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Organic fertilization in top dressing in jambu production

Nicholas Taborda Nordi*, Antonio Ismael Inácio Cardoso, Thatiane Nepomuceno Alves, Vinícius Pereira de Moraes, Joseantonio Ribeiro de Carvalho

Paulista State University, Botucatu, Brazil
*Corresponding author, e-mail: thatinepomuceno@hotmail.com

Abstract

In the state of São Paulo, jambu has been grown with a view to its industrial uses. However, there are few works involving mineral nutrition and organic fertilization in jambu, which leads farmers to use fertilizer recommendations intended for other similar leafy crops and several different fertilizers. Thus, the objective of this study is to evaluate different sources of organic fertilizers in top dressing in the production of jambu under organic management. The experiments were carried out at the Experimental Farm of São Manuel, SP, and at the Zodíaco farm, located in the Demétria district, Botucatu, SP. Six treatments (organic fertilizers in top dressing: ferticel®, provaso, castor bean cake, bokashi, hoof and horn powder, and a control without top dressing) were evaluated, using a randomized block design with five replicates. From two harvests in each location, the following characteristics were evaluated: the fresh weight of vegetative parts (FWVP) and of inflorescences (FWI), the total fresh weight (TFW), the number of inflorescences (NI), and the average weight per inflorescence (AWI). The results show an increase of 158% and 78%; 103 and 101%; 143 and 86%; and 144 and 85%, in FWVP, FWI, NI, and TFW, respectively, with the use of hoof and horn powder (the best treatment, not differing from castor bean cake) compared to the control at Zodíaco farm and at the Experimental Farm of São Manuel, respectively. These results indicate that hoof and horn powder and castor bean cake were the best fertilizers in both harvests and locations, with higher production of both fresh and dry weight of the vegetative and reproductive parts of jambu.

Keywords: *Acmella oleracea*, hoof and horn powder, castor bean cake, nitrogen

Introduction

Jambu (*Acmella oleracea* (L.) R. K. Jansen), also known as *agrião do Pará*, *agrião bravo*, *jambuaçú*, among others, is a perennial herb plant belonging to the Asteraceae family, found mostly in the north of Brazil (Borges et al., 2012). The popular use of this plant as a medicinal herb draws interest from companies, producers, and researchers, who seek to scientifically validate its applications. Studies report that *A. oleracea* acts as an analgesic (Dias et al., 2012), anti-inflammatory (Dias et al., 2012), antioxidant (Abeysinghe et al., 2014), and insecticidal (Benelli et al., 2019). In the cosmetic industry, it can be used in replacement to Botox as an anti-wrinkle cream (Barbosa et al., 2016).

The main substance of economic importance present in jambu is the spilanthol, which is chemically classified as an alkylamide and can be found in the essential oil extracted from jambu (Borges et al., 2012). Its highest occurrence is observed in inflorescences (Dubey et al., 2013).

In the state of São Paulo, jambu has been grown for industrial use, with almost all being produced in the organic system (Nikitin et al., 2018). The practice of organic fertilization has the purpose of improving the physical, biological, and chemical structures of the soil (Quiroz & Flores, 2019). There are few studies on organic fertilization in jambu production, which leads farmers to use fertilizer recommendations for other similar leafy crops and fertilizer sources that may be inadequate for the crop (Peçanha et al., 2019). Therefore, more research on organic fertilization sources for jambu crops is necessary, in order to obtain higher yields, both of biomass and inflorescences, hence higher quality of the final product (Rodrigues et al., 2014). For most leafy vegetables, nitrogen is the most absorbed and accumulated nutrient and, generally, the recommendation is to split its application,

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putting part of the total amount needed in top dressing after planting. However, there are also few studies with organic fertilization in top dressing (Silva et al., 2016; Silva et al., 2018; Cardoso et al., 2020), and producers end up using different organic fertilizers made on the farm or purchased from certified companies, not knowing which is the best option.

Thus, the objective of this research is to evaluate different sources of organic fertilizers in top dressing in jambu production under organic management.

