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Production and quality of watermelon fruits (*Citrullus lanatus*) in response to different sources of fertilization

*Produção e qualidade de frutos de melancia (*Citrullus lanatus*) em resposta a diferentes fontes de fertilização*

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ABSTRACT
The objective of this work was to evaluate the production and quality of watermelon fruits in response to different sources of fertilization in the municipality of Humaitá (AM). The experimental design used was a randomized block design with three replications. The treatments were: T1 – without fertilization (control), T2 – 20 ton.ha^{-1} of cattle manure, T3 – 10 ton.ha^{-1} of vegetable ashes, T4 – 10 ton.ha^{-1} chicken manure, T5 – 10 ton.ha^{-1} of açaí kernels and T6 – liming and mineral fertilizer with NPK. Fruit quality and yield attributes were evaluated, such as number of fruits, yield, total soluble solids (°Brix) and titratable acidity. All treatments differed statistically in yield and quality, in relation to soil without fertilization. The T6 treatment provided higher productivity and higher levels of total soluble solids of commercial fruits. It was demonstrated that the type of fertilizer, if used in the right way, can improve the general quality of watermelon fruits and improve the crop's production system. In the cultivation of watermelon, several sources of organic fertilizer can be used, such as manure from cattle, sheep, goats or poultry, which recommends future tests with supplementation of mineral fertilizer.
Keywords: fertilizers; productivity; soil.

RESUMO
O objetivo deste trabalho foi avaliar a produção e a qualidade de frutos da melancia em resposta a diferentes fontes de fertilização, no município de Humaitá (AM). O delineamento experimental utilizado foi em blocos casualizados com três repetições. Os tratamentos foram: T1 – sem fertilização (testemunha), T2 – 20 ton.ha^{-1} de esterco bovino, T3 – 10 ton.ha^{-1} de cinzas vegetais, T4 – 10 ton.ha^{-1} de esterco de galinha, T5 – 10 ton.ha^{-1} de caroços de açaí e T6 – calagem e fertilização mineral com NPK. Avaliaram-se os atributos de qualidade e produtividade dos frutos, como número de frutos, produtividade, sólidos solúveis totais (°Brix) e acidez titulável. Todos os tratamentos diferiram estatisticamente em rendimento e qualidade em relação ao solo sem fertilização. O tratamento T6 proporcionou maior produtividade e maiores teores de sólidos solúveis totais dos frutos comerciais. Ficou demonstrado que o tipo de fertilizante, se utilizado da forma correta, pode aprimorar a qualidade geral dos frutos da melancia e melhorar o sistema de produção da cultura. No cultivo da melancia, várias fontes de adubo orgânico podem ser usadas, como esterco de bovinos, ovinos, caprinos ou aves. Recomendam-se testes futuros com suplementação de adubo mineral.
Palavras-chave: fertilizantes; produtividade; solo.

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INTRODUCTION

Watermelon (*Citrullus lanatus*) is cultivated in several countries around the world, including Brazil, being one of the main vegetables grown in the country (IBGE, 2020). Due to the simplicity of management compared to other horticultural species, and quick financial return provided by the short cycle of the species, its production is concentrated in family farming and small farmers (BOARI *et al.*, 2017).

In Amazonas, watermelon is the main species among cucurbits cultivated, with approximately 3.045 hectares planted, involving about 4.500 family farmers in floodplain or *terra firme* systems, confirming the great economic and social importance of this crop in the region but, however, the productivity in the State, of 15.031 t.ha^{-1} is below the values observed in other States of Brazil, such as Rondônia (19.488 t.ha^{-1}), Mato Grosso (19.907 t.ha^{-1}), Tocantins (27.271 t.ha^{-1}) Goiás (41.069 t.ha^{-1}) (IBGE, 2020).

In this sense, the improvement of techniques that enable the reduction of costs and maintenance of the ideal physiological and productive characteristics for the plant is extremely important for the North region of Brazil, especially for the State of Amazonas, which, despite having adequate edaphoclimatic characteristics for the crop, has low productivity due to inadequate cultural treatments used (ARAÚJO NETO *et al.*, 2000).

