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THE INFLUENCE OF MICROORGANISMS ON THE QUANTITATIVE AND QUALITATIVE CHARACTERISTICS OF TOMATO FRUITS

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Abstract

Tomato (Solanum lycopersicum L.) is one of the vegetables with the highest global production value. In an effort to achieve an increasing both quantity and quality production, researchers have been and are still looking for strategies to improve crop technology using various plant protection and stimulation products.
Over the years, different technologies have been developed for cultivating and treating plants with Bacillus spp. in order to increase plant productivity but also to reduce residual elements in plants, thus helping to protect the consumer. The present study aims to highlight the effect of the microbial inoculants Rizobac and Bactilis on fruit quality indicators for the three tomato hybrids. Both microbial inoculations had a tendency to increase fruit size in the treated tomato hybrids, for total dry matter they ranged between 4.03% and 4.38% for Buffalosun F1, pH ranged from 4.07 to 4.12 for Kingset F1, from 4.05 to 4.18 for Bucanero F1 and from 4.01 to 4.21 for Buffalosun F1, when Bactilis was applied.

Key words: *beneficial bacteria, fertilization, microorganisms, production, environmental protection, tomatoes.*

INTRODUCTION

The tomato *(Solanum lycopersicum* L.) is one of the most valuable vegetables globally in terms of production (Nanu et al., 2024). It is consumed in a wide variety of forms and provides numerous health benefits due to its high content of lycopene, folic acid, ascorbic acid, flavonoids, α-tocopherol, potassium, and phenolic compounds (Erba et al., 2013).
Tomatoes are part of the human diet both in fresh form and in various processed products such as tomato juice, tomato paste, puree, and dried tomatoes (Wu et al., 2022). These products are consumed in greater quantities than fresh tomatoes (Reimers & Keast, 2016), while green or semi-ripe tomatoes are used for pickling, candying, and preservation. Due to their versatility, tomatoes are highly valued and widely consumed around the world, being incorporated into numerous culinary recipes (Javaria et al., 2012). Their high antioxidant content provides significant health benefits (Li et al., 2024), and their seeds can be used to extract a valuable edible oil (Rubatzky & Yamaguchi, 1997).
Praised for their distinct aroma, tomatoes owe their unique taste to the combination of sugars, organic acids, free amino acids, volatile organic compounds (VOC), and the complex interactions between these elements (Tieman et al., 2012).
High serum levels of lycopene, resulting from tomato consumption and derived products,

contribute to reducing the risk of stroke and ischemic stroke in men (Karppi et al., 2012). Additionally, carotenoids, predominantly from tomatoes, may protect against breast cancer (Aune et al., 2012; Sato et al., 2002) and reduce the incidence of prostate, lung, and stomach cancer (Giovannucci, 2002).

Due to their rich content of minerals and antioxidants, tomatoes are essential in human nutrition, helping to neutralize free radicals in cells and preventing various diseases that can affect health (Kalogeropoulos et al., 2012; Porto et al., 2016).

To achieve higher and better-quality agricultural yields, researchers have explored and continue to develop technological solutions that include the use of plant protection and stimulation products. A key step in this direction has been the adoption of products that do not harm the environment or the treated plants.

Over time, cultivation and treatment technologies based on *Bacillus* spp. have been developed, aiming to increase plant productivity while reducing the accumulation of chemical residues, thus protecting consumers. *Bacillus* spp. is a bacterium recognized for its benefits in various fields, and research continues to fully assess its usefulness. This study aims to highlight the beneficial effects of biological products based on *Bacillus* spp. through their application at the root level. The research targets both agricultural producers, by providing efficient alternatives for conventional and organic technologies, and consumers, by promoting less polluted products.

