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Organic fertilizer doses for top-dressing fertilization in jambu (Acmella oleracea [(L.) R. K. Jansen]) production

Thatiane Nepomuceno Alves[1*], Antonio Ismael Inácio Cardoso[1], Nicholas Taborda Nordi[1], Joseantonio Ribeiro de Carvalho[1], Marcelo Munhoz Venâncio de Oliveira[2], Débora Cristina Mastroleo Luís[1], Renan Lima de Sousa[1]

[1]Universidade Estadual Paulista - UNESP, Botucatu-SP, Brazil
[2]Instituto Agronômico de Campinas - IAC, Campinas-SP,Brazil
*Corresponding author, e-mail: thatinepomuceno@hotmail.com

Abstract

Due to the lack of specific fertilization recommendations for jambu cultivation, producers commonly use fertilizers recommended for other vegetables. This study aimed to evaluate the effect of different doses of organic fertilizers, namely hoof and horn powder and castor bean cake, on jambu plant production under an organic system. The experiments were conducted at the Experimental Farm of São Manuel, SP, belonging to the School of Agriculture (FCA) – UNESP, and at the "Estância Três Nascentes" site, located in Botucatu, SP, Brazil. Twelve treatments were evaluated, in a 2 x 6 factorial design, consisting of two organic fertilizers (castor bean cake (CBC) and hoof and horn powder (HHP)) x 6 top dressing N doses (50, 75, 100, 125, 150, and 0 (control without these fertilizers)). The experimental design was a randomized block with four replications. Plant height (PH), number of inflorescences (NI), the fresh weight of inflorescence (FWI), the fresh weight of vegetative parts (FWVP), and the total fresh weight (TFW) were evaluated at each location. Linear increases were observed in all characteristics in both locations as the fertilizer doses increased. Comparing the highest dose (150 kg ha-1 of N) with the control, increases of 109%, 251%, 218%, 283%, and 227% were obtained at the farm in São Manuel, and 69%, 79%, 111%, 276%, and 118% in Botucatu, for PH, NI, FWVP, FWI, and TFW, respectively. When comparing the two fertilizers, HHP presented better results than CBC for most characteristics in both areas.

Keywords: Castor bean cake, horn and hoof powder, nitrogen, organic system

Introduction

Jambu (*Acmella oleracea* (L.) R. K. Jansen) is a non-conventional herbaceous vegetable with small size and branching creeping stems, belonging to the Asteraceae family. It is consumed in typical dishes of the Northern region of Brazil and used for medicinal purposes (Gusmão & Gusmão, 2013; Ferreira et al., 2021).

Furthermore, there is a growing interest from companies in the cosmetics and pharmaceutical industries. Although all parts of the jambu plant are used, it is the inflorescences that contain the highest concentration of the most interesting secondary compound, called spilanthol (Dias et al., 2012; Rodrigues et al., 2014). In regions such as the Southeast, specifically in the state of São Paulo, crops occur during the spring-summer season, when conditions are favorable for the development of the cultivar (Nordi et al., 2022; Nordi et al., 2022).

Both for consumption and industrial use, the highest demand is for jambu cultivated in the organic system. However, there is still a scarcity of research on organic fertilization, especially in top dressing (Borges et al., 2013; 2018; Souto et al., 2018; Nordi et al., 2022). There are several options for organic fertilizers, which vary in their chemical composition, and the amount to be applied will depend on the soil fertility conditions (Nordi et al., 2022) among other factors.

Organic fertilization, in addition to supplying nutrients to the plants, can also promote the reuse of agricultural and industrial waste with potential for agriculture. Among the fertilizers with potential to be used in top dressing for vegetables are castor bean cake and hoof and horn powder, which are excellent sources of nitrogen and have a rapid release due to their low carbon-to-nitrogen ratio (Almeida et al., 2021).

In organic fertilizers rich in nitrogen such as castor

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bean cake and hoof and horn powder, fertilization should be applied in a way to avoid excess nutrients in the soil solution (Candian, 2018; Nordi et al., 2022). The speed of nutrient release by organic fertilizers should be according to the crop demand (Cardoso et al., 2020).