The proper application of fertilizers for watermelon has promoted significant effects on production, increasing the size and improving the appearance of the plants (ANJOS *et al.*, 2022). Organic fertilization with animal manure and/or organic compounds has been widely used in the production of watermelon (ADNAN *et al.*, 2017), with the aim of reducing the amounts of mineral fertilizers and improving the physical, chemical and biological quality of the soil.

In general, the response to fertilization with organic matter by vegetables has excellent results, both in quality and in production, especially in nutrient-poor soils, as the organic matter is considered an efficient soil conditioner, with the ability to substantially increase water retention, as well as the increase in the availability of nutrients in the form assimilable by the roots, such as phosphorus, potassium, nitrogen and sulfur (SILVA *et al.*, 2012).

For decades, producers adopted, as a cultural practice, management based on chemical products (mineral fertilizers, insecticides, herbicides, fungicides, etc.), however, in recent years the number of supporters of agriculture with sustainable production has been growing in Brazil (CAVALLET *et al.*, 2018), boosting the demand for organically produced food.

The use of organic fertilizer, through the composting of organic waste, is a concentrated and accelerated method of waste decomposition, similar to the processes that occur naturally and gradually in nature for the decomposition and formation of humus from organic matter (ADNAN *et al.*, 2017).

Fertilization and mineral nutrition are essential factors for gains in the quantity and quality of the product, ensuring an adequate return and, if applied correctly, they can allow reaching high efficiency of production, aiming, in addition to lower production cost, to lessen environmental damage.

Thus, the objective of this work was to evaluate the production and quality of watermelon fruits, in response to different sources of fertilization in the municipality of Humaitá, state of Amazonas, Brazil.

MATERIAL AND METHODS

The experiment was conducted in a savanna area (*cerrado*) at the Federal Institute of Education, Science and Technology of the State of Amazonas – *Campus* Humaitá, located in the municipality of Humaitá, state of Amazonas, whose reference coordinates are: 07°30'22" S 63°01'15" W and 90 m altitude. The climate in the region is of the Am type, according to Köppen, because the annual precipitation varies from 2250 to 2750 mm, with a dry season of short duration (month of July). The average annual temperature varies from 24°C to 26°C, the air relative humidity, quite high, varies from 85 to 90% and the average altitude is 90 meters above sea level (EMBRAPA, 1997a).

The cultivar of watermelon used in the experiment was Crimson Sweet, which is the most planted variety in Brazil, has high market acceptability, is adapted to all Brazilian regions, being a variety of rounded fruits, with light green skin and dark stripes, red pulp, high sugar content and that responds better, if compared to hybrids, to conditions that use less technology, a situation found among producers in Amazonas (LEMOS *et al.*, 2022).

Before the installation of the experiment, the soil was collected at a depth of 0-20 cm for analysis of fertility and particles size, according to the methodology described in Embrapa (1997b).

Table 1 – Physical and chemical soil characterization in the experimental area located in the municipality of Humaitá, AM.

pH	O.M.	P	K	Ca	Mg	H+Al	Al	CTC	m	V
	$g.Kg^{-1}$	$mg.dm^{-3}$			———————cmol$_c$.dm^{-3}———————				%	
4.9	20.1	2	0.1	1.93	1.35	7.4	1.1	10.8	25	31

Cattle and chicken manure, *açaí* kernels and vegetable ashes, were chemically analyzed on a dry basis, according to the methodology described by Embrapa (1997b). The results of the macro and micronutrients analysis are shown in table 2 and the organic components are shown in table 3.

Table 2 – Results of macro and micronutrients analysis of organic fertilizers.