The use of *Bacillus* spp. in agriculture is a current and innovative practice due to its multiple roles: natural biocontrol against pathogens (inhibiting the development of fungi and harmful bacteria), plant growth stimulation (by colonizing roots and enhancing nutrient absorption), bioremediation and ecological agriculture (degrading toxic compounds and fixing atmospheric nitrogen, thereby reducing pollution and protecting biodiversity), as well as emerging technologies based on *Bacillus* spp. for optimizing agricultural production.

Recent research explores the integration of these bacteria into precision agriculture, using advanced technologies such as drones and automated systems for intelligent treatment application.

Biological control, through the use of microorganisms to combat diseases and pests in vegetable crops, represents a valuable alternative to chemical treatments applied to tomatoes. *Bacillus* and *Paenibacillus* species help reduce pathogens either by producing metabolites with antibiotic effects or by directly stimulating the plant's natural defense mechanisms. Additionally, some strains improve nutrient absorption by promoting symbioses or directly fixing atmospheric nitrogen (Gardener, 2004).

The increasing concentration of heavy metals in the soil, caused by unsustainable agricultural practices, excessive use of chemical fertilizers, and large-scale pesticide application, poses a serious threat to soil ecosystems and environmental health (Jaishankar et al., 2014). In this context, the use of organic fertilizers and manure, alongside sustainable management practices, can reduce dependence on chemical fertilizers. This method helps farmers lower costs by providing a slow-release source of nutrients, maintaining soil fertility and long-term agricultural productivity (Praharaj, 2007).

The degradation of agricultural land due to intensive chemical fertilizer use has led farmers to explore alternative cultivation methods. Thus, there is a growing interest in organic farming and the implementation of efficient water and nutrient management techniques (Verma et al., 2023).

Unicellular microorganisms, such as bacteria and protozoa, play an essential role in soil ecology, being present everywhere - in water, air, soil, and food (Kadner & Kara Rogers, 2024). These microorganisms contribute to carbon fixation in low-vegetation areas and transform atmospheric nitrogen into organic compounds (Peng et al., 2021). Soil fertility depends on its biological component, which includes bacteria, viruses, fungi, and other essential microorganisms that maintain soil health.

Although bacteria are often associated with pathogens, most are harmless and play a beneficial ecological role, supporting life and ecosystem balance (Singh et al., 2019). The rhizosphere provides a crucial habitat for soil microorganisms, facilitating plantmicroorganism interactions. Among these, species from the *Bacillus* spp. genus are plant growth-promoting rhizobacteria (PGPR), improving mineral nutrient absorption and crop yields (Kalam et al., 2020).

Tomatoes, as a high-yield crop, require a substantial nutrient supply to support growth and maximize production. They respond positively to various technological interventions, such as increasing the number of stems to boost yield or using biofertilizers containing substances like arginine and cysteine (Apahidean et al., 2021; Becherescu et al., 2021; Hoza et al., 2019).

Applying nitrogen (N) in large quantities is a widespread agricultural practice. However, rising fertilizer costs have led farmers to optimize their usage and manage financial resources more efficiently. An alternative method for reducing nitrogen consumption is soil inoculation with *Bacillus pumilus*, which biologically fixes nitrogen and enhances its absorption by tomatoes. Additionally, *Bacillus pumilus* induces leaf transpiration, facilitating nitrogen transport to the shoots (Masood et al., 2020).

Among the bacteria recently used in agriculture is *Bacillus velezensis* 83, which, after application, has shown a positive impact on the productivity of greenhouse-grown tomatoes (Balderas-Ruíz et al., 2021). Furthermore, bacterial use can begin at the seed stage, with *Bacillus cereus* demonstrating improved germination rates and a higher vigor index compared to untreated seeds (Guo et al., 2019).

In addition to nitrogen absorption, *Bacillus* spp. promotes plant growth by enhancing phosphorrus uptake and producing phytohormones such as auxins, enzymes like ACC deaminase, and volatile organic compounds (VOC) such as 2,3-butanediol and acetoin (Asari et al., 2016; Borriss, 2020; Fazle Rabbee & Baek, 2020).