However, despite castor bean cake and hoof and horn powder being fertilizers with great potential, which has already been proven for different vegetables (Silva et al., 2016; Cardoso et al., 2020; Lanna et al., 2020; Almeida et al., 2021; Hounmenou et al., 2021, Nordi et al., 2022), more studies are needed to allow the recommendation of the best fertilizer and doses, aiming to increase crop productivity and reduce costs. The objective of this study was to evaluate the effect of doses of the organic fertilizers castor bean cake and hoof and horn powder on jambu plant production in an organic system.

Material and methods

The experiments were carried out in the Experimental Farm of São Manuel, belonging to the Faculty of Agronomic Sciences (FCA) - São Paulo State University 'Júlio de Mesquita Filho' (UNESP), located in the municipality of São Manuel, SP, at 22º 46' 35" S and 48º 34' 44" W with an altitude of 740 m; and in the organic producer's site at 'Estância Três Nascentes', located in Botucatu, SP, at 22º 58' 11" S and 48º 23' 56" W with an altitude of 870 m. The climate in both municipalities, according to the Köppen classification, is Cwa-type mesothermal, humid subtropical, with a rainy summer and a dry winter (Alvares et al., 2014).

Before the experiments were installed, soil samples were collected in both areas at a depth of 0-20 cm, and their chemical characteristics were evaluated according to (Raij et al., 2001) methodology. The following results were obtained for the farm area in São Manuel: pH ($_{CaCl2}$) = 5.6; organic matter (O.M.) = 11 g dm^{-3}; Presin = 319 mg dm^{-3}; H+Al = 12 $mmol_c$ dm^{-3}; K = 3.1 $mmol_c$ dm^{-3}; Ca = 49 $mmol_c$ dm^{-3}; Mg = 8 $mmol_c$ dm^{-3}; sum of bases (SB) = 60 $mmol_c$ dm^{-3}; cation exchange capacity (CEC) = 72 $mmol_c$ dm^{-3}; base saturation (V%) = 83. For the area in Botucatu, the following results were obtained: pH ($_{CaCl2}$) = 5.6; organic matter (O.M.) = 39 g dm^{-3}; Presin = 64 mg dm^{-3}; H+Al = 21 $mmol_c$ dm^{-3}; K = 4.4 $mmol_c$ dm^{-3}; Ca = 40 $mmol_c$ dm^{-3}; Mg = 12 $mmol_c$ dm^{-3}; SB = 56.4 $mmol_c$ dm^{-3}; CEC = 77.4 $mmol_c$ dm^{-3}; V% = 73.

Soil preparation in each area was performed by incorporating organic class A fertilizers (Provaso 30 t ha^{-1}) in São Manuel and organic compost Floral (20 t ha^{-1}) in the producer's site in Botucatu, with the use of a tractor-rotoencanteirator prior to planting. The chemical analyses of these fertilizers are shown in Table 1. The Floral compost contains agro-industrial organic residues class A, manure and poultry litter, ashes, concentrated corn maceration residues, eggshells, and pruning and mowing residues.

Twelve treatments were evaluated in a 2 x 6 factorial scheme, with two organic fertilizers (castor bean cake and hoof and horn powder) x 6 rates of N in top dressing (50, 75, 100, 125, 150, and 0 (control without these fertilizers)). The experiment design was a randomized block with four replications, totaling 48 plots of 1 m^2. The choice of the minimum dose of 50 t ha^{-1} N was based on the results of (Nordi et al., 2022) research on jambu culture in the region, where the best results were obtained when using the castor bean cake and hoof and horn powder fertilizers.

According to the chemical analysis of the fertilizers (**Table 1**), the amount applied in top dressing was calculated (**Table 2**), following the established doses. The castor bean cake and hoof and horn powder fertilizers applied in top dressing were placed in the interlines, without incorporation into the soil at 15 days after transplanting (DAT).

In the experiment conducted in São Manuel, the sowing was carried out on August 20, 2020, in 200-cell polypropylene trays containing Carolina substrate, with 3 to 5 seeds per cell. The variety used was the one with yellow and purple jambu flowers. The seedlings were transplanted on September 29, 2020.