Material	Macronutrients						Micronutrients				
	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Cu	Fe	Mn	B
	————$g.Kg^{-1}$————							————$mg.Kg^{-1}$————			
Acai kernel	12,3	4,1	4,7	3,7	1,3	1,2	33,9	18,7	23270	592,4	26,9
Vegetable ash	2,6	16,0	78,9	77,5	27,8	4,4	126,3	121,6	42090	3299,0	89,5
Cattle manure	21,9	15,5	30,2	95,8	8,6	2	734,3	68,5	33450	295,5	143,3
Chicken manure	42,3	13,7	24,8	185	10,5	0,4	274	9,7	1140	314	87,6

Table 3 – Characterization of organic matter, organic carbon, C / N ratio, pH and humidity of organic fertilizers.

Material	Characteristics				
	O.M	Total organic C	C/N Relationship	pH	Moisture 65°C
	———$g.Kg^{-1}$———				(%)
Açai kernels	896.0	497.8	40.5	6.3	54.8
Vegetable ashes	60.0	33.3	12.8	11.7	0.6
Cattle manure	375.6	86.8	4.13	6.5	7.8
Chicken manure	291.0	72.5	5.24	7.59	24.5

The experimental design used was a randomized block design, with three replications. Each experimental unit had three rows of eight plants, with a spacing of 3.0 m between rows and 2.0 m between plants. The central line was used as the useful area of the plot, excluding the first and last plant of the line.

The treatments were: T1 – without fertilization (control), T2 – 20 $ton.ha^{-1}$ of cattle manure, T3 – 10 $ton.ha^{-1}$ of vegetable ash, T4 – 10 $ton.ha^{-1}$ chicken manure, T5 – 10 $ton.ha^{-1}$ of açaí kernels and T6 – liming and mineral fertilizer with NPK.

Chemical fertilization was carried out according to the recommendation for the crop (FIGUEIRA *et al.*, 1999), that is, fertilization with cattle and chicken manure and vegetable ashes, according to Carvalho (2005). The cattle and chicken manure used in the experiment were obtained from local farms, the vegetable ashes from pottery units and the *açaí* seeds collected in a processor unit in the city. The manure and vegetable ashes used were sieved through a 4 mm mesh.

Deep plowing and harrowing with a harrow were carried out, which enabled the soil not to be completely pulverized, keeping clods that favored the fixation of the plants in the soil through their tendrils (OLIVEIRA et al., 2013).

At sowing, five seeds were used at a depth of 2 to 3 cm, and thinning was carried out in two stages. The first when the plants had three permanent leaves, removing the less developed seedlings, leaving three seedlings. The second thinning was carried out 15 days after the first, leaving one plant per hole. Thinning was carried out in order to eliminate malformed fruits. Cultural treatments such as control of invasive plants, diseases and pests and management of vines were carried out in accordance with Embrapa's recommendations (2010).

To obtain the results, three harvests were carried out, the first around 80 to 100 DAE (days after emergence), the other harvests were carried out when the harvest point was identified by observing the dry tendril closer to the fruit and the peduncle, the change in color of the fruits, especially on the part resting on the ground, that changed from white to pale yellow.

The evaluations involving the production components were carried out in the period corresponding to the three harvests, discarding the fruits with deformities, spots, injuries or any type of apparent damage. Fruit quality and yield attributes were evaluated, such as: number of fruits: obtained by counting the fruits of the useful area of the plot and converting to fruits ha^{-1}; productivity: determined from the sum of the fruits of the useful area of the plot, expressed in kg ha^{-1}; total soluble solids (°Brix) determined with the aid of a field refractometer and titratable acidity, obtained from the pulp, determined by neutralization titration, by titration of 10 g of pulp, homogenized and diluted to 100 mL in water distilled, with a standardized 1N NaOH solution, with a turning point at pH 8.2, the results being expressed in percentage, in accordance with the IAL method (2008).

The results of the variables were subjected to analysis of variance and their means, that, when significant, were compared using the Tukey test at $p<0.05$ of significance. Analyzes were performed using the statistical software Sisvar 5.6 Software (FERREIRA, 2019).

RESULTS AND DISCUSSION

There was a significant increase in productivity as well as in the quality of watermelon fruits according to the source of fertilization used (table 4). The yield using limestone and mineral fertilizer (62.250 $ton.ha^{-1}$) was higher than the other treatments, surpassing the regional yield of 16.143 $ton.ha^{-1}$ (IBGE, 2020). The importance of soil correction and fertilization was demonstrated, both for increasing productivity and for the sugar content of the fruits, which is a characteristic demanded by consumers.