Another major benefit of using microorganisms is stimulating the absorption and transport of nutrients, particularly the solubilization of insoluble zinc compounds and their assimilation by plants (Mumtaz et al., 2017).

Bacterial colony metabolism significantly enhances biological processes in the soil and nutrient assimilation efficiency. These effects can lead to a remarkable increase in tomato production, estimated at up to 36.82%, supporting both productivity and agricultural sustainability (Dragomir & Hoza, 2022; Wang et al., 2024).

In conclusion, bacteria play a crucial role throughout the entire technological process, from sowing and harvesting to fertilization and fruit storage. These microorganisms represent a valuable resource, continuously supporting every stage of plant cultivation.

MATERIALS AND METHODS

Location and Experimental Design

The experiment was conducted in Scărișoara, Olt County, located in the Oltenia region of Romania. The locality is situated in the southern part of the county, approximately 30 km from Caracal and 75 km from Slatina, with coordinates 43.9934 latitude and 24.5719 longitude (Romanian Population, 2024). The area's terrain is predominantly flat, and the climate is temperate-continental, characterized by very hot summers and relatively mild winters.

The experiment was organized using a completely randomized block design, including two fertilization treatments and one unfertilized control, applied to three tomato hybrids. Each treatment had three replications, with 15 plants per replication.

Experimental Factors

Factor A - Indeterminate-growth tomato hybrids intended for greenhouse and tunnel cultivation: Kingset F1, Bucanero F1, Buffalosun F1.

Factor B - Fertilization treatments: Control (untreated), Rizobac fertilizer (5 L/ha), Bactilis fertilizer (5 L/ha). Both fertilizers are certified for organic farming. By combining the two experimental factors, nine experimental variants were obtained.

Fertilizer Application

Fertilizers were applied via fertigation, starting immediately after crop establishment in the greenhouse, according to Table 1, which details the biofertilizer application schedule at regular intervals in each decade of the month, over three years (2022-2024).

The application frequency remained constant, with minor variations across the years, reflecting efficient fertilizer management. The structured application plan ensured optimal plant nutrition.

Table 1. The application schedule of treatments

Number of applications	Application period		
	Year 2022	Year 2023	Year 2024
1	Early April	Early April	Early April
2	Late April	Mid-April	Mid-April
3	Mid-May	Late April	Early May
4	Late May	Mid-May	Mid-May
5	Early June	Late May	Early June
6	Mid-June	Early June	Mid-June
7	Early July	Mid-June	Late June
8	Mid-July	Early July	Early July

Tomato Cultivation Technology

The tomato cultivation followed standard greenhouse production practices. The study was conducted over three years (2022-2024) in the greenhouses of a private producer in Scărișoara, Olt County.

Biological Material

Kingset F1 - Indeterminate tomato hybrid, ideal for early production in protected spaces.

Bucanero F1 - A fleshy tomato variety with dark brown, nearly black fruits. This vigorous hybrid has short internodes and produces black tomatoes of the Kumato type.

Buffalosun F1 - Indeterminate, vigorous, and compact tomato hybrid, known for its extra-early maturity. The fruits are large with a yellow-orange coloration.

Product Descriptions

Rizobac - A microbial inoculant rich in nutrients and beneficial microorganisms, designed to improve root establishment, facilitate rapid crop stabilization, and enhance root penetration and expansion. It contains a population of beneficial soil bacteria with a concentration of 1×10^{11} CFU/L, contributing to maintaining a healthy soil environment.

Bactilis - A microbial inoculant containing beneficial bacteria in the form of endospores. After application, the spores germinate rapidly, and the resulting bacteria multiply and colonize plant roots, promoting plant growth.

Measurements and Determinations

Number of fruits per plant - Obtained by summing all fruits from the inflorescences.

Fruit set percentage - Determined using the formula: % Fruit set = Total number of fruits × 100)/Total number of flowers

Yield per plant - Calculated using the formula: Yield per plant = Number of fruits per plant × Average fruit weight. The value was expressed in kg/plant.

