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Jambu production (*Acmella oleracea* [(L.) R. K. Jansen]) using different organic fertilizers at planting and as top dressing

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Abstract

The aim of this study was to evaluate the effect of different forms of application (before planting and as top dressing) of organic fertilizers, namely castor bean cake and hoof and horn powder, on the production of jambu plants. The experiments were conducted at the Experimental Farm of São Manuel, SP, and at the 'Estância Três Nascentes' site in Botucatu, SP. Seven treatments were evaluated in a 2 x 3 + 1 factorial design, with two organic fertilizers, castor bean cake (CBC) and hoof and horn powder (HHP), and three forms of application (100% before planting, 100% as top dressing, and 50% before planting + 50% as top dressing), plus a control treatment. The experimental design was a randomized complete block with four replications. Plant height, number of inflorescences (NI), fresh weight of inflorescences (FWI), fresh weight of vegetative parts (FWVP), and total fresh weight (TFW) were evaluated at each location. In São Manuel, there was a difference between fertilizers in the forms of application, 100% before planting and 50% before planting + 50% as top dressing, for FWVP and for TFW only in the first form. In Botucatu, HHP resulted in higher NI when applied 100% before planting and FWVP and TFW between fertilizers when applied 100% as top dressing. The increases compared to the control, with HHP and CBC, were 81%, 83%, 168%, 83%, and 95% in São Manuel and 19%, 42%, 316%, 56%, and 67%, in Botucatu, for plant height, NI, FWI, FWVP, and TFW, respectively, confirming the importance of supplementing base fertilization with organic compounds.

Keywords: castor bean cake, fresh weight, hoof and horn powder, inflorescences, nitrogen

Introduction

Jambu (*Acmella oleracea* [(L.) R. K. Jansen]) is an herbaceous vegetable native to the Amazon region, used as a condiment in typical dishes from northern Brazil. It also has applications in popular medicine, through the practice of infusions in the treatment of throat diseases, malaria, tuberculosis, dyspepsia, among others (Gusmão & Gusmão, 2013). This vegetable has chemical properties that have been attracting the interest of the pharmaceutical and cosmeceutical industry, mainly due to the presence of the bioactive metabolite called spilanthol (Souto et al., 2018).

According to (Borges et al., 2013), the highest concentration of spilanthol is in the inflorescences, with a lower content in the leaves. In addition to spilanthol, jambu contains other nutritional and functional constituents, such as high levels of iron, calcium, and vitamins B1, B2, niacin, C, and pro-vitamin A (Marchesini et al., 2020).

Currently, the highest demand for this vegetable is in organic systems. Among the management practices in vegetables, organic fertilization can favor greater productivity, as well as reducing the use and costs of inorganic fertilizers. Organic fertilization has an influence on the physical, chemical, and biological characteristics of the soil, and these contributions are important for the productive potential of soils, especially in tropical and subtropical environments (Souto et al., 2018; Cardoso et al., 2020). The availability of nutrients through organic fertilization is slower (Monsalve; Gutiérrez & Cardona 2017; Cardoso et al., 2020).

Among the various organic fertilizers with the potential to be used in top dressing fertilization of vegetables, there are hoof and horn powder and castor bean cake (Cardoso et al., 2020; Lanna et al., 2020; Almeida et al., 2021; Hounmenou et al., 2021; Nordi et al., 2022). Castor bean cake, a residue from castor

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bean processing, is an important source of nitrogen, with phosphorus, potassium, and micronutrients in smaller quantities (Nasser et al., 2020). Hoof and horn powder are a residue from the processing and slaughter of cattle, rich in nitrogen (Nordi et al., 2022). Both fertilizers have a low C:N ratio.

Plants have different nutritional requirements during their growth, with greater demand for nutrients usually in the reproductive phase. In addition, some nutrients, such as nitrogen, can be lost through leaching, mainly in periods of high precipitation. Therefore, it is usually recommended to split the application of some fertilizers, applying part before planting and part as top dressing. With the correct timing and dose of fertilizer application, productivity can be increased and costs reduced (Colombari et al., 2018, Cardoso et al., 2020).