Table 1- Analysis results for macronutrients, moisture, and organic matter (OM) of the fertilizers used: provaso (PRO), floral compost (FLOC), castor bean cake (CBC), and hoof and horn powder (HHP)

Fertilizers	N	P_2O_5	K_2O	Ca	Mg	S	Moisture	OM	Ratio C/N
	---------- * % ----------								
PRO	0.35	0.46	0.67	1.61	0.29	0.30	36.00	19.00	20/1
FLOC	8.8	1.9	1.1	5.96	0.66	0.25	26.00	42.18	1.93/1
CBC	4.34	0.93	0.96	0.69	0.48	0.29	6.00	42.00	4.3/1
HHP	14.59	0.20	0.11	0.17	0.06	1.33	8.00	92.00	0.5/1

Table 2- Quantity of organic fertilizers, hoof and horn powder and castor bean cake, applied as top dressing according to the treatments

Fertilizer	Doses of N (kg ha^{-1})					
	Control	50	75	100	125	150
	Quantity of fertilizer (g m^{-2})					
Castor bean cake	0	104.17	157.00	209.00	261.00	312.50
Hoof and horn powder	0	33.80	50.68	68.00	84.50	101.35

For the experiment conducted in Botucatu, the seedlings were produced by the producer himself, in trays with 200 cells, with 3 to 4 plants per cell, and were transplanted on October 18, 2020.

In both areas, the seedlings were transplanted into beds, spaced 0.25 m between rows and 0.20 m between holes, totaling 20 holes m^{-2}, with three plants per hole.

The irrigation system in Botucatu was by sprinkling, and in the farm in São Manuel, it was by micro-sprinkling, and weed control in both areas was carried out manually whenever necessary. The fertilization in top dressing was carried out 15 days after transplanting (DAT), on October 14, 2020, and November 02, 2020, at the São Manuel farm and in Botucatu, respectively.

Harvesting was carried out at 60 DAT in both areas. For production evaluation, only the plants from four central holes (useful parcel) were harvested. The aerial part was cut to approximately 7 cm from the ground and taken to the laboratory at the Vegetal Production Department, in the Horticulture sector, at FCA/UNESP, Botucatu campus, for later separation of the inflorescences and the rest of the plant material produced to evaluate the following characteristics:

a) plant height: measured with a graduated ruler;

b) number of inflorescences, estimated per m^{-2};

c) the fresh weight of vegetative parts, inflorescences, and total (vegetative part + inflorescences): determined by weighing each part of the plants on an analytical balance with a precision of 0.1 g and estimating the values in kg m^{-2}.

The experimental data were subjected to the Shapiro-Wilk normality test ($p \leq 0.05$). Then, the analysis of variance and regression was carried out using the statistical software SISVAR (Ferreira, 2014).

Results and discussion

The results showed a significant interaction between the factors (fertilizers and doses), according to the F-test, for the number of inflorescences and the fresh weight of inflorescences, as well as statistical differences for the doses in all characteristics in both the research conducted at the farm in São Manuel and the producer's area in Botucatu. For the fertilizer factor, almost all characteristics in both areas were significant according to the F-test, except for the fresh weight of vegetative parts in the research conducted in Botucatu (**Table 3**).

The results showed that for the plant height of jambu characteristic, there was a difference between fertilizers in both areas, with greater height in the treatments that used hoof and horn powder (**Table 4**). In São Manuel, for the fertilizer doses factor, the best fit was the increasing linear (**Figure 1**A), with an estimate of 25.5 and 24.7 cm for the highest dose (150 kg ha^{-1} of N) with hoof and horn powder and castor bean cake, respectively, representing an average increase of 109% compared to the control (dose 0).