Yield per hectare - Calculated using the formula: Yield per ha = Yield per plant × Number of plants per hectare (35 000). The value was expressed in t/ha.

Average fruit weight - Measured using the precision balance PS 6000.R2. The value was expressed in grams (g).

Fruit height and circumference - Measured using a digital caliper micrometer. The value was expressed in millimeters (mm).

Firmness N - Determined using a digital penetrometer (53205 TR Italia) with an 8 mm piston.

Total soluble solids - Measured with a Kruss DR301-95 digital refractometer.

Total dry matter - Determined by weighing fresh material, drying in a MEMERT UN 110 oven at 105˚C until constant weight, cooling in a desiccator, and reweighing. The value was expressed in percentage (%).

Total titratable acidity (citric acid %) - Measured using an automatic TitroLine Easy titrator.

Ascorbic acid content - Determined by extracting 1 g of raw material, ground with 2 mL of 2% (v/v) orthophosphoric acid for 1 minute at room temperature. The mixture was quantitatively transferred to a 15 mL centrifuge tube and brought to a final volume of 10 mL with 2% (v/v) orthophosphoric acid. After extraction, all samples were centrifuged, filtered, and stored for HPLC analysis (Stan et al., 2019). Quantification of ascorbic acid was performed using HPLC-DAD equipment (Agilent Technologies 1200 chromatograph), with results expressed in mg/100 g fresh matter of product.

Statistical Analysis

For data processing and interpretation, IBM SPSS 20 (SPSS Inc., Chicago, IL, USA) was used. Statistical analysis was conducted using a one-way ANOVA test ($p=0.05$), followed by Duncan's post-hoc test ($p=0.05$) for pairwise comparisons of sample means.

The results are presented as means and standard deviations, with means accompanied by letters; different letters indicate statistically significant differences ($p=0.05$). Similar to the multiple t-test, Duncan's test allows the comparison of multiple samples but employs a different calculation method and stricter significance levels.

RESULTS AND DISCUSSIONS

Number of Fruits per Plant

The obtained data indicate that the application of the biofertilizers Rizobac and Bactilis led to a significant increase in fruit production for the three hybrids compared to the unfertilized control.

Unfertilized plants recorded the lowest fruit counts (7.91-14.97 fruits/plant), indicating reduced physiological efficiency in the absence of biofertilizers. This may be attributed to limited absorption of essential nutrients, negatively affecting the generative development of plants.

The application of Rizobac resulted in a significant increase of the number of fruits, with values ranging from 17.14 to 9.31 fruits/plant. This effect is due to the presence of nitrogen-fixing bacteria and growth-promoting agents in its composition, which enhance nutrient uptake and plant metabolism, stimulating fruit formation.

Similarly, treatment with Bactilis led to significant increases of the number of fruits, with values between 8.89 and 16.69 fruits/plant. This biofertilizer contains beneficial sporulated bacteria capable of solubilizing phosphates in the soil and stimulating the synthesis of phytohormones, thereby promoting fruit set and reproductive development (Figure 1).

These results are consistent with findings from other scientific studies (Zhou et al., 2022), where a single inoculation with PGPR led to a 19% increase in the number of fruits - comparable to the 11-25% range observed in this study.

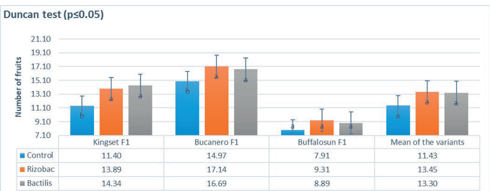

Figure 1. Influence of biofertilizer application on the average number of fruits per plant depending on the hybrids used

Fruit Set Percentage

Figure 2 illustrates the effects of Rizobac and Bactilis treatments on the fruit set percentage of Kingset F1, Bucanero F1, and Buffalosun F1, compared to the control variant.