In this context, this study aimed to evaluate the effect of the application form (before planting and as top dressing) of organic fertilizers hoof and horn powder and castor bean cake on the production of jambu plants.

Materials and methods

Two experiments were conducted, one in the area of 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 (22º 46' 35 "S and 48º 34' 44" W and altitude of 740 m) and another on the producer's site in 'Estância Três Nacentes', located in the municipality of Botucatu, SP (22º 58' 11" S and 48º 23' 56" W and altitude of 870 m). The climate in both municipalities, according to the Köppen classification, is Cwa-type mesothermal, humid subtropical, with rainy summers and dry winters (Alvares et al., 2014).

Soil samples were collected from both areas at a depth of 0-20 cm before the experiments were installed, and their chemical characteristics were evaluated according to the methodology by (Raij et al., 2001). 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}; V% = 83. For the producer's 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}; sum of bases (SB) = 56.4 $mmol_c$ dm^{-3}; cation exchange capacity (CEC) = 77.4 $mmol_c$ dm^{-3}; V% = 73.

Seven treatments were evaluated in a 2 x 3 + 1 factorial scheme, consisting of two organic fertilizers (castor bean cake (CBC) and hoof and horn powder (HHP)) x 3 application methods (100% before planting; 100% as top dressing; 50% before planting + 50% as top dressing) and the control without these fertilizers. The experimental design was randomized blocks, with four replications, totaling 28 plots of 1 m^2.

The amount of each commercial fertilizer applied (**Table 1**) was according to the chemical analysis results found in the fertilizers (**Table 2**) and corresponded to the recommended nitrogen rate for top dressing (80 kg ha^{-1}), based on watercress (Trani et al., 2013), as there is no specific recommendation for the culture of jambu. In Botucatu, the previous crop planted in the area by the producer was corn (*Zea mays*). In the São Manuel farm area, the previous crops were chicory (*Cichorium intybus*) and jambu, but they had not been cultivated for eight months.

The soil preparation in each area was carried out by incorporating the 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, on the full area during pre-planting using a tractor-rotoencanteirator. The castor bean cake and hoof and horn powder fertilizers applied before planting (according to the treatments) were incorporated with a hoe in each plot. As for the top dressing, fertilization was carried out according to the treatments, with the fertilizers being placed in the inter-rows without soil incorporation. In the control treatment, only the base fertilizer (Provaso or organic compost Floral) was applied. The floral compost is a fertilizer produced by the producer using agro-industrial class A organic waste, manure and poultry litter, ashes, concentrated corn maceration residues, eggshells, and pruning and mowing residues.

For the production of seedlings for the experiment on the farm in São Manuel, sowing was carried out on August 20, 2020, in 200-cell polypropylene trays containing Carolina substrate with an average of 3 to 5 seeds per cell. The variety used was the one with yellow and purple jambu flowers. The trays remained in the nursery for 40 days after sowing (DAS) and were transplanted (September 29, 2020) into beds with a spacing of 0.25 m between rows and 0.20 m between holes, totaling 20 holes per m^{-2}. Each cell of the tray had three to four plants, which were transplanted into single holes in the beds. For the experiment in the producer's area in Botucatu, the seedlings were produced by the producer himself in trays with 200 cells, with 3 to 4 plants per cell, and were later transplanted on October 18, 2020, in the same spacing.

Table 1- Quantities of castor bean cake and hoof and horn powder fertilizers applied before planting and as top dressing according to the treatments

Fertilizers	Control	100% before planting	100% as top dressing	50% before planting + 50% as top dressing
	grams m^{-2}			
Castor bean cake	0	167	167	83.5 + 83.5
Hoof and horn powder	0	54	54	27.0 + 27.0

Table 2- Macronutrient analysis 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	O.M.	Ratio
	---------- * % ----------								C/N
PRO	0.35	0.46	0.67	1.61	0.29	0.30	36.00	19.00	20/1
FLOC	8.80	1.90	1.10	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

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

a) plant height: measured using a graduated ruler;

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

c) fresh weight of the vegetative parts, inflorescences, and total (vegetative + 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 ($p \leq 0.05$). Next, analysis of variance and Tukey's test were performed to compare the fertilizer application methods and between fertilizers, and the T-test was carried out using the statistical software AGROESTAT (Barbosa and Maldonado Júnior, 2015).

