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RESEARCH PAPER

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EFFECTS OF BACTERIAL AND FUNGAL BIO-FERTILIZERS ON YIELD AND QUALITY OF SOILLESS-GROWN CLUSTER TOMATO

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ABSTRACT

This study evaluated the effects of bacterial (*Arthrobacter globiformis*, *Streptomyces griseus*) and fungal (*Aspergillus oryzae*) preparations on the growth, yield, and fruit quality of cluster tomato (*Solanum lycopersicum* L. cv. Cletego F1) grown in cocopeat substrate under greenhouse conditions. Treatments significantly improved plant growth, cluster number, and yield compared with the control, with *Streptomyces griseus* producing the highest yield (58.6 t da^{-1}) and superior fruit quality (SSC = 4.85%, acidity = 0.28 g citric acid 100 mL^{-1}). The control recorded the highest vitamin C content. The study concludes that microbial inoculation enhances yield and quality in soilless tomato cultivation, supporting eco-friendly and sustainable production systems.

Keywords: *Arthrobacter globiformis*, *Aspergillus oryzae*, cocopeat, soilless agriculture, *Streptomyces griseus*

INTRODUCTION

Tomatoes (*Solanum lycopersicum* L.) have been shown to offer significant benefits to human health by strengthening the immune system. This is due to the phenolic compounds, especially lycopene, vitamins, and minerals they contain [Rao and Agarwal 2000, Barber and Barber 2002, Imran et al. 2023]. Tomatoes are a very important vegetable (13 million tons) that is widely cultivated worldwide, including in Turkey. A substantial proportion of tomatoes, which are the most widely cultivated vegetable in both global and Turkish production, are produced soilless greenhouse [TÜİK 2024, FAO 2024]. Soilless agriculture, which exhibits numerous advantages in comparison to traditional cultivation techniques, is categorized into two distinct methods: hydroponic culture and solid media culture. In the context of commercial tomato cultivation, solid media culture is a prevalent practice, owing to its cost-effectiveness and its role in creating a protective barrier around the plant's root zone [Toprak and Gül 2013]. Solid medium culture supports the plant grown on the growing medium, thereby increasing success. In soilless farming, many organic and inorganic media are used in solid medium culture. Cocopeat has become the preferred choice due to its high capacity to retain water and nutrients, its light weight, high air permeability, and

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ability to provide healthy cultivation [Frolking et al. 2001].

It has been established that microorganisms residing in the root zone of growing media employed in solid media culture exert an impact on crop health through antagonism against pathogens. Future efforts to enhance soilless yield should prioritize the development of intelligent environmental control methodologies and the advancement of microbiome science [Masquelier et al. 2022, Tuxun et al. 2025]. The emergence of pathogens over time within the growing environment poses a significant challenge. Consequently, the utilization of beneficial microorganisms in soilless agriculture is of paramount importance, as they ensure the effective use of nutrient solutions and promote the formation of beneficial microflora by suppressing fungal pathogens [Grover et al. 2021, Masquelier et al. 2022, Aktaş and Hor 2024, Tuxun et al. 2025]. The utilization of fungal and bacterial microorganisms as biocontrol agents within biological control approaches represents a novel methodology for combating issues pertaining to fungicide resistance. A variety of *Bacillus* and *Trichoderma* species, which possess strong biocontrol potential are employed extensively in the management of plant diseases, including early blight in tomatoes [Mazrou et al. 2020, Stracquadanio et al., 2020, Castro-Restrepo et al. 2022, Narware et al. 2023, Imran et al. 2023]. Similarly, it reveals that naturally occurring bacterial microbes can control many diseases in vegetable cultivation and increase pathogen resistance in plants [Imran et al. 2022, 2023, Abo-Elyousr et al. 2022, 2024]. Bio-fertilizer is defined as a material consisting of living microorganisms which, when applied to seed, plant surface, soil or substrate are capable of fixing atmospheric nitrogen, increasing the uptake of mineral elements from both organic and inorganic sources, or promoting plant growth through the production of secondary metabolites [Grover et al. 2021, Tuxun et al. 2025]. The composition of the material to be used in the growing medium is of paramount importance. It is a commonly held view amongst researchers that it is correct to develop the growing medium to be used in conjunction with the microorganisms to be used. In the context of sustainable tomato production, the growth, flowering and fruit formation of tomatoes are contingent on the relationship between the mineral enrichment of the growing medium, primarily calcium uptake, and microorganisms [Orta-Guzmán 2021, Mahapatra et al. 2022, Masquelier et al. 2022, Gulia et al. 2022].