Table 3- Table 3 - Summary of variance analysis for plant height (PH), number of inflorescences (NI), fresh weight of vegetative parts (FWVP), fresh weight of inflorescence (FWI), and total fresh weight (TFW) of jambu plants in relation to nitrogen doses for the organic fertilizer's castor bean cake and hoof and horn powder. São Manuel, SP, and Botucat, SP, 2020

	PH	NI	FWVP	FWI	TFW
		São Manuel			
MS Adubos (F)	18.75**	31505.42**	3.22**	0.1869**	4.959**
MS Doses (D)	238.13**	4500211**	10.52**	0.5793**	15.928**
MS Interaction (FxD)	2.30^{ns}	124953.90**	0.30^{ns}	0.027**	0.479^{ns}
MS Residue	2.59	8503.43	0.204	0.0069	0.233
CV (%)	8.4	12.4	17.8	15.5	15.6
		Botucatu			
MS Adubos (F)	16.33**	83500.08**	0.311^{ns}	0.019**	0.485**
MS Doses (D)	453.18**	388703.08**	14.04**	0.227**	17.73**
MS Interação (FxD)	2.03^{ns}	31336.08**	0.088^{ns}	0.008**	0.114^{ns}
MS Residue	3.10	3113.40	0.117	0.0006	0.115
CV (%)	4.0	5.6	5.9	5.34	5.4

MS = Mean square,
*, ** = significant by F test at 5% and 1%, respectively.

Tabela 4 - Means for plant height (PH), fresh weight of vegetative parts (FWVP), and total fresh weight (TFW) of jambu plants for the fertilizers hoof and horn powder (HHP) and castor bean cake (CBC). São Manuel, SP, and Botucatu, SP, 2020

Adubos	PH	FWVP	TFW
	São Manuel		
HHP	19.91 a	2.804 a	3.404 a
CBC	18.67 b	2.286 b	2.761 b
CV (%)	8.4	17.8	15.6
	Botucatu		
HHP	44.79 a	5.914 a	6.400 a
CBC	42.62 b	5.753 a	6.199 b
CV (%)	4.0	5.9	5.4

C.v%: Coefficient of variation,
*Means followed by the same lowercase letter in the column, for each area, do not differ from each other by the Tukey's test at 5% probability.

