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Effect of three biostimulants and three doses on the production and quality of watermelon (*Citrullus Lanatus L.)* crops

Efecto de tres bioestimulantes y tres dosis en la producción y calidad del cultivo de sandía (*Citrullus Lanatus L.)*

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Abstract: With the aim of evaluating the effect of biostimulants on the production and quality of watermelon (Citrullus lanatus L.) crops in the Montecristi district, an experimental plot was set up in the field using a completely randomised block design (CRBD) in a 3 x 3 +1 factorial arrangement, where the study factors were: Factor A (biostimulants) and Factor B (dose), with 9 treatments, a control and 3 replicates. The experiment was implemented at a density of 0.50 m between plants and 4 m between rows, on a total area of 412 m2, with 120 plants. The variables evaluated were: guide length (LG), days to flowering (DIF), number of fruits per treatment (NFRU), fruit length (LFRU), fruit diameter (DFRU) and fruit weight per plant (PFRU). The results determined that the biostimulants used were best for fruit length of 41.31 cm and fruit weight of 7.15 kg per plant, with a dose of 2 L/ha.

Keywords: experimental design, biostimulants, production variables, fruit quality, application dose.

Resumen Con el objetivo de evaluar el efecto de los bioestimulantes en la producción y calidad del cultivo de sandía (Citrullus lanatus L.) en el cantón Montecristi, se implementó una parcela experimental en campo en un diseño experimental de bloques completamente aleatorio (DBCA) en arreglo factorial de 3 x 3 +1, donde los factores de estudio fueron: Factor A (bioestimulantes) y Factor B (dosis), con 9 tratamientos, un testigo y 3 repeticiones. El experimento fue implementado a una densidad de 0,50 m entre plantas y 4 m entre hileras, en una superficie total de 412 m2, con 120 plantas. Las variables evaluadas fueron: la longitud de guía (LG), días de inicio de la floración (DIF), número de frutos por tratamiento (NFRU), longitud de fruto (LFRU), diámetro de fruto (DFRU) y peso de fruto por planta (PFRU). Los resultados determinaron que los bioestimulantes utilizados fueron mejores para el largo de fruto de

41,31 cm y un peso de fruto de 7,15 kg por planta, con una dosis de 2 L/ha.

Palabras clave: diseño experimental, biostimulantes, variables productivas, calidad de fruto, dosis de aplicación.

Introduction

Watermelon (*Citrullus lanatus* L.) originated in the Kalahari Desert in Africa, where it still grows wild, and there is evidence that modern domesticated watermelon is more closely related genetically to the Sudanese Kordofan melon than to other varieties (Renner et al., 2021). According to the FAO (2019), the largest producer of watermelons is China, with an annual production of more than 60 million tonnes, followed by Turkey with 3.7 million tonnes, and India and Brazil with 2 million tonnes each. Watermelons are sold in numerous markets, but the main export markets in Central America are the United States (56%), the Netherlands (25%), the United Kingdom (9%) and Belgium (3%) (Cervantes et al., 2022).

The lack of organic matter exacerbates the situation, as it causes nutrients to leach out quickly. This highlights the importance of conducting a thorough soil analysis and choosing crops that optimise available resources. In this regard, watermelon (*Citrullus lanatus*) has shown promise as a crop thanks to its heat tolerance and adaptability. However, to achieve good results, proper soil management is crucial, including the use of organic amendments and effective irrigation systems (Melendres et al., 2025).

This crop does not require very specific soils due to its ability to adapt to arid conditions, however, better results have been observed in soils that have a high organic matter content, good porosity and sandy loam texture. For growing watermelons in clay soils, it is crucial that the soil allows for good drainage. It is best for the field capacity to be around 70%, as the root system shows optimal development within this range (Díaz, 2024).

To improve both national and global production, different management and treatment programmes have been established, involving the use of various horticultural products such as biostimulants (Muñoz & Brainard, 2022). Currently, there are biostimulants available on the market, generally in the form of concentrated liquid substances of plant origin, such as fulvic acid, which contain different concentrations. These products can improve nutrient absorption and help plants obtain better yields, while meeting the needs of crops during the energy demand phase. They offer advantages in terms of the physicochemical properties of the colloidal active components, biological characteristics thanks to the maintenance of the carbon-nitrogen ratio, and stimulation of the root system (Atlántica 2020).