Results and discussion

1.3.1 Experiment at the Experimental Farm in São Manuel

The control treatment was inferior to the factorial treatments for all evaluated characteristics: plant height (12.25 cm), number of inflorescences (335 per m^2), fresh weight of vegetative parts (1.300 kg m^{-2}), fresh weight of inflorescences (0.219 kg m-2), and total fresh weight (1.520 kg m^{-2}) (**Table 3**). Therefore, it can be affirmed that the organic fertilizers, hoof and horn powder and castor bean cake, are efficient in increasing jambu production in the organic system, as they are the main sources of N, which is the most required nutrient by the jambu crop. In addition to nutrient release, according to (Primavesi, 2016), organic fertilizers improve the physical, chemical, and biological structures of the soil by favoring numerous microbiological processes related to mineralization (Monsalve et al., 2017), especially in tropical environments where organic matter degradation is more intense and rapid.

There was no difference between the fertilizers for plant height within each application method, only in the comparison between the application methods of the fertilizers (Table 3). When the fertilizers were applied 100% before planting and 50% before planting + 50% as top dressing, the plants showed greater height for both hoof and horn powder and castor bean cake, compared to the 100% as top-dressing application (Table 3). The increases of the factorial in comparison to the control were 81% higher.

There was no difference between the fertilizers and application methods in terms of the number of inflorescences per m^2, with an average of 616 inflorescences per m^2, representing 83% more than the control (Table 3). The same was observed for the fresh weight of inflorescences, where the average of the factorial was 168% more than the control, and there was no difference between the fertilizers and application methods, with an average of 0.587 kg m^{-2}. Therefore, the producer can choose the fertilizer and application method if the objective is only the inflorescences. Thus, the treatment with a split application (50% before planting + 50% as top dressing) would be the least recommended because it requires more labor, as it involves two operations. Regarding fertilizers, the producer could choose the cheapest one, considering the cost per

Table 3 - Mean plant height, number of inflorescences, fresh weight of inflorescences, fresh weight of vegetative parts, and total fresh weight of jambu plants as a function of the use of hoof and horn powder and castor bean cake fertilizers and their application methods. São Manuel, SP, 2020

Treatments	100% before planting	100% as top dressing	50% before planting + 50% as top dressing	CV (%)
		Plant height (cm)		
Hoof and horn powder	20.50 aB	22.50 aA	22.75 aA	
Castor bean cake	19.75 aB	23.50 aA	23.75 aA	4.6
Control	12.25*			
		Number of inflorescences (units m^{-2})		
Hoof and horn powder	633 aA	645 aA	631 aA	
Castor bean cake	583 aA	593 aA	608 aA	9.7
Control	335*			
		Fresh weight of inflorescences (kg m^{-2})		
Hoof and horn powder	0.589 aA	0.618 aA	0.665 aA	
Castor bean cake	0.535 aA	0.547 aA	0.564 aA	15.6
Control	0.219*			
		Fresh weight of vegetative parts (kg m^{-2})		
Hoof and horn powder	2.385 aA	2.634 aA	2.673 aA	
Castor bean cake	1.811 bB	2.475 aA	2.340 aA	11.8
Control	1.300*			
		Total fresh weight (kg m^{-2})		
Hoof and horn powder	3.003 aA	3.224 aA	3.338 aA	
Castor bean cake	2.347 bB	3.023 aA	2.904 bA	10.1
Control	1.52*			

CV: Coefficient of variation.

*The average of the control treatment is lower than the treatments of the factorial.