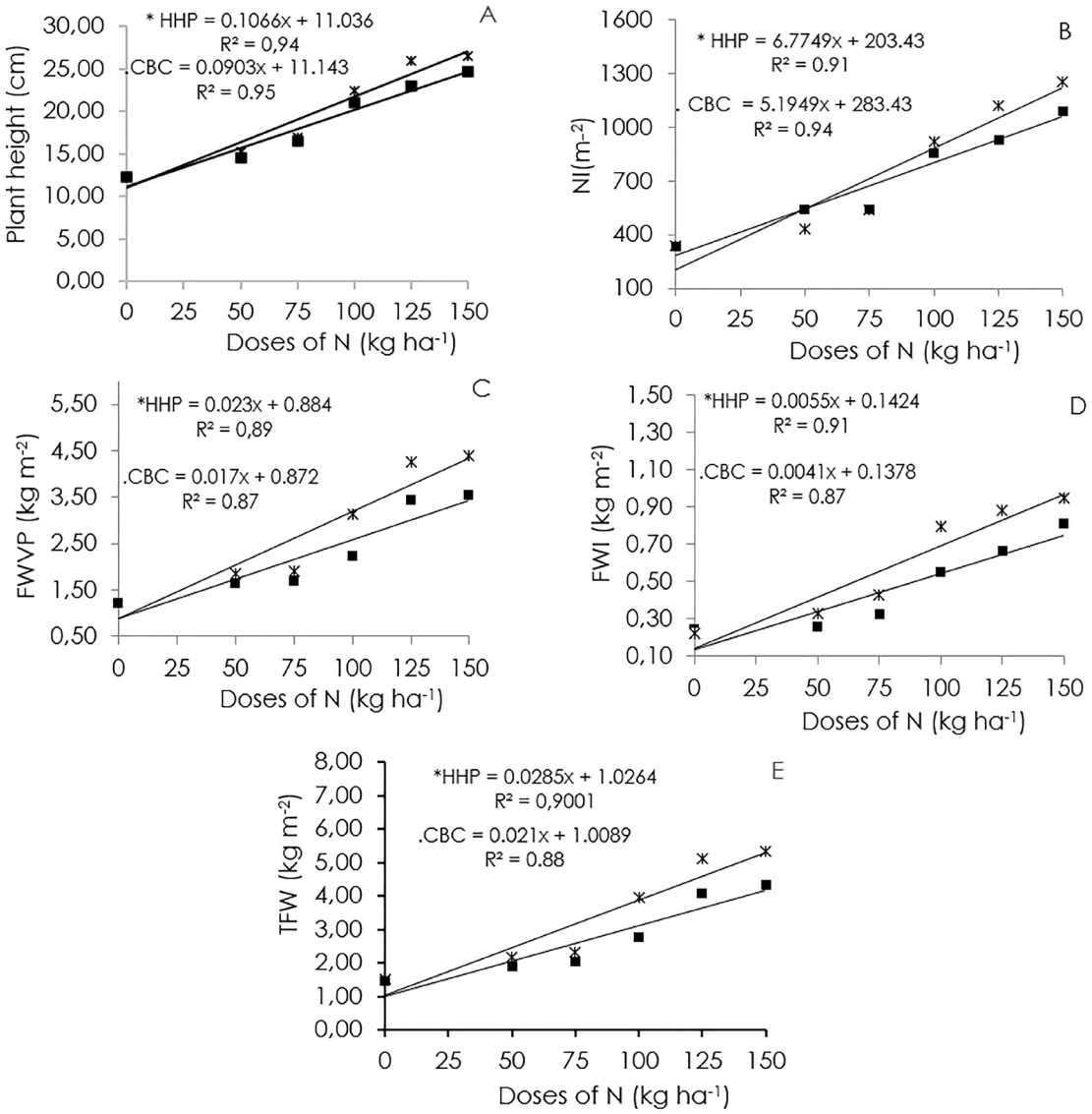

Figure 1- Plant height, number of inflorescences (NI), fresh weight of vegetative parts (FWVP), fresh weight of inflorescence (FWI), and total fresh weight (TFW) of jambu plants as a function of nitrogen doses for the fertilizers hoof and horn powder and castor bean cake. São Manuel, SP, 2020.

In the producer's area in Botucatu (**Figure 2**A), the best fit was quadratic, both for hoof and horn powder and castor bean cake, with maximum heights estimated at 49.5 and 49.2 cm, for doses of 113 and 133 kg ha^{-1} of N, respectively. The values obtained are within the range described by (Gusmão & Gusmão, 2013) as normal for jambu, which is from 20 to 50 cm. (Borges et al., 2014) obtained heights of 27 and 21 cm with the Jamburana and Nazaré cultivars, respectively, when grown with organic fertilization, which is similar to the values obtained in the São Manuel Farm.

For the number of inflorescences, at the São Manuel farm, the data fit a linear increasing model, with maximum values estimated at 1253 and 1093 inflorescences per m^{-2}, that is, values 273% and 228% higher than the control (dose 0), for the hoof and horn powder and castor bean cake, respectively (Figure 1B). On the other hand, in the producer's area in Botucatu (Figure 2B), the data in the treatments with hoof and horn powder fit a cubic model, with a maximum estimated at 1293 inflorescences per m^{-2} at the highest dose tested, while with castor bean cake, the fit was linear, with a maximum estimated at 1162 inflorescences per m^{-2}, also at the highest dose (150 kg ha^{-1} of N).

In comparing the fertilizers, plants fertilized with hoof and horn powder produced more inflorescences than those fertilized with castor bean cake only at the two highest doses (125 and 150 kg ha^{-1} of N), both at the São Manuel farm (**Table 5**) and in the producer's area in Botucatu (**Table 6**).

Despite the importance of inflorescences, which according to (Homma et al., 2014) have a higher concentration of spilanthol and, therefore, are of great importance for medicinal and cosmetic use, few studies