This research was carried out because it is necessary for farmers to learn about new products such as biostimulants that stimulate plant growth to generate good productive development and obtain high-quality commercial fruit. The purpose of this research was to evaluate the responses of watermelon crops (*Citrullus lanatus* L) to the application of three biostimulants, since watermelon producers in the Santa Rita area of the Montecristi canton use excessive amounts of chemicals that affect the soil, degrading it at the expense of good production. Therefore, the objective of this research was to evaluate the effect of biostimulants on the production and quality of watermelon (*Citrullus lanatus* L.) crops in the Montecristi canton.

Methodology

Location

The research was carried out in the canton of Montecristi, in the Santa Rita area of the canton of Montecristi, Manabí province. Montecristi is located at 1°02′44″ south latitude, 80°39′32″ west longitude at an altitude of 135 metres above sea level, and the temperature varies from 24° to 28°C (PDOT, 2019).

study factors

Two factors were studied: Factor A: biostimulants (A1: Activer, A2: Aminocrop SL, A3: Humega) and Factor B: application dose (B1: 1 L/ha, B2: 2 L/ha, B3: 3 L/ha).

Specific management of the research

The germination trays were cleaned using a 1% chlorpyrifos-based product to prevent any microorganisms that could harm the germination process. A mixture of peat soil (organic material formed by the slow decomposition of plant matter) was prepared. The germination trays were then filled to sow the seeds. The seedbed was watered by micro-sprinkling using a portable pump, twice a day, once in the morning and once in the afternoon. To prepare the soil, weeds were removed, and then the soil was harrowed twice to loosen it and encourage plant root

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growth. A drip irrigation system was installed, with the tape placed at a distance of four metres apart. Once pre-transplant irrigation was carried out, the plants were sown at a distance of 0.50 m between plants. Each experimental unit had an area of 12 m^2. Biostimulants were applied every two weeks after transplanting, at 15, 30, and 45 days, according to the treatments and doses indicated in the materials and methods. Drip irrigation was performed three times a week until field capacity was reached. Weed control was carried out manually, and the herbicide Gramoxone (Paraquat) was applied at a dose of 1 L/ha. Solaris (Spinotoram) was used to control insect pests at a dose of 10 cc/20 L, plus Abertiicc (abamectin) at a dose of 25 cc/20 L. Hammer (Mancozeb + Cymoxanil) was applied to control diseases at a dose of 10 g/20 L every 5 days. Basic fertilisation was carried out with three nutrients that are essential for cultivation: nitrogen, phosphorus and potassium. The fertilisers used were urea 165 kg/ha, triple superphosphate 105 kg/ha and potassium muriate 250 kg/ha. Harvesting took place between 65 and 75 days after transplanting (ddt). The fruits were harvested and the number of watermelons per treatment and the average weight were recorded.

Experimental design

The research was implemented in a completely randomised block design (CRBD) in a 3 x 3 +1 factorial arrangement with 9 treatments, a control and 3 replicates (Gabriel et al., 2022).

The following response variables were evaluated: *Guide length (GL)*. A tape measure was used, extending from the neck of the plant to the main guide. It was evaluated three times (15, 30, and 45 ddt). *Days to flowering onset (DIF*). The days from transplanting until 50% plus one of all plants were in bloom were counted. *Fruit diameter cm (DFRU).* The centre of the fruit was measured using a tape measure. The diameter was calculated by dividing the number of fruits harvested to find the average diameter per treatment. *Fruit length cm (FLF)* . The length was measured in centimetres using a tape measure, then added up and divided by the total number of fruits to find the average fruit length per treatment. *Fruit weight per plant kg (PFRU)* . This was measured in kilograms using a digital scale, then divided by the total number of fruits harvested to calculate the average weight per treatment . *Number of fruits per treatment (NFRU)* **.** To record this variable, the number of fruits harvested was counted according to the treatments.

Statistical analysis

Based on the defined model, analyses of variance (ANOVA) were performed to test hypotheses about fixed effects, as well as comparisons of treatment means using Tukey's test at a 5% probability level. The ANOVA was also used to estimate the variance components for random effects. The analyses indicated were performed using Infostat software (Infostat, 2020).