Means followed by the same uppercase letter in the rows (Tukey test) and lowercase letter in the columns (T-test) do not differ statistically at 5% probability.

kg of N. Regarding the values obtained, 335 to 645 inflorescences per m^2 are lower than those reported by (Nordi et al., 2022), which were 1010 inflorescences per m^2 and 1.830 kg m^{-2}, in their research in the same location, applying hoof and horn powder (50 kg N ha^{-1}) as top dressing.

It is worth noting that the highest concentration of spilanthol is found in the inflorescences of jambu, making it the most interesting part for the cosmetic and pharmaceutical industry (Dias et al., 2012; Borges et al., 2013). This bioactive compound, naturally occurring in the species, plays an important role in the plant's growth regulatory functions and defense against herbivory and even interspecific defense (Dias et al., 2012).

For the fresh weight of vegetative parts, the factorial showed 83% more than the control treatment (Table 3). When comparing fertilizers, the use of hoof and horn powder resulted in higher production (2.385 kg m^{-2}) than castor bean cake (1.811 kg m-2) only when these fertilizers were used 100% before planting. There was no difference in the application methods for hoof and horn powder, while for castor bean cake, the 100% before planting application showed lower production of the vegetative parts compared to the other two methods (100% as top dressing and 50% before planting + 50% as top dressing).

The results for the production of total fresh matter followed those of the vegetative parts, with the hoof and horn powder being superior to the castor bean cake only with 100% before planting application. There was no difference between the application forms with the use of the hoof and horn powder and lower production with 100% before planting application compared to the other application forms only with the use of the castor bean cake. The total fresh weight of the factorial was 95% higher than the control.

The values for total fresh weight are similar to those found by (Nordi et al., 2022) in the best treatment with hoof and horn powder (3.13 kg m^{-2}), in their research with different organic fertilizers in the production of jambu, using 50 kg ha^{-1} of nitrogen in top dressing. When comparing the fertilizers, a difference was only obtained with 100% before planting application, when the treatment with hoof and horn powder was superior to that with castor bean cake, which was also observed by (Nordi et al., 2022), despite this author having applied it only in top dressing.

Among the factorial treatments, the one that showed the lowest results for the fresh weight of vegetative and total parts was the 100% castor bean cake before planting. In this treatment, there was probably a large release of nutrients, mainly N, at the beginning of the jambu plant cycle and there may have been a lack of nutrients at the end of the cycle, which is the time of

greatest demand for nutrients. However, no symptoms of nutritional deficiency were observed. It can be seen (Table 1) that castor bean cake has a low carbon:nitrogen ratio (4.3:1), meaning that excess N accelerates the process of decomposition and mineralization, but the response can also be influenced by the type of soil, climate, and management in the area.

In a study by (Severino et al., 2004) on the mineralization of castor bean cake, bovine manure, and sugarcane bagasse estimated by microbial respiration, the authors concluded that the amount of CO_2 released by castor bean cake over a period of 33 days was six times higher than that of bovine manure and 14 times higher than that of sugarcane bagasse. Thus, its decomposition is very rapid and nutrients are more quickly released and utilized by plants.

In a study by (Cruz et al., 2021) with arugula, the authors did not observe any difference in using castor bean cake in top dressing or before planting, unlike in the present study. However, the cycle of arugula (about 30 days after sowing) is much shorter, so the castor bean cake applied by these authors before planting probably provided nutrient release throughout the entire arugula cycle, which did not occur with jambu, which has a cycle of 60 days after planting. It is also important to consider that the soils are different, as are the cultivation and climate conditions.

It is important to note that even though the nitrogen dose was the same for both fertilizers and application forms (except in the control treatment), each fertilizer may have different nutrient release speeds. The hoof and horn powder are one of the most efficient organic fertilizers for short-term nutrient release for vegetables, especially nitrogen, in the production of biofertilizers. (Almeida et al., 2021) reported that hoof and horn powder releases N more quickly than castor bean cake. However, the direct application to the soil is different from the release in water, as occurs in biofertilizers.

