rate at 2166 kg ha^{-1}. Takeishi et al. (2009) reported that this nutrient is very accumulated in inflorescence in the last 15 days before harvest. However, from 75 days after sowing, it is very accumulated by leaves, and brassicas are considered sulfur accumulators, especially in seeds (Magro et al., 2009; Cardoso et al., 2016).

The presence of organic matter helps in the buffering power of the soil, maintaining pH stability and nutrient availability. The soil has been worked for a long time with significant incorporation of organic matter. The content values observed in the different treatments tend to be more stable, and the response of dry biomass and nutrients accumulation is less pronounced than in other researches made in poor soil. The increase in organic matter content caused by the addition of organic fertilizers is significant for nutrient availability and plant development, not only acting as fertilizer but also performing some functions of a soil conditioner. So, if the producer decides to fertilize with castor bean cake as side-dress, perhaps only one application is enough, since the release of nutrients is slow and, with a single application, there is labor-saving and, consequently, lower costs.

Materials and Methods

The research was carried out in Botucatu, SP, in a Farm (Alvorada) certified by the Brazilian Association of Biodynamic Agriculture (IBD) in open field conditions. Geographical coordinates of the area are 22° 56' south latitude, 48° 23' west longitude, and altitude of 810m. According to Cunha and Martins (2009), the city has a humid warm (mesothermal) temperate climate, with concentrated rainfall from October to March.

Characterization of soil and castor bean cake

The soil was an Oxy soil stage Sandy. The soil (0-20 cm deep) and castor bean cake was analyzed and the chemical characteristics were showed at the Table 1 and 2, respectively.

The field was fertilized with a mixture (300g per hole) of organic compost, bone meal, termophosphate (Yoorin®) and castor bean cake, which was incorporated into the soil one day before the seedlings transplantation, according to the management used by the producer.

Conduction of study and experimental design

Ten treatments were studied at open field, in a 3 x 3 + 1 factorial, with three rates of castor bean cake (1290, 2580 and 3870 kg ha^{-1}), combined with three application times as side-dress (single application at 30 or 45 days after transplanting (DAT) and application times at 30 and 45 DAT), and a control (without fertilization as side-dress, considered as rate zero), in a randomized block design, with four replications.

The rates of castor bean cake were based on the percentage of nitrogen present in it, corresponding to 64.5, 129 and 193.5 kg ha^{-1} of N. In São Paulo State, 15 to 200 kg ha^{-1} of N is recommended (Trani et al., 1997).

The hybrid Nina was used, and sowing was on May 18, 2016, in 162-cell polypropylene trays. The seedlings, with four leaves, were transplanted on May 07, 2016, to beds of 1.0 m wide, spaced 0.8 m between rows and 0.4 m between plants, totaling 16 plants per plot, where the eight central plants being evaluated.

Weeds were controlled with weeding throughout the crop cycle, and sprinklers performed irrigation. The harvests took place between 09/13 and 09/20/2016.

Traits measured

The following traits were evaluated the cycle (days after transplantation = DAT), leaf number, inflorescence diameter and height, inflorescence fresh biomass, vegetative part (stem and leaves) fresh and dry biomass, pH, titratable acidity (TA), ascorbic acid (AA) (Brazil, 2005), soluble solids (SS) (AOAC, 2005), maturation index/ratio (Tressler and Joslyn, 1961), reducing sugar contents (RSC), determined by the method described by Somogyi and adapted by Nelson (1944), protein, determined by the digestion method proposed by Kjeldahl (Zenebon et al., 2008), inflorescence dry biomass, macronutrient content, and accumulation in inflorescence.

Sulfuric digestion was used to obtain the extract to determine the N content, and nitric-perchloric digestion was used to obtain the extracts to identify the other macronutrients (P, K, Ca, Mg, S), according to methodologies presented by Malavolta et al. (1997).

Statistical analysis

Factorial scheme variance analysis and regression analysis were performed to verify the effect of castor bean cake rates on the evaluated characteristics, and Tukey test ($p < 0.05$) was used to compare application times, using the Sisvar program (Ferreira, 2011).

Conclusion

The rates from 3000 to 3800 kg ha^{-1} of castor bean cake as side-dress (150 to 190 kg ha^{-1} of nitrogen) is recommended regardless of the time of application. This rate promoted higher yield, diameter, and height of inflorescence. The rates and application times have few influences on the physicochemical characteristics of inflorescence. Potassium and nitrogen are the most accumulated nutrients in inflorescence, regardless of the application time and rates of castor bean cake, being K>N>P≈Ca>Mg>S the decreasing order of accumulation.

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