Analysis of normality and homogeneity of variance

The data for the variables evaluated were not significant (P<0.05) with the Shapiro-Wilks test. Likewise, no significance (P<0.05) was observed with the Levene test, showing homogeneity of variances. The analysis suggested continuing with the ANOVA and the comparison of means of the variables evaluated.

Results

Table 1 shows the analysis of variance for the variables evaluated, determining that there were no significant differences (P<0.05) for any of the variables. The coefficients of variation (CV) ranged from 5 to 36%.

Table 1. Analysis of variance for evaluated variables.

FV	gl	Mean squares							
		LG15	LG30	LG45	DIF	DFRU	LFRU	PFRU	NFRU
Rep	2	0.0004	0.06	0.10	0.90	5.83	9.75	0.20	1.23
Treatments	9	0.01	0.28	0.42	7.35	14.97	14.08	1.72	4.17
Biostimulant	2	0.01 ns	0.18 ns	0.62 ns	5.33 ns	22.62 ns	9.69 ns	1.50 ns	4.70 ns
Dose	2	0.01 ns	0.26 ns	0.49 ns	7.11 ns	12.85 ns	35.85*	4.93*	7.26 ns
Bioes per dose	4	0.01 ns	0.38 ns	0.26 ns	5.11 ns	14.06 ns	8.16 ns	0.63 ns	4.31 ns
Test vs. rest	1	0.02 ns	0.11 ns	0.55 ns	20.83 ns	7.54 ns	3.14 ns	0.09 ns	5.35 ns
Error	18	0.0003	0.15	0.30	8.86 ns	11.42 ns	7.28	0.73	4.16
Total	29								

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CV	32.09	24.09	19.18	7.54	5.27	6.89	13.41	35.57

DIF: Fruit diameter, LFRU Fruit length, PFRU: Fruit weight, NFRU: Number of fruits, LG15: Length of shoots at 15 days, LG30: Length of shoots at 30 days, LG45: Length of shoots at 35 days, DIF: Day of flowering onset.

The F test was not significant for any of the variables (DFRU, LFRU, PFRU, NFRU, LG15, LG30, LG45 and DIF).

The analysis of means using Tukey's multiple test did not detect significant differences (P<0.05) for the biostimulants used in any of the variables evaluated. However, a higher value was observed for Activer in all variables and a lower value for Aminocrop SL (Table 2).

Table 2. Analysis of means using Tukey's multiple test for biostimulants.

Biostimulants	**LG15**	**LG30**	**LG45**	**DIF**	**DFRU**	**LFRU**	**PFRU**	**NFRU**
Activer	0.24	1.70	3.03	40.22	65.82	39.70	6.75	6.33
Humega	0.22	1.60	2.84	40.22	64.38	39.53	6.32	5.56
Aminocrop SL	0.19	1.42	2.51	38.89	62.66	37.83	5.94	4.89
Tukey 0.05%	0.12	0.46	0.66	3.58	4.08	3.24	1.02	2.45
	ns	ns	ns	ns	n/a	ns	ns	ns
Dosage								
2L/ha	0.21	1.58	2.99	40.67	65.54	41.31a	7.15a	6.56
1L/ha	0.25	1.74	2.86	39.78	64.14	37.64b	6.15ab	5.44
3L/ha	0.20	1.40	2.53	38.89	63.17	38.11ab	5.70b	4.78
Tukey 0.05%	0.12	1.11	0.66	3.58	4.08	3.25	1.03	2.45
	ns	ns	ns	ns	n/a	*	*	ns
Biostimulant per dose								
Activer 1L	0.28	2.01	3.23	38.67	67.27	38.80	6.71	7.67
Aminocrop 2L	0.28	1.86	3.06	41.00	66.37	41.67	7.07	6.00
Humega 2L	0.17	1.53	2.98	40.67	65.67	41.70	7.26	4.33