Material and Methods

The experiments were carried out in two locations: in the Experimental Farm of São Manuel, SP, belonging to the School of Agriculture (FCA) - Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), located at 22º 46'35" S, 48º 34'44" W and an altitude of 740 m; and in the Zodíaco farm (producer Adriano Lopes de Souza), located in the Demétria district, municipality of Botucatu, SP, at 22º 58' 11" S, 48º 23' 56" W and an altitude of 870 m. The climate of both locations, according to Köppen's classification, is Cwa type, mesothermal humid subtropical with rainy summer and dry winter (Alvares et al., 2014).

Before performing the experiments, soil samples were collected in both locations for chemical analysis. These samples were obtained from 15 sub-samples taken from the experimental areas at a depth of 0-20 cm. For the Zodíaco farm, the following results were obtained: pH(CaCl2) = 4.5; organic matter (OM) = 19 g dm^{-3}; Presin = 9 mg dm^{-3}; Al3+ = 2 mmol dm^{-3}; H+Al = 29 mmol dm^{-3}; K = 0.3 mmol dm^{-3}; Ca = 15 mmol dm^{-3}; Mg = 5 mmol dm^{-3}; SB = 20 mmol dm^{-3}; CEC = 49 mmol dm^{-3}; V%= 41 mmol dm^{-3}; S = 2 mg dm^{-3}; B = 0.22 mg dm^{-3}; Cu = 5.5 mg dm^{-3}; Fe = 31 mg dm^{-3}; Mn = 2.5 mg dm^{-3}; Zn = 0.5 mg dm^{-3}. As for the São Manuel farm, the following results were obtained: pH(CaCl2) = 5.8; OM = 13 g dm^{-3}; Presin = 190 mg dm^{-3}; Al3+ = 0; H+Al = 11; K = 3.5 mmol dm^{-3}; Ca = 12 mmol dm^{-3}; Mg = 7 mmol dm^{-3}; SB = 22 mmol dm^{-3}; CTC = 33 mmol dm^{-3}; V%= 67 mmol dm^{-3}; S = 5 mg dm^{-3}; B = 0.22 mg dm^{-3}; Cu = 2 mg dm^{-3}; Fe = 47 mg dm^{-3}; Mn = 5.8 mg dm^{-3}; Zn = 18.2 mg dm^{-3}.

At Zodíaco farm, liming was performed 90 days prior to transplanting the seedlings. Soil preparation was carried out on October 11, 2019, by incorporating poultry litter, during pre-planting, with a tractor-rotoencanteirator, at a dose of 40 t ha^{-1} as proposed by Trani et al. (2014) for watercress cultivation, which is used for jambu by producers in the region.

Five treatments were evaluated, corresponding to the fertilizers that are normally used in top dressing by local producers, namely: Ferticel® (Class A Simple Organic Fertilizer), Provaso® (Class A Organic Fertilizer), castor bean cake (Nutrisafra®), bokashi (Nutrisafra®), hoof and horn powder, and a control treatment without any top dressing.

All plots were fertilized in pre-planting only with poultry manure, including the control. As for top dressing, fertilization was carried out according to the nitrogen content found in the analysis of the organic fertilizers (table 1), following the recommendation of 50 kg of N ha^{-1} proposed by Trani et al. (2014). Thus, for each top-dressing treatment, one of the following doses was applied per square meter: 320.5 g of ferticel, 1420 g of proof, 116 g of castor bean cake, 210 g of bokashi, and 34.2 g of hoof and horn powder.

The experimental design was of randomized blocks, with five replications of 20 holes per parcel, considering the four central holes the useful parcel for evaluation.

Table 1 – Micronutrients analysis of the fertilizers used.

Fertilizers	N	P_2O_5	K_2O	Ca	Mg	S	Humidity	OM
	* %							
Poultry litter	1.28	3.25	2.33	---	---	---	4	---
Ferticel	1.56	2.88	3.28	---	---	---	20	---
Provaso	0.35	0.46	0.67	1.61	0.29	0.30	36	19
Castor bean cake	4.34	0.93	0.96	0.69	0.48	0.29	6	42
Bokashi	2.39	2.00	1.58	5.21	0.56	0.48	7	47
Hoof and horn powder	14.59	0.20	0.11	0.17	0.06	1.33	8	92