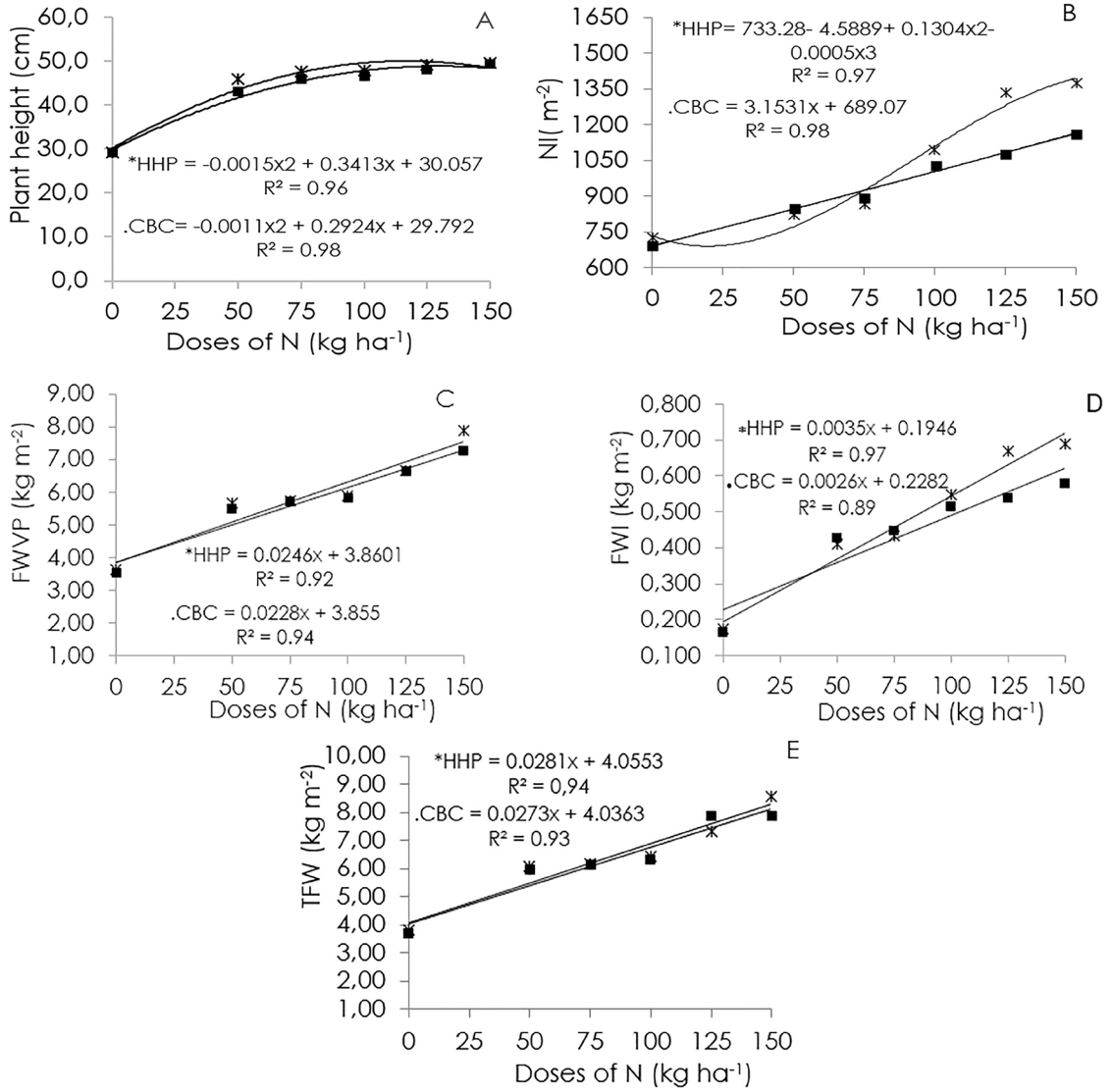

Figura 2- Plant height, number of inflorescences (NI), fresh weight of vegetative parts (FWVP), fresh weight of inflorescence (FWI), and total fresh weight (TFW) of jambu plants as a function of nitrogen doses for the fertilizers hoof and horn powder and castor bean cake. Botucatu, SP, 2020.