Considering the chemical contents of the soil in the area of the experiment (table 1), low values of macronutrients are verified, which will hardly produce commercial fruits, because the plants of the control treatment had low productivity and fruits with non-marketable weight. Leão *et al.* (2008) found that chemical fertilization is essential for the production of watermelon, and plants that are not chemicaly fertilized have almost zero production, resulting from the low availability of nutrients, especially N and P, indicating that the watermelon is a demanding crop with regard to soil fertility.

Table 4 – Productive and qualitative characteristics of watermelon fruits fertilized with different nutrient sources in the city of Humaitá, AM.

Treatments	Productivity ($t.ha^{-1}$)	Average fruit weight (Kg)	Number of fruits	Titratable acidity (%)	Total soluble solids (°Brix)	Relation TSS/TA
Conventional fertilization	62,250a	8,5a	3,37a	1,63a	12,2a	7,48a
Chicken manure	25,520b	4,85b	2,1b	1,55b	10,62b	6,81b
Cattle manure	14,877c	4,15c	1,3c	1,52b	9,85c	6,46c
Vegetable ash	14,066c	3,45d	1,65c	1,51b	10,5b	6,93b
Açaí kernels	12,525c	4,05 c	1,25c	1,52b	9,75c	6,41c
Control test	2,775d	2,05e	0,5d	1,33c	9,15d	6,85b
C.V (%)	12,37	2,02	15,79	1,46	1,82	1,91

Means followed by the same letter in the column do not differ statistically from each other by the Tukey test at 5% probability.

It was demonstrated that the watermelon plant is nutrient demanding and that, in the studied soil, nutritional correction and increase is imperative. Leão *et al.* (2008), working with the same cultivar (Crimson Sweet), obtained greater productivity with approximately 48, 360 and 192 kg of N, P_2O_5 and K_2O ha^{-1}, respectively, and this dose resulted in 22.989 $kg.ha^{-1}$; In the mentionned reseach, plants fertilized only with cattle manure at doses of 3 to 9 L per hole showed small productive increments and by the F test there was no significant effect.

Regarding the average fruit weight, mineral fertilization provided effects similar to productivity (table 4). Only mineral fertilization resulted in fruits with desirable weight by the consumer market, being above the minimum required by the domestic market, according to Alvarenga and Resende (2002), who observed that, in the domestic market, the preferred fruits are the largest, weighing over 7 kg and, therefore, those with the highest market price.

Leão *et al.* (2008) obtained fruits with little more than 1 kg for control treatment (without treatment) and up to 6 kg for the dose of NPK 4-30-16 which corresponds to 42.8, 321.4 and 171.4 kg of NPK per hectare, respectively.

Grangeiro (2003) obtained fruits with an average weight between 6.9 and 9.8 Kg with the application of 206 kg ha^{-1} of K_2O.

In the present work, plants that were not fertilized practically did not produce fruit, indicating the need for fertilization to ensure production. However, the conventional treatment resulted in 3.37 fruits per plant, differing from the other treatments that presented lower numbers of fruits.

Andrade Júnior *et al.* (2006) observed that total production, commercial production, total and commercial fruit number increased significantly with increasing nitrogen levels, following a quadratic response model.

As noted for other vegetables, watermelon depends on mineral nutrition for production with quantity and quality. It is evident that liming associated with N-P-K must be applied according to the requirements of each cultivar and expected production, a finding of the present work supported by the general literature. Brazil's northern region has good climatic conditions for watermelon production (BASTOS *et al.*, 2008) and this factor must be combined to soils with adequate levels of nutrients. It is recommended that producers can have access to information on adequate methods to increase the fertility level of highly weathered soils of that region.