The seedlings used in the Zodíaco farm were grown in the FCA's seedling nursery, in Botucatu, SP. The jambu variety used was the one with yellow flowers, which is from seeds provided by the producer. Sowing was carried out on September 23, 2019, in 162-cell polypropylene trays, containing Carolina Soil® substrate, with seven to ten seeds per cell, following the same protocol used by the producer. These seedlings remained in the nursery until the date of transplanting, on October 28, 2019. The first fertilization in top dressing was performed on November 10, 2019. On December 12, 2019, the first cutting/harvesting took place, and, after the harvest, new fertilization in top dressing was performed, with the same fertilizers and doses used previously; that is, 50 kg ha^{-1} of N in each application. In both fertilization, the fertilizers were applied between the lines and incorporated into the soil with a hoe. The second cutting/harvesting took place on February 17, 2020.

The seedlings used at the Experimental Farm of São Manuel were also grown in the FCA's nursery, in Botucatu, SP, similarly to those prepared for the experiment at the producer's farm. The sowing occurred on October 11, 2019. Next, they were transplanted into raised beds on December 2, 2019. The first fertilization in top dressing was conducted on December 15, 2019, while the first cutting/harvesting was on February 5, 2020. The second top-dressing application was on February 7, 2020, while the second cutting/harvesting was on March 26, 2020.

For both locations, the aspersion irrigation method was adopted and performed daily throughout the cultivation cycle, with an average depth of 6 mm of water per day when it did not rain. The control of invasive plants was done through manual weeding.

In both areas, the seedlings were transplanted into beds (1.0 m wide and 0.2 m high) with a spacing of 0.25 m between rows and 0.20 m between holes, totaling 20 holes per square meter.

The harvests happened when the opening of most flower buds was observable, and always during the morning. Two harvests were carried out in each location, for the plants regrow after cutting. The branches were manually cut close to the ground by using pruning shears, leaving about 7 cm to allow regrowth. After harvesting, the plants were taken to the laboratory at the Vegetal Production Department, in the Horticulture sector, at FCA/UNESP, where the inflorescences were separated from the rest of the plant material produced.

After each harvest, the following characteristics related to the production from the four holes located in the central part of the plots were evaluated: the fresh weight of vegetative parts (FWVP), which is obtained with a precision digital scale (at an accuracy of 0.01 g) by weighing the whole vegetative parts (stem and leaves); the fresh weight of inflorescences (FWI), obtained with the same precision digital scale by weighing all the inflorescences; the total fresh weight (TFW), which is the fresh weight of vegetative parts plus the fresh weight of inflorescences; and the number of inflorescences (NI), which is evaluated by counting the inflorescences harvested in the plot.

All these characteristics were analyzed by estimating their numerical values per square meter. The average weight per inflorescence (FWI/NI) and the total production (sum of FWVP, FWI, TFW, and NI from the first and second harvests) were also calculated.

The experimental data were subjected to analysis of variance and Tukey's test ($p \leq 0.05$) by using the statistical software Agroestat (Barbosa & Maldonado Júnior, 2015).

Results and Discussion

The analyses of the production of both Zodíaco farm (Table 2) and São Manuel farm (Table 3) show that there was a significant difference in the two cuttings for almost all characteristics.

In the experiment performed at the Zodíaco farm, the treatment with hoof and horn powder fertilizer was superior to almost all other treatments, with the exception of the castor bean cake one, for the number of inflorescences per square meter, both in the first and second cuttings (Table 2).

In the first cutting, only the treatments with hoof and horn powder and castor bean cake were superior to the control without top-dressing treatment, with values ranging from 1069 (control) to 2534 (hoof and horn powder) inflorescences per square meter. On the other hand, in the second cutting, all treatments were superior to the control, with values ranging from 584 (control) to 1488 (hoof and horn powder) inflorescences per square meter. In the sum of both cuttings, the treatment with hoof and horn powder was superior to all the others, and the treatments with ferticel, bokashi, and castor bean cake did not differ from one another.

Regarding the fresh weight of inflorescences (FWI) at the Zodíaco farm, all treatments differed from the control without top dressing, both in the first and second cutting as well as in the total of the two cuttings (Table 2).