Table 5- Means of the number of inflorescences and fresh weight of inflorescences of jambu plants as a function of nitrogen doses in top dressing for the fertilizers castor bean cake (CBC) and hoof and horn powder (HHP). São Manuel, SP, 2020

Doses (N)	0	50	75	100	125	150	CV%
Number of inflorescences (units m^{-2})							
HHP	337 a	431 a	540 a	923 a	1124 a	1253 a	12.4
CBC	333 a	540 a	542 a	857 a	933 b	1093 b	
Fresh weight of inflorescences (kg m^{-2})							
HHP	0.220 a	0.331 a	0.430 a	0.794 a	0.879 a	0.949 a	15.5
CBC	0.245 a	0.257 a	0.327 a	0.551 b	0.663 b	0.810 a	

C.v.%: Coefficient of variation.
Means followed by the same lowercase letter in the column (T-test) do not differ statistically ($p < 0.05$).

Table 6 - Means of the number of inflorescences and fresh weight of inflorescences of jambu plants as a function of nitrogen doses in top dressing for the fertilizers castor bean cake (CBC) and hoof and horn powder (HHP). Botucatu, SP, 2020

Doses	0	50	75	100	125	150	CV%
Number of inflorescences (units m^{-2})							
HHP	726 a	823 a	863 a	1092 a	1335 a	1373 a	5.8
CBC	693 a	853 a	893 a	1031 a	1079 b	1162 b	
Fresh weight of inflorescences (kg m^{-2})							
HHP	0.173 a	0.411 a	0.432 a	0.546 a	0.668 a	0.687 a	5.6
CBC	0.165 a	0.427 a	0.447 a	0.516 a	0.539 b	0.581 b	

C.v.%: Coefficient of variation.
Means followed by the same lowercase letter in the column (T-test) do not differ statistically ($p < 0.05$).

evaluate their number. In the study by (Rodrigues et al., 2014), when ammonium sulfate was applied at a dose of 112.5 kg ha^{-1} of N, they reached 423.7 inflorescences per m-2, and (Nordi et al., 2022) reported in the research conducted at the same São Manuel farm, 1010 and 769 inflorescences per m-2, with hoof and horn powder and castor bean cake, respectively, which means lower values than those observed at the highest doses (Table 5). However, the authors evaluated a single dose of 50 kg ha^{-1} of N, and for this dose, the values observed in this study are higher than those in the two studies when compared to the lowest dose (50 kg ha^{-1} of N).

Linear increases were observed for the fresh weight of inflorescences, vegetative parts, and the total weight of jambu plants as the dose of both fertilizers increased, both on São Manuel farm (Figure 1) and on the producer's area in Botucatu (Figure 2). For the fresh weight of inflorescences, increases were obtained on São Manuel farm (Figure 1) of 332% and 238% with the highest dose (150 kg ha^{-1} of N) compared to the control (dose 0) for hoof and horn powder and castor bean cake, respectively; while on the producer's area (Figure 2), the increases were 299% and 252%.

For the fresh weight of the vegetative parts, the increases on São Manuel farm (Figure 1) were 237% and 197% for hoof and horn powder and castor bean cake, respectively, and on the producer's area (Figure 2), the increases were 116% and 105%. For the total fresh weight, increases were obtained on São Manuel farm (Figure 1) of 251% and 202% with the highest dose (150 kg ha-1 of N) compared to the control (dose 0) for hoof and horn powder and castor bean cake, respectively, while on the producer's area (Figure 2), the increases were 124% and 112%.

In the comparison between fertilizers, plants fertilized with hoof and horn produced a greater mass of inflorescences than those fertilized with castor cake only at the two highest doses (125 and 150 kg ha^{-1} of N) on São Manuel farm (Table 5) and on the producer's area in Botucatu at doses of 100 and 125 kg ha^{-1} of N (Table 6). On São Manuel farm, plants fertilized with hoof and horn powder produced a greater fresh matter mass of the vegetative part than plants in treatments with castor cake (Table 4), regardless of the dose, while in the Botucatu area, there was no difference between fertilizers. For the total fresh weight, hoof and horn powder resulted in higher values in both experimental areas.