For Kingset F1, the application of biofertilizers resulted in a significant increase in the fruit set percentage. The control variant recorded 65.47%, while treatments with Rizobac (72.36%) and Bactilis (71.35%) showed notable improvements, confirming their efficiency in optimizing reproductive processes.

In the case of Bucanero F1, biofertilizers contributed to an increase in the fruit set percentage compared to the control (60.10%), reaching 66.53% for Rizobac and 64.85% for Bactilis. The differences were significant, and the treated variants were classified in a higher-performing group than the control, indicating a beneficial effect on floral fertility.

For Buffalosun F1, the application of biofertilizers led to a moderate increase in the fruit set percentage, though without significant differences from the control. The recorded values were 49.84% for the control, 56.24% for Rizobac, and 55.87% for Bactilis, suggesting a limited influence on this hybrid.

The mean analysis of the variants indicates that biofertilizers had an overall positive effect on the fruit set process. The average fruit set percentage was 58.47% for the control, significantly increasing to 65.05% for Rizobac and 64.02% for Bactilis. These results confirm the contribution of biofertilizers to improving fruit formation, with a more pronounced impact on Kingset and Bucanero hybrids.

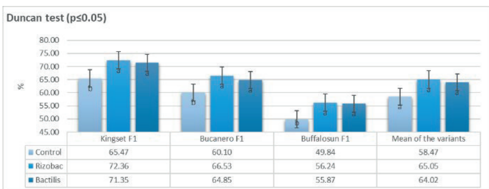

Figure 2. Influence of biofertilizer application on the set percentage depending on the hybrids used (%)

Tomato Yield per Plant

Figure 3 presents the effects of Rizobac and Bactilis treatments on tomato yield for Kingset F1, Bucanero F1, and Buffalosun F1, compared to the control variant.

For Kingset F1, the application of biofertilizers led to a significant increase in yield. The control variant recorded 2.35 kg/plant, while treatments with Rizobac (3.08 kg/plant) and Bactilis (3.23 kg/plant) showed notable improvements, confirming their effectiveness in stimulating generative development.

In the case of Bucanero F1, biofertilizers increased yield compared to the control (3.02 kg/plant), reaching 3.27 kg/plant for Rizobac and 3.29 kg/plant for Bactilis.

For Buffalosun F1, the application of biofertilizers resulted in a moderate yield increase, but without significant differences from the control. The recorded values were 3.20 kg/plant for the control, 3.45 kg/plant for Rizobac, and 3.52 kg/plant for Bactilis, suggesting a limited influence of biofertilizers on this hybrid.

The mean analysis of the variants indicates that biofertilizers had an overall positive effect on tomato yield. The average yield was 2.86 kg/plant for the control, increasing significantly to 3.27 kg/plant for Rizobac and 3.34 kg/plant for Bactilis. These results confirm that biofertilizers contribute to improving productivity, with a more pronounced impact on Kingset and Bucanero hybrids.

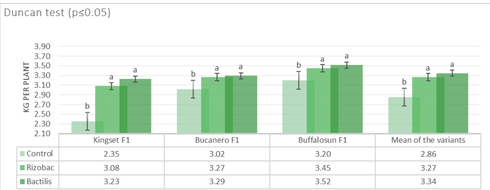

Figure 3. Influence of biofertilizer application on fruit production per plant kg)

Tomato Yield per Hectare

Tomato yield is influenced by essential physiological and morphological factors, such as the number of flowers per plant, fruit set percentage, number of fruits per plant, and fruit size. These parameters directly impact crop productivity, and their interaction determines the efficiency of metabolic processes and overall plant yield.

The results indicate a significant increase in yield in the biofertilizer-treated variants compared to the control.

For Kingset F1, the control yield was 69.7 t/ha, while Rizobac application led to 81.45 t/ha, and Bactilis resulted in the highest yield, 89.3 t/ha.