In the cutting and in total, the treatment with hoof and horn powder was superior to all other treatments, followed by the treatment with castor bean cake. Meanwhile, in the second cutting, the hoof and horn powder treatment did not surpass only the castor bean cake one (Table 2). The values ranged from 0.88 (control) to 1.54 (hoof and horn powder) kg m^{-2} in the first cutting; from 0.30 (control) to 0.85 (hoof and horn powder) kg m^{-2} in the second cutting; and from 1.18 (control) to 2.40 (hoof and horn powder) kg m^{-2} in total.

The differences in FWI were due to differences in the number of inflorescences, as there was no difference in the average weight of each inflorescence both in the first and second cutting, with averages of 0.80 g and 0.52 g per inflorescence, respectively.

Table 2 - Number of inflorescences (NI), fresh weight of vegetative parts (FWVP), fresh weight of inflorescences (FWI), total fresh weight (TFW), average weight per inflorescence (AWI). First and second cutting and total production of jambu, at Zodíaco farm, 2020.

Treatments	NI	FWVP	FWI	TFW	AWI
	(units/m^{-2})		Kg/m^{-2}		g
		1st cutting			
Control	1069 c	1.99 e	0.88 d	2.88 e	0.83 a
Castor bean cake	1875 ab	3.67 b	1.37 b	5.05 b	0.76 a
Bokashi	1316 bc	2.87 c	1.06 c	3.93 c	0.81 a
Provaso	1275 bc	2.43 d	1.09 c	3.53 d	0.93 a
Ferticel	1169 c	2.52 d	1.02 c	3.54 d	0.88 a
Hoof and horn powder	2534 a	4.44 a	1.54 a	5.99 a	0.61 a
CV%	19.2	2.3	4.5	2.5	18.4
		2nd cutting			
Control	584 d	1.41 c	0.30 c	1.71 c	0.51 a
Castor bean cake	1311 ab	3.82 a	0.72 ab	4.55 a	0.55 a
Bokashi	1201 bc	3.05 b	0.53 b	3.58 b	0.44 a
Provaso	1021 c	2.64 b	0.60 b	3.25 b	0.59 a
Ferticel	1188 bc	2.67 b	0.59 b	3.26 b	0.49 a
Hoof and horn powder	1488 a	4.39 a	0.85 a	5.24 a	0.57 a
CV%	7	10.3	15.2	9	17.4
		Total			
Control	1652 d	3.41 e	1.18 d	4.60 d	0.72 a
Castor bean cake	3186 b	7.50 b	2.10 b	9.60 b	0.66 a
Bokashi	2517 c	5.92 c	1.59 c	7.52 c	0.63 a
Provaso	2296 cd	5.08 d	1.70 c	6.78 c	0.76 a
Ferticel	2357 c	5.19 d	1.61 c	6.81 c	0.68 a
Hoof and horn powder	4022 a	8.83 a	2.40 a	11.24 a	0.59 a
CV%	10.70%	5.10%	6.10%	4.50%	12.50%

Averages followed by the same letter in the columns, for each cutting, do not differ statistically by the Tukey's test at 5% probability.

Table 3 - Number of inflorescences (NI), fresh weight of vegetative parts (FWVP), fresh weight of inflorescences (FWI), total fresh weight (TFW), average weight per inflorescence (AWI). First and second cutting and total production of jambu, at the Experimental Farm of São Manuel, 2020.