Activer 3L	0.27	1.75	2.95	40.67	65.60	38.80	6.71	5.33
Activer 2L	0.17	1.34	2.91	41.33	64.60	40.57	7.12	6.00
Humega 1L	0.31	1.88	2.97	40.67	64.23	37.03	5.82	6.33
Humega 3L	0.19	1.40	2.55	40.33	63.23	39.87	5.88	6.00
Aminocrop 1L	0.16	1.33	2.38	38.33	60.93	36.17	5.93	5.67
Aminocrop 3L	0.14	1.06	2.10	37.33	60.67	35.67	4.81	3.00
Tukey 0.05%	0.29	1.10	1.57	8.51	9.71	7.72	2.44	5.83
	ns	ns	ns	ns	n/a	ns	ns	ns
Treatment vs. contrast								
Control vs. rest	0.02	0.11	0.55	20.83	7.54	3.14	0.09	5.35
	ns	ns	ns	ns	n/a	ns	ns	ns

ns: not significant, FDR: fruit diameter, FLDR: fruit length, FWR: fruit weight, NFR: number of fruits, FL15: length of shoots at 15 days, FL30: length of shoots at 30 days, FL45: length of shoots at 35 days, DIF: days to flowering. DSH: honest significant difference

The analysis of means using Tukey's multiple test (P<0.05) for the treated doses determined significant differences for the LFRU variable, where the best treatment was for the 2 L/ha dose with a mean of 41.31 cm and for the PFRU with a mean fruit weight of 7.15 kg (Table 3).

The comparison of means using Tukey's multiple test (P<0.05) for the interaction between biostimulants and dose showed no significant interaction for any of the variables evaluated (Table 3).

The contrasts performed using the F test at P<0.05 probability (Table 3) showed no significant differences for any of the contrasts performed.

Discussion

The findings of this study indicate that the biostimulants used did not show differences between the different treatments. However, they did promote positive characteristics in the plants and fruits of the watermelon crop, with the treatments outperforming the control, although this was not statistically significant. This coincides with the findings of Vélez (2010), who points out that biostimulants did not increase production yields. This contrasts with the findings of Villamar (2012), who mentions that products with a 100% biodegradable natural

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organic concentrate, when applied to the leaves, promote plant growth by activating their physiological processes.

In this research, significant differences were determined for the LFRU and PFRU variables, where the best treatment was for the dose of biostimulants (Activer, Humega, Aminocrop) with 2L/ha. The results agree with Cervantes (2018), showing the best averages in terms of root mass volume, with the highest weight obtained by treatment 2 (Humitrex 2 kg·ha-1 + Radix 2 L·ha-1) treatment, with an average weight of 208.3 g, while treatments T1 (Humitrex 2 kg·ha-1) and T3 (Radix 2 L·ha-1) achieved lower values with averages of 180.4 and 156.33 g/plant, respectively, while the control was 139.4 g/plant. These results coincide with those reported by Pazmiño (2021), who states that the DFRU of the fruit is due to the fact that biostimulants help the plant absorb nutrients and thus stimulate growth.

Similar results were reported by Veobides et al. (2018), who mention that biostimulants incorporate minerals into the stem and leaves, thus increasing yields and improving fruit quality. The DFRU increases in thickness and volume and is also beneficial to the environment as it does not pollute or leave residues. The main action of foliar biostimulants is to moisten and absorb water and solutes through the leaves, incorporating them into the plant and thus providing adequate nutrition. In this regard, Pazmiño (2021) indicates that the leaves act as water and mineral capturers. This is due to the chemical composition of the biostimulants, which allow for easy foliar penetration through the stomata, as these are very important for the survival and growth of the plant.

In this study, comparisons of means for biostimulant interaction by dose showed no significance, which contrasts with Zaldivar (2012), who reports that all treatments in his study based on the substances applied significantly outperformed the control ( ), with the treatment combining botanical products, the biological medium and the biostimulant, which significantly outperformed the rest of the treatments. There were no statistical differences between treatments 2, 3 and 4, which are the treatments based on plant extracts + the biostimulant or the biological medium + the biostimulant.

Conclusions

It was determined that the biostimulants used in this research had an impact on the characteristics of the plants and the fruit production of the watermelon crop, although no significant differences were observed. However, the doses used did show significant differences for the LFRU of 41.31 cm and a PFRU of 7.15 kg per plant, with Humega at a dose of 2 L/ha.

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