A similar effect was observed in Bucanero F1, where yield increased from 77.92 t/ha (control) to 93.34 t/ha (Rizobac) and 95.76 t/ha (Bactilis).

For Buffalosun F1, biofertilizer application also led to a significant yield increase, ranging from 71.24 t/ha (control) to 92.69 t/ha (Rizobac) and 88.14 t/ha (Bactilis) (Figure 4).

The mean yield analysis confirms the efficacy of biofertilizers, with Rizobac leading to an average yield of 89.16 t/ha and Bactilis reaching 91.07 t/ha, compared to 72.95 t/ha in the control variant.

The significant differences between treatments demonstrate that biofertilizers stimulate physiological processes and plant metabolism, leading to higher yields.

Species of Bacillus, recognized for their symbiotic efficiency, play a crucial role in promoting plant growth, improving yield, and enhancing stress resistance (Haile et al., 2024).

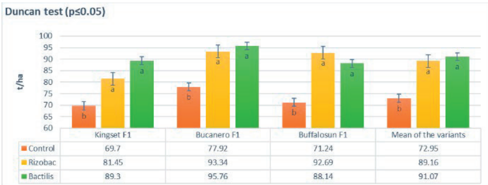

Figure 4. Influence of biofertilizer application on production per hectare depending on the hybrids used (t/ha)

Average Fruit Weight

Fruit weight is a key agronomic trait in many crops (Knaap et al., 2014).

The Duncan test analysis indicates a significant variation in fruit mass, primarily influenced by genetic characteristics.

Among the analyzed hybrids, Buffalosun F1 stands out for its larger fruit size compared to the others.

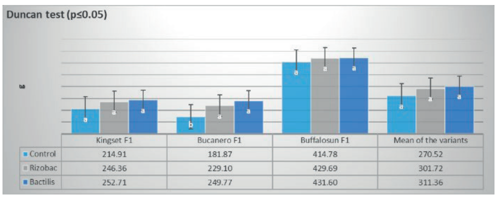

Figure 5. Influence of biofertilization variant on average fruit weight depending on hybrid (g)

Overall, all three hybrids responded positively to biofertilizers in terms of fruit mass (Figure 5).

For Kingset F1, the average fruit weight increased from 214.91 g (control) to 246.36 g (Rizobac) and 252.71 g (Bactilis).
For Bucanero F1, the control recorded the lowest value (181.87 g), while Rizobac (229.10 g) and Bactilis (249.77 g) led to a significant increase.
For Buffalosun F1, the average fruit weight was significantly higher than in the other hybrids, ranging from 414.78 g (control) to 429.69 g (Rizobac) and 431.60 g (Bactilis).
On average, Bactilis resulted in the highest average fruit weight (311.36 g), followed by Rizobac (301.72 g) and the control (270.52 g).
The differences between treatments are statistically significant, with a more pronounced effect in Bucanero F1 and Buffalosun F1.

Fruit Firmness

Microbial inoculations with Rizobac had a positive impact on fruit firmness across all three investigated hybrids (Figure 6). Although a consistent improvement in tomato firmness was observed after Rizobac application, the results were not statistically significant.
For the Bactilis biofertilizer, fruit firmness showed a slight decrease in Kingset F1 (-6.0%) and Bucanero F1 (-6.6%), but in Buffalosun F1, a significant increase (+18.57%) in fruit firmness was recorded. However, these differences were not statistically significant.
The results align with findings reported by Bilalis et al. (2018) and Wang et al. (2021).
The overall trend in fruit firmness remained constant, regardless of the applied fertilization. While the control variant did not show significant differences among hybrids, after biofertilizer application, Buffalosun F1 stood out with the highest firmness, exceeding 7.50 N.