Treatments	NI	FWVP	FWI	TFW	AWI
	(units/m^{-2})		Kg/m^{-2}		g
			1st cutting		
Control	650 b	1.51 d	0.65 d	2.15 e	1.03 a
Castor bean cake	769 b	2.00 a	0.86 b	2.86 b	1.12 a
Bokashi	796 ab	1.98 ab	0.78 bc	2.77 bc	1.00 a
Provaso	750 b	1.79 c	0.72 cd	2.51 d	0.96 a
Ferticel	766 b	1.84 bc	0.71 cd	2.56 cd	0.94 a
Hoof and horn powder	1010 a	2.12 a	1.00 a	3.13 a	1.00 a
CV%	13.02	3.6	7.2	3.4	13.4
			2nd cutting		
Control	470 b	0.68 bc	0.26 c	0.94 c	0.55 ab
Castor bean cake	675 b	0.98 b	0.44 b	1.43 b	0.67 ab
Bokashi	501 b	0.61 c	0.28 bc	0.90 c	0.58 ab
Provaso	656 b	0.72 bc	0.31 bc	1.03 bc	0.48 b
Ferticel	711 b	0.94 bc	0.43 bc	1.37 bc	0.61 ab
Hoof and horn powder	1076 a	1.79 a	0.82 a	2.61 a	0.79 a
CV%	20.6	15.2	18	15	21.2
			Total		
Control	1120 b	2.19 d	0.91 d	3.10 d	0.82 a
Castor bean cake	1443 b	2.99 b	1.30 b	4.29 b	0.91 a
Bokashi	1297 b	2.60 c	1.07 cd	3.67 c	0.83 a
Provaso	1406 b	2.51 cd	1.03 cd	3.54 cd	0.73 a
Ferticel	1477 b	2.78 bc	1.15 bc	3.94 bc	0.77 a
Hoof and horn powder	2086 a	3.92 a	1.83 a	5.74 a	0.89 a
CV%	11.80%	5.40%	7.20%	5.40%	13.50%

Averages followed by the same letter in the columns, for each cutting, do not differ statistically by the Tukey's test at 5% probability.

Regarding the fresh weight of vegetative parts at the Zodíaco farm, all treatments differed from the control without top dressing, both in the first and second cutting and in total (Table 2). In the first cutting and in total, the treatment with hoof and horn powder was superior to all other treatments, followed by the castor bean cake treatment as the second most superior, while in the second cutting, the hoof and horn powder was not superior to the castor bean cake. The values ranged from 1.99 (control) to 4.44 (hoof and horn powder) kg m^{-2} in the first cutting; from 1.41 (control) to 4.39 (hoof and horn powder) kg m^{-2} in the second cutting; and from 3.41 (control) to 8.83 (hoof and horn powder) kg m^{-2} in total.

As for the total fresh weight (vegetative parts + inflorescences) at the Zodíaco farm, all the treatments were superior to the control without fertilization in top dressing both in the first and second cutting and in the sum of these (Table 2).

In the first cutting, the treatment with hoof and horn powder was superior to all the others, followed by the castor bean cake and then by the bokashi. Meanwhile, in the second cutting, the treatments with hoof and horn powder and castor bean cake fertilizers did not differ from each other and were superior to all the others. As for the total, the hoof and horn powder was superior to all others, followed by the castor bean cake, while the others (bokashi, ferticel, and provaso) did not differ from one another. The values ranged from 2.88 (control) to 5.99 (hoof and horn powder) kg m^{-2}, from 1.71 (control) to 5.24 (hoof and horn powder) kg m^{-2}, and from 4.60 (control) to 11.24 (hoof and horn powder) kg m^{-2} in the first and second cuttings, and in total, respectively (Table 2).

On the Experimental farm of São Manuel, the treatment with hoof and horn fertilizer stood out, obtaining a greater number of inflorescences per square meter. It was superior to almost all other treatments in the first cutting with the exception of the castor bean cake treatment, and also superior to all treatments in the second cutting and in the sum of both cuttings (Table 3). In this location, for this characteristic, only the hoof and horn powder fertilization was superior to the control without top dressing. The values ranged from 650 (control) to 1010 (hoof and horn powder) inflorescences/ m^2 in the first cutting; from 470 (control) to 1076 (hoof and horn powder) inflorescences/m^2 in the second cutting; and from 1120 (control) to 2086 (hoof and horn powder) inflorescences/m^2 in total (Table 3).

Again, on the Experimental Farm, the treatment with hoof and horn fertilizer was superior to all the other treatments for the fresh weight of inflorescences in both first and second cuttings as well as for the sum of them (Table 3). In the first cutting, only the treatments with hoof and horn powder, castor bean cake and bokashi were superior to the control; in the second cutting, only hoof and horn powder and castor bean cake were superior to the control; and in total, only provaso and bokashi did not differ from the control (Table 3). The values ranged from 0.65 (control) to 1.00 (hoof and horn powder) kg m^2 in the first cutting; from 0.26 (control) to 0.82 (hoof and horn powder) kg m^2 in the second cutting; and from 0.91 (control) to 1.83 (hoof and horn powder) kg m^2 in total (Table 3).