The use of organic fertilizers in vegetable production is important not only for the supply of nutrients to plants, but also represents an important management strategy, due to the increase in organic carbon and total nitrogen stocks, which positively influence the physical properties of the soil, such as water retention, plasticity, and porosity; chemical properties, by increasing macro and micronutrients in the soil; and biological properties, through microbiological processes influenced by mineralization and nutrient release to plants (Primavesi, 2016).

The surface application of organic fertilizers in top dressing presents a longer mineralization time compared to fertilizers incorporated before planting, because, with incorporation, the fertilizers come into contact with the soil microorganisms, which are essential for the mineralization process and availability of nutrients to plants (Monsalve et al., 2017; Cardoso et al., 2020; Nordi, 2022). However, for the culture of jambu, top-dressing fertilization with incorporation afterward could be harmful to the plant's shallow roots, leading to production losses for the crop.

Despite the slower release when applied as top dressing without incorporation, the application of castor bean cake showed to be more advantageous when applied as top dressing (50 or 100% of the dose), which was also reported by several authors in different vegetable species (Silva et al., 2016; Cardoso et al., 2020; Lanna et al., 2020; Cruz et al., 2021). Working with cauliflower, (Candian, 2018) observed that in nutrient-poor and organic matter-poor soil, top-dressing fertilization with castor bean cake resulted in linear increases in production. However, in soils rich in organic matter, top-dressing fertilization favored an increase in production up to a certain dose, and at high doses, it harmed production.

1.3.2 Experiment at the Producer's Site in Botucatu

As in the research at Fazenda de São Manuel (Table 3), the control treatment was also inferior to the factorial treatments for all characteristics. The factorial treatment showed an average increase of 19%, 42%, 56%, 316%, and 67% for plant height, number of inflorescences, fresh weight of vegetative parts, fresh weight of inflorescences, and total fresh weight of jambu, respectively (**Table 4**), confirming the importance of supplementing the base fertilization with only the organic compost Floral applied in the producer's area.

According to the Technical Bulletin 100 by (Raij et al., 1997), the usual mineral fertilization at planting is 40 Kg ha^{-1} of N, and 60 to 90 Kg ha^{-1} of N for top dressing, based on watercress.

When the hoof and horn powder was applied 100% before planting, the plants showed greater height (49.00 cm) compared to the treatment with castor bean cake (39.37 cm) (Table 4). In the comparison between the application forms, plants with castor bean cake applied 100% before planting had lower height than those of the other two forms of application of this fertilizer, whereas for the hoof and horn powder, there was no difference between the application forms. The height values are within the expected range for jambu, which is 20 to 50 cm (Gusmão & Gusmão, 2013).

It is observed that, as occurred in the São Manuel farm (Table 3), there was no difference between

Tabela 4 - Mean plant height, number of inflorescences, fresh weight of inflorescences, fresh weight of vegetative parts, and total fresh weight of jambu plants as a function of the use of hoof and horn powder and castor bean cake fertilizers and their application methods. Botucatu, SP, 2020

Tratamentos	100% before planting	100% as top dressing	50% before planting + 50% as top dressing	CV (%)
		Plant height (cm)		
Hoof and horn powder	49.00 aA	48.00 aA	45.50 aA	
Castor bean cake	39.37 bB	46.75 aA	46.75 aA	7.3
Control	38.50*			
		Number of inflorescences (units m^{-2})		
Hoof and horn powder	1048 aA	912 aB	964 aAB	
Castor bean cake	968 aA	1008 aA	1040 aA	7.9
Control	696*			
		Fresh weight of inflorescences (kg m^{-2})		
Hoof and horn powder	0.727 aA	0.710 aA	0.649 aA	
Castor bean cake	0.683 aA	0.720 aA	0.635 aA	8.7
Control	0.165*			
		Fresh weight of vegetative parts (kg m^{-2})		
Hoof and horn powder	5.807 aA	6.322 aA	5.314 aA	
Castor bean cake	5.028 aA	5.250 bA	5.551 aA	13.8
Control	3.561*			
		Total fresh weight (kg m^{-2})		
Hoof and horn powder	6.533 aA	7.032 aA	5.963 aA	
Castor bean cake	5.711 aA	5.979 bA	6.186 aA	12.5
Control	3.73*			

CV: Coefficient of variation.