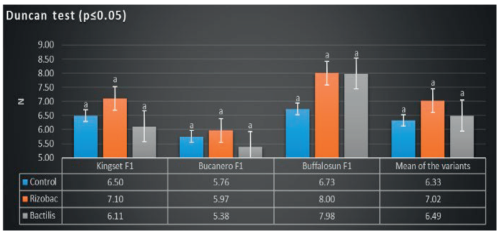

Figure 6. Influence of biofertilization variant on average fruit firmness depending on hybrid (N)

Soluble Solid Content

Figure 7 illustrates the effect of biofertilizers on the soluble solid content in the three analyzed tomato hybrids.
Rizobac treatments did not have a significant influence on the soluble solid content in any of the studied hybrids. On average, the total soluble solid content was very similar between the control variant (4.41°Brix) and the Rizobac-treated variant (4.40°Brix).
In contrast, the Bactilis biofertilizer had a significant impact on the total soluble solid content, forming two homogeneous value groups. However, in Buffalosun F1 and Kingset F1, the differences compared to the untreated variant were not statistically significant.
The results presented in Figure 7 indicate a consistent trend for this quality parameter across all hybrids. Buffalosun F1, followed by Bucanero F1, recorded the highest soluble solid content.

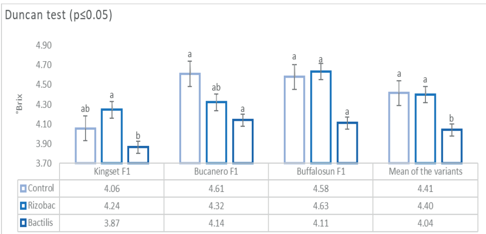

Figure 7. Influence of biofertilization variant on average total soluble substance of fruits depending on hybrid (°Brix)

Total Dry Matter

Various factors, including genotype, environmental conditions, cultivation technology, and water supply, influence the dry matter composition of tomatoes.
The highest total dry matter values were recorded in the untreated control for Kingset F1 (4.26%) and Bucanero F1 (4.31%), while for Buffalosun F1, the highest value was observed in the Bactilis-treated variant (4.38%). These values are lower than those reported by Davies and Hobson (1981).
On average, across the biofertilization treatments, the highest values were recorded in the untreated control, while the lowest values were found in the Rizobac-treated variant. However, the differences between variants were not statistically significant (Figure 8).

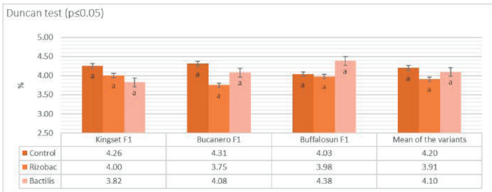

Figure 8. Influence of biofertilization variant on average total dry matter of fruits depending on hybrid (%)

The fluctuations in mean total dry matter values in this study ranged between 4.03% and 4.13%. The dry weight of Buffalosun F1 fruits was higher than that of Kingset F1 and Bucanero F1 over the three-year study period, despite being lower in the untreated control (Figure 8).

Fruit Acidity

Overall, the concentration of organic acids in tomatoes showed a slight decrease in Kingset F1 and Buffalosun F1, but a significant reduction in Bucanero F1 following the application of biofertilizers (Figure 9). However, when analyzing the mean values across variants, the reduction was not statistically significant, according to the Duncan test ($p \leq 0.05$).

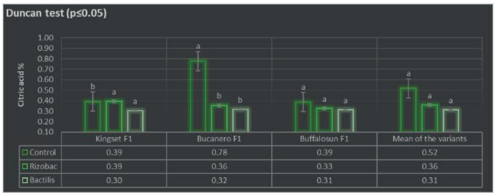

Figure 9. Influence of biofertilization variant on average fruit acidity depending on hybrid (citric acid %)

The ANOVA variance analysis indicates an insignificant variation in fertilization treatments and genetic factors on tomato acidity. However, scientific literature confirms that organic acid levels are influenced by environmental factors and cultivation conditions (Fandi et al., 2010; Hernández-Pérez et al., 2020; Rusu et al., 2023), as well as genotypic variations (Dufera et al., 2018).