Borges et al. (2014) obtained 1.4 kg m^{-2} of fresh weight of inflorescences in a jambu harvesting by using barn manure at planting and then castor bean cake in top dressing, i.e., a numerically higher value than most treatments in this study, except for the treatment with hoof and horn powder at the Zodíaco farm, where 1.5 kg m^{-2} was obtained in the first cutting (Table 2).

The increase in both the number and fresh weight of inflorescences in São Manuel by using hoof and horn powder compared to the control without top dressing was by 55% and 56% in the first cutting, 128% and 215% in the second cutting, and 86% and 101% in total, respectively.

In the Zodíaco farm, the increases observed by using hoof and horn powder fertilizer compared to the control without top dressing were by 137% and 76% in the first cutting, 154% and 184% in the second, and 143% and 103% in total for the number and fresh weight of inflorescences, respectively. These significant increases show the advantage of this treatment, mainly because the inflorescences are part of the plant most valued by pharmaceutical and cosmetic industries in terms of jambu production, as they have a higher content of spilanthol (DUBEY et al., 2013). Oliveira & Innecco (2015) observed that there was an estimate of maximum biomass production of flower heads at a dose of 4 kg m^{-2} of organic compost, with a reduction in mass of both fresh and dry matter after this dose.

As for the average weight per inflorescence in São Manuel, there was no significant difference between the treatments in the first cutting and in total, while in the second cutting, the treatment with hoof and horn powder had heavier inflorescences compared to ferticel. However, all the treatments did not differ noticeably from the control in the first and second cuttings, as well as in their average when calculated (Table 3).

Due to the absence of statistical difference between all treatments in relation to the control, both in the Zodíaco farm (Table 2) and in the Experimental Farm of São Manuel (Table 3), it can be stated that the weight of each inflorescence, unlike the number of inflorescences, is practically not affected by the source of fertilization in top dressing used.

At the Experimental Farm of São Manuel, all fertilizers were superior in comparison to the control for the variable fresh weight of vegetative parts in the first cutting, and the hoof and horn powder, castor bean cake, and bokashi fertilizers were also superior in comparison to provaso. However, in the second cutting, only the treatment with hoof and horn powder was superior to the control. In the sum of both cuttings, the treatment with hoof and horn powder was superior to all others, followed by castor bean cake as the second most superior, and only the treatment with provaso did not differ from the control (Table 3). The values ranged from 1.51 (control) to 2.12 (hoof and horn powder) km m^{-2} in the first cutting; from 0.68 (control) to 1.79 (hoof and horn powder) km m^{-2} in the second cutting; and from 2.19 (control) to 3.92 (hoof and horn powder) km m^{-2} in total.

Regarding the total fresh weight (vegetative parts + inflorescences) in São Manuel, all the treatments were superior to the control without top dressing in the first cutting, with the hoof and horn powder fertilizer standing out. In the second cutting, only the treatments with hoof and horn powder and castor bean cake differed from the control, while in total only the provaso did not differ from the control. The values ranged from 2.15 (control) to 3.13 (hoof and horn powder) km m^{-2} in the first cutting; from 0.94 (control) to 2.61 (hoof and horn powder) km m^{-2} in the second cutting; and from 3.10 (control) to 5.74 (hoof and horn powder) km m^{-2} in total (Table 3).

Several authors have reported an increase in the fresh weight of vegetables as a result of the addition of organic fertilizers, such as endive (Lanna et al., 2017), cauliflower (Candian, 2018), rocket (Solino et al., 2010), and cabbage (Cardoso et al., 2020). This increase occurs because organic fertilizers are responsible for promoting soil protection; nutrition of microorganisms that mobilize nutrients, which are available to plants; formation of soil aggregates (structure conditioner), consequently reducing bulk density; the entry of water and air; and sufficient water retention, that is, water available at field capacity (Primavesi, 2016).