The values obtained in the best treatments are similar to or higher than those reported by other authors. (Borges et al., 2013) reported a total fresh weight of 2.78 kg m^{-2} with the use of corral manure (4 kg m^{-2}). (Oliveira et al., 2014) obtained 323.7 g m^{-2} of inflorescences, applying 445 kg ha^{-1} of N in the form of organic compost, and (Rodrigues et al., 2014) obtained 3.46 kg m^{-2} of the vegetative parts and 423.7 inflorescences per m^{-2}, applying ammonium sulfate (112.5 kg ha^{-1} of N). Using hoof and horn powder and castor bean cake in top dressing, both at a dose of 50 kg ha^{-1} of N, (Nordi et al., 2022) obtained 1.00 and 0.86 kg m^{-2} of inflorescences, 2.12 and 2.00 kg m^{-2} of the vegetative parts, and 3.13 and 2.86 kg m^{-2} total per plant, respectively, on the same São Manuel farm, in the first harvest.

Considering that the chemical characteristics of the soil for both areas presented chemical composition that were not very different, except for phosphorus, which had higher levels in the farm in São Manuel, the higher values for the production of fresh weight obtained in the area of the producer in Botucatu are probably due to the base fertilization, which were different. Phosphorus has an effect on the root system, influencing the formation of new roots, their functioning, and the absorption of water and nutrients. Moreover, its role in storing energy in the form of ATP makes this element an important component of metabolic pathways, directly influencing processes that will generate essential oil compounds (Lopes & Lima, 2015).

The floral compound used by the producer is much richer in nitrogen than the provaso fertilizer used in São Manuel (Table 1). In addition to the higher N content, the floral compound also has a lower C:N ratio than the provaso, favoring a faster release of nutrients, which is important in the initial phase of the crop, before applying the top dressing. On the other hand, this higher amount of N favored more the increase in the vegetative parts than in the reproductive (inflorescences).

While the mass of fresh matter of the inflorescences represents about 18% of the total fresh matter at the São Manuel farm, it represents only about 8% in the area of the producer in Botucatu. Considering that the producer sells the whole plant, without separating the vegetative parts from the inflorescences, this lower proportion of inflorescences may result in a final product with a lower content of spilanthol and, therefore, lower industrial value.

For almost all the evaluated characteristics, an increase in values was observed with higher fertilizer doses, showing the need for complementation of the base fertilization carried out with at least one top dressing application. Considering the linear effects, higher doses may still result in higher production. However, the excess can also be harmful, as observed by (Candian, 2018),

who reported linear increases in cauliflower production with increasing doses of castor bean cake in a less fertile area, and for the same doses in another area with soil rich in organic matter, the effect was quadratic, with a reduction in production with higher doses.

In this study, in the producer's area in Botucatu, the increases, proportionally to the control, were smaller than in São Manuel, and for plant height and the number of inflorescences, the increases were no longer linear, which may indicate that the highest doses may already be close to the limit. It should also be remembered that the production increases observed with organic fertilization are not only due to the release of nutrients but also to the physical and biological properties and protection of the soil, even more so in tropical areas (Primavesi, 2016).

Tropical soils are usually poor in organic matter due to their rapid mineralization (Primavesi, 2016), and the use of organic material in every crop is of fundamental importance because if the organic material in the soil is too low, it can limit production (Malavolta et al., 1997). Production increases with the use of these organic fertilizers have been reported in several vegetables grown under tropical and subtropical conditions (Lanna et al., 2017; Silva et al., 2018; Souto et al., 2018; Cardoso et al., 2020).

The fertilizers used, hoof and horn powder and castor bean cake, were chosen because they were the best in previous research (Nordi et al., 2022), compared to other organic fertilizers. When there was a difference between fertilizers, the hoof and horn powder one was superior to the castor bean cake. According to (Almeida et al., 2021), hoof and horn powder is one of the most efficient fertilizers in releasing nutrients, specifically nitrogen. In addition, because it has a higher nitrogen content, a smaller amount of hoof and horn powder (Table 1) is needed to apply the same N dose, which can be advantageous as transportation costs need to be considered.

Although the results obtained indicate the need to use organic fertilizer as a top dressing in jambu production, further research on organic fertilization is necessary to assist in the choice of the best doses and sources, aiming to increase soil fertility, productivity, and to reduce costs of inputs and labor.

Conclusion

The best agronomic performance of jambu was obtained with the application of 150 kg ha^{-1} N of the organic fertilizer hoof and horn powder for both areas.

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