*The average of the control treatment is lower than the treatments of the factorial.

Means followed by the same uppercase letter in the rows (Tukey test) and lowercase letter in the columns (T-test) do not differ statistically at 5% probability.

fertilizers and application methods for the number of inflorescences, with an average of 990 inflorescences per m^2 (Table 4), and the control (696 inflorescences per m^2) was inferior to the factorial treatments. These values are lower than those reported by (Nordi et al., 2022), which were on average 2534 inflorescences per m^2. For the fresh weight of inflorescences, there was no difference between fertilizers (HHP and CBC) or between fertilizer application methods, with an average of 0.687 kg m^{-2} (Table 4).

(Nordi et al., 2022) found an inflorescence weight of 1.54 and 1.37 kg m^{-2}, with hoof and horn powder and castor bean cake, respectively. (Borges et al., 2014), in their study with jambu, used cattle manure at planting and castor bean cake as top dressing, also obtaining higher values (1.4 kg m^{-2}) of fresh weight of inflorescences.

Plants treated with hoof and horn powder showed greater fresh weight of vegetative parts compared to those fertilized with castor bean cake, only when the 100% top-dressing fertilization occurred (Table 4). On the other hand, there was no difference between the fertilizer application methods, for both fertilizers, with a general average of 5.55 kg m^{-2}, except for the control, which showed a lower average of 3.561 kg m^{-2}. Considering only the factorial treatments, the values observed are higher than those obtained by (Nordi et al., 2022), who reported an average of 4.39 kg m^{-2} and were also higher than those found in the experiment at the São Manuel farm (average of 2.386 kg m^{-2}) (Table 3). (Borges et al., 2014), in their research with organic and inorganic fertilization in jambu culture, found a fresh mass of 1.310 kg m^{-2} for organic and 2.96 kg m^{-2} for inorganic, harvesting at 90 days.

When the hoof and horn powder was applied 100% as top dressing, it showed a greater total fresh weight (7.032 kg m^{-2}) than the treatment with castor bean cake (5.979 kg m^{-2}), with no difference between the fertilizers in the other application methods or between the application methods (Table 4). (Almeida et al., 2021) reported that the biofertilizer made with hoof and horn powder released a greater amount of N (for the same fermentation time) than the biofertilizer with castor bean cake, which is advantageous when used as top dressing.

As hoof and horn powder has a lower C:N ratio, nutrients become more readily available, resulting in greater total fresh weight when applied as top dressing, performed at the time of greatest nutrient demand by plants. The speed of organic matter decomposition in tropical soils is faster, and various factors interfere with this process, such as the chemical composition of organic material, soil type, temperature, and moisture of the environment and soil (Souto et al., 2018; Cardoso et al., 2020).

Through the addition of organic fertilizers, several

studies have shown an increase in the fresh weight of vegetables, such as arugula (Solino et al., 2010; Cruz et al., 2021), jambu (Borges et al., 2013; Souto et al., 2018; Nordi et al., 2022), chicory (Lanna et al., 2017), beetroot (Silva et al., 2016), cauliflower (Candian, 2018), and cabbage (Cardoso et al., 2020). The application method and whether or not to split the application depends on the type of fertilizer, the species, climatic conditions, among other factors, and further research is needed to provide better recommendations for each situation, as already exists for several crops in conventional systems.

In general, applying 100% of the fertilizer as top dressing has always been among the best treatments, being superior to the application of 100% before planting for some characteristics and not differing from the split application (50% before planting + 50% as top dressing). However, with splitting, there are two operations, i.e., higher labor costs.

Conclusion

The application of hoof and horn powder resulted in higher fresh weight of the vegetative and total parts compared to castor bean cake when applied 100% before planting in São Manuel and when applied 100% as top dressing in the study conducted in Botucatu.

In comparison between the application methods, it can be recommended to apply 100% as top dressing.

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