The hoof and horn powder fertilizer proved to be an excellent fertilizer for jambu, which is a short-cycle vegetable, as it resulted in greater production, both of the vegetative parts and of the inflorescences, probably, according to Laber (2003), due to the fact that this fertilizer is considered one of the most efficient organic fertilizers for the release of nutrients, mainly nitrogen. Almeida et al. (2021) also reported that this fertilizer is more efficient in releasing nitrogen compared to other organic fertilizers, such as bone meal, blood meal, and castor bean cake. According to this author, castor bean cake was the second most efficient organic fertilizer tested for the release of nitrogen, similar to what was observed in this research.

According to Severino et al. (2004), castor bean cake is a material with high microbial activity, its decomposition is very fast, and nutrients are more quickly released and used by plants. Some studies have already demonstrated the beneficial effect of using castor bean cake, both in fertilization at planting and in top dressing, in the production of beet (Silva et al., 2016), cauliflower (Candian, 2018), zucchini (Lanna et al., 2017), and cabbage (Cardoso et al., 2020).

Although the N dose was the same (50 kg ha^{-1}), the nutrient release rate by organic fertilizers is different. In addition, these two fertilizers (hoof and horn powder and castor bean cake), as they are more concentrated in N (Table 1), were added in smaller amounts, 34.2 and 116 g m^{-2}, respectively. Therefore, the potential for supplying other nutrients is smaller, which helps validate the hypothesis that the best results obtained with these fertilizers are related to the nutrient release rate and not to the greater amount of nutrients to be mineralized.

As the hoof and horn powder and castor bean cake fertilizers release nitrogen efficiently, there was an increase in biomass production. Normally, plants that are not fertilized in top dressing have thin, fibrous stems, because of the excess of carbohydrates that are not used in the synthesis of amino acids and other nitrogenous compounds that could compose the inflorescences (Taiz et al., 2017). However, in this research, no nutrient deficiency was observed in the plants under study. These fertilizers come with the purpose of improving the physical, biological, and chemical structures of the soil, and this, for some species, is closely linked to biomass production.

Bokashi was the third best fertilizer tested, considering the production of inflorescences, which is the most valued material in the plant to the pharmaceutical industry (Rodrigues et al., 2014). This fertilizer has the important function of stimulating the increase of microorganisms that live in the soil. These microorganisms decompose the organic matter, providing nutrients for the plants; it has a better effect if incorporated into the soil. Despite having been incorporated into the soil after the application, this incorporation was not very deeply done so as not to harm the plant roots and may have reduced the efficiency not only of the bokashi but also of the other fertilizers used in top dressing.

The importance of incorporating organic fertilizers so that there can be greater action by soil microorganisms and, consequently, greater and faster release of nutrients for plants was highlighted by Monsalve et al. (2017) in a literature review on the use of organic fertilizers in the production of horticultural species.

Jambu is a crop with a short cycle, and because the hoof and horn powder and castor bean cake fertilizers release nitrogen very efficiently, it made them the best options. Rodrigues et al. (2014) reported a linear increase in fresh weight of jambu plants as nitrogen fertilization increased. In leafy vegetables, the adequate supply of nitrogen favors vegetative growth, leading to leaf expansion, increasing the photosynthetic tissue, and consequently enhancing the productive potential (Filgueira, 2008).

Nitrogen is closely linked to the constitution of plant cell structures, including amino acids, proteins, and nucleic acids. In addition, nitrogen is directly correlated with chlorophyll biosynthesis (Lee et al., 2019). This relationship directly reflects on the accumulation of plant dry matter weight, since chlorophyll is directly involved in photosynthesis (Taiz et al., 2017). Perhaps higher doses of these fertilizers could result in an even greater increase in production, as they could release greater amounts of nutrients. By using castor bean cake and bokashi, Silva et al. (2016; 2018) reported a linear increase in fresh and dry weight of beet the higher the dose of these fertilizers.

Studies on fertilization in top dressing are rare, and the results obtained in this research aid in making the decision of which source to use in order to increase productivity, benefiting both organic producers and conventional producers who seek to revitalize soils.

Conclusion

The best agronomic performance of jambu was obtained through the application of the hoof and horn powder and castor bean cake organic fertilizers, which are the best options among those used by producers in the region of Botucatu, SP.

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