In this study, biofertilizer application facilitated the availability of potassium and phosphorus in the soil, but the antagonistic effect between these nutrients may explain the non-significant variations in the treatments applied.

For the analyzed hybrids, the mean titratable acidity values varied as follows: Kingset F1: 0.30-0.39%, Bucanero F1: 0.32-0.78%, Buffalosun F1: 0.31-0.39%.

Titratable acidity was higher in Kingset F1 across all microbial inoculations. However, the differences in mean titratable acidity among the three hybrids were not statistically significant, although Bucanero F1 exhibited a slightly higher value (0.48%) compared to Kingset F1 (0.36%) and Buffalosun F1 (0.34%).

Ascorbic Acid Content

The ascorbic acid in tomatoes varies significantly, with reported values ranging from 6 to 50 mg/100 g of fresh matter, according to the literature (Gest et al., 2013; Sérino et al., 2019; Valšíková-Frey et al., 2017). In this study, the values obtained for the analyzed hybrids were below this range.

Statistical analysis indicates that fertilization variants significantly influenced ascorbic acid biosynthesis (Figure 10). In Kingset F1, vitamin C accumulation decreased after the application of biofertilizers. Conversely, in Bucanero F1, vitamin C content increased significantly by 55.06% following Rizobac application.

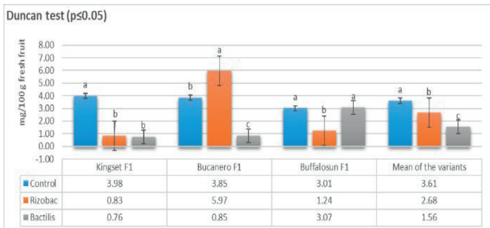

Figure 10. Influence of biofertilization variant on average ascorbic acid of fruits depending on hybrid (mg/100 g fw)

However, when analyzing the mean values across variants, Rizobac and Bactilis treatments led to a significant decrease in ascorbic acid levels, by 25.97% and 56.91%, respectively, over the three-year study period, compared to the control variant.

The response of hybrids to the applied treatments varied, showing significant differences depending on the type of biofertilizer used.

CONCLUSIONS

The application of biofertilizers can contribute to increased yield and improved crop productivity, depending on the floral development stage and the hybrid used.

In conclusion, Rizobac and Bactilis biofertilizers had a significant positive impact on fruit set, with more evident results in Kingset F1 and Bucanero F1. These treatments stimulated fertilization and optimized fruit formation, generating statistically significant differences compared to the control variant.

By activating physiological processes and enhancing nutrient absorption, biofertilizers contributed to higher tomato production, proving their efficiency as a solution for yield improvement. Their application represents a promising method for enhancing productivity and sustainability in tomato cultivation.

All three hybrids analyzed benefited from biofertilizer application, showing a positive impact on fruit weight. Microbial inoculations with Rizobac had a favorable effect on firmness, though without statistically significant differences, while Bactilis reduced firmness in some hybrids, except for Buffalosun F1, where an improvement was observed.

Rizobac treatments did not have a significant impact on the soluble solid content, with mean values nearly identical between the control and treated variants. In contrast, Bactilis significantly influenced total soluble solids, but the differences were not statistically significant for Buffalosun F1 and Kingset F1.

Fluctuations in total dry matter values were minimal, with the dry weight of Buffalosun F1 fruits surpassing that of the other hybrids. The application of biofertilizers led to a slight decrease in acidity in Kingset F1 and Buffalosun F1, while Bucanero F1 recorded a significant decrease, though without statistically significant differences when analyzing mean values across variants.

The vitamin C concentration varied significantly among hybrids, with Kingset F1 having the lowest value under Bactilis treatment, while Bucanero F1 recorded the highest value under Rizobac treatment.

The different responses of hybrids to treatments confirm the influence of genetic and environmental factors on quality and productivity parameters in tomatoes.

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