Regarding the applied organic materials, the use of chicken manure increased productivity by 59%, while the other treatments decreased productivity compared to that observed in the State of Amazonas in 2020 (15.031 $ton.ha^{-1}$) according to IBGE (2020). In comparison to the control, chicken manure, cattle maure, vegetable ashes and *açaí* kernels increased the productivity and size of the fruits. However, it is necessary to emphasize that even the productivity, 25.520 $t.ha^{-1}$, reached with chicken manure, is generally considered low for Crimson sweet, as suggested by Cavalcanti (2008).

To increase crop productivity, more work will be needed to support correct fertilization, since the current cultivars are improved genetically, that is, they have greater nutritional demand depending on the production potential. In this way, information contained in fertilizer manuals need to be constantly revised, to provide accurate information. In addition, watermelon plants may have needed nutrients at the time of fruit filling. So, for the future, we recommend tests that split these organic fertilizers, to promote better distribution of nutrients throughout the production cycle.

For the quality variables of the fruits (table 4), the conventional treatment provided higher values of titratable acidity and total soluble solids (TSS). High TSS contents in watermelon fruits are quite desirable and of large acceptance, since this index is considered an important parameter in many countries, including in Brazil, as 10% represent the minimum acceptable for marketing (DIAS *et al.*, 2018). For Jie *et al.* (2013), the soluble solids content is the most important characteristic, which determines the internal quality of the watermelon and also the acceptance by the consumer. The high levels of total soluble solids are desirable to the point that some markets adopt a minimum content of them for the commercialization of watermelon, such as the Brazilian market, which requires a minimum of 10 °Brix, and the European Union, with a minimum of 9 °Brix.

According to Scott and Lawrence (1975), the high temperatures inherent in the study region influence the quality of the fruit, due to the greater synthesis of secondary compounds and the accumulation of higher concentrations of soluble sugars. This helps to explain the high levels of soluble solids obtained in the different watermelon cultivars studied in the edaphoclimatic conditions of the Cerrado from Humaitá (AM).

According to Villanueva *et al.* (2004), sugar accumulation, during fruit growth and development, is of great importance by virtue of the high correlation between sugar content and fruit quality. According to Valantin *et al.* (2006), competition by assimilates reduces TSS. In this way, the TSS, which is directly related to the content of sugar, constitutes a good indicator of the quality, as of the taste of the fruit, a fact attributed mainly to the elevation of the concentration of sucrose in the fruit pulp. This information corroborates the results found in this experiment, since the treatment with better supply of nutrients (mineral fertilization) provided higher TSS content. Farmers who are concerned about obtaining better prices and conquering new markets for the quality of the desired product, i.e., the more appreciated watermelon flavor by consumers, should be aware that soils, with chemical conditions more favorable to watermelon, will result in higher ºBrix values.

Regarding the acidity, this component is influenced by the presence of organic acids, whose predominance in the watermelon is from malic acid (SILVA, 2015), an important parameter to the palatability of many fruits. As a result of the respiratory process and its conversion into sugars, acidity usually decreases with maturation.

Tituliable acidity tends to raise with fruit growth to its complete physiological development. As observed in table 4, acidity was higher in the conventional treatment. It can be inferred that the largest amounts of offered nutrients may provide indirect impact on fruit acidity, that increased vegetative growth which by turn can cause shading, which decreases the temperature and the perspiration, or it can divert assimilations towards vegetative growth to the detriment of fruit development. Martins *et al.* (2013), when evaluating the post-harvest characteristics of the fruits of watermelon cultivars submitted to the application of bioestimulant, found an increase in the titratable acidity of the fruits of the cultivar Quetzali due to the BioStimulant Crop Set.

In this work, organic fertilizers did not surpass the regular fertilization and these organic compounds are friendlier to the environment and cheaper, increasing the soil organic matter and elevating pH, contributing for the adsorption and availability of cationic nutrients for plants. We recommend subsequent research applications to be carried out in installments and combined with chemical fertilization, in order to ensure that the genotypes fully express their productive potential, so producers can offer watermelon fruits with better qualities and reducing costs.

CONCLUSION

Watermelon production increased significantly with liming and fertilization, compared to organic fertilizers. The watermelon quality components were influenced by the type of fertilizer used.

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