Soilless tomato cultivation is a profitable production method due to its high yield. However, in comparison with soil-based cultivation, the soilless growing media is characterized by a deficiency in microorganisms. The agricultural practice of cultivation is undertaken with the application of intensive fertilization in commonly utilized growing media, such as cocopeat substrate. The number of studies investigating the effects of changes in the quantity and diversity of microorganisms in growing media on tomato yield and quality is limited. Therefore, this study was conducted with the objective of ascertaining the effect of bacterial (*Arthrobacter globiformis* and *Streptomyces griseus*) and fungal (*Aspergillus oryzae*) preparations applied to cocopeat used in substrate culture on the plant growth, yield, and quality of tomatoes cultivated in a soilless culture.

MATERIAL AND METHODS

Experimental time and location. The study was carried out between 15 March – 20 July 2022 in the greenhouse of Tutku Agriculture greenhouse enterprises. The greenhouse where the cultivation part was carried out is a plastic greenhouse located at '39.004814, 33.943019' on 40 acres of land in Sarıyahşi district of Aksaray province. Fruit quality analyses were carried out in the laboratories of Ordu University, Faculty of Agriculture, Department of Horticulture.

Plant material. In the study, seedlings of the cultivated tomato variety Cletego F1 (*Solanum lycopersicum* L.) (Syngenta, İzmir, Türkiye), which is particularly suitable for soilless agriculture, were used.

Experiment description. The prepared growing bags (Cocopeat; 100 × 20 × 5 cm) were placed in 60 m long, 25 cm wide and 1.5% slope channels in the greenhouse. The seedlings of the Cletego F1 tomato cultivar were then planted in the growing bags at equal intervals (60 cm between rows and 30 cm above rows) with 4 plants per slab. Following this, the macro and micronutrients utilised in the fertilization process were meticulously prepared as stock solutions in two tanks (A and B), each with a capacity of 2000 L. The nutrient solutions to be used in the experiment [Hoagland and Arnon 1938] are given in Table 1.

The stock solutions presented in Table 2 were administered at varying doses, contingent upon the growth and developmental phases of tomato plants. Temperature values recorded with data loggers in the greenhouse ranged from 17 °C to 28 °C, while relative humidity values varied between 43 and 86%. When relative humidity values exceeded 70%, the ventilation system was used to control them.

The fertilization process was initiated at 1.5 hours after sunrise and concluded at 2 hours before sunset during the growing period. During the growing period, the tanks containing stock solutions were re-prepared according to necessity. Conductivity (EC) and pH were measured continuously from the water extracted from the growing media from seedling planting to harvest. When elevated levels of salinity were recorded, the media was subjected to a 10-minute cycle of water alone. This process was repeated until the desired level of salinity reduction was achieved.

The study utilised a range of bio-fertilizers, namely, *Aspergillus oryzae* (Mılıcard, MCC075 pure culture), *Arthrobacter globiformis* (Mılıcard, MCC296 pure culture), and *Streptomyces griseus* (Mılıcard, MCC1973 pure culture) were used. One of the bio-fertilizers is of fungal origin (*Aspergillus oryzae* 1 × 1010 cfu/gr) and two are of bacterial origin (*Arthrobacter globiformis* 1 × 1010 cfu/gr, *Streptomyces griseus* 1 × 1010 cfu/gr).

Table 1. Macro and micronutrient solutions and ratios to be applied in soilless culture [Hoagland and Arnon 1938]

Stock solutions	Chemical substances	The amounts
A (2000 L)	potassium nitrate	50 kg
	calcium nitrate	260 kg
	nitric acid	1 L
	iron chelate	3 L
	potassium chloride	10 kg
	previcur energy	600 mL
B (2000 L)	potassium nitrate	52 kg
	mono potassium phosphate	54 kg
	potassium sulfate	84 kg
	magnesium sulfate	84 kg
	zinc sulfate	430 g
	manganese sulfate	1000 g
	sodium molybdate	24 g
	copper sulfate	60 g
	borax	570 g

Table 2. Fertilizer doses to be applied to tomatoes according to growth and development periods

Developmental periods	N	P	K	Ca	Mg
	mg/L				
Until flowering	200	50	275	250	70
4–5. after the inflorescence appears	230	55	360	230	70
7–8. after the inflorescence appears	220	55	470	230	60

The fungal and bacterial applications were made during the seedling period (1 month). Mixtures (10 g L^{-1}) were prepared, comprising 1 litre of each organism. Each plant was treated with 100 mL of the mixture, and 6 plants were used for each experiment. A total of 24 plants were incorporated into the experimental design, with 2 applications of the 10 g L^{-1} solution administered at 2-week intervals during the vegetation period, subsequent to the seedling stage. It should be noted that no microorganisms were used as a control in the study. In order to ensure that the control applications and all microorganism applications are isolated from each other, the growing bags used for the applications are placed in different slope channels.

Planting preparation, planting and cultivation

Prior to the planting of the seedlings, the distances were determined, and the planting sites were opened in the growing bags. Subsequent to the creation of the planting sites, drainage holes were made in the growing bags at a height of 2–3 cm above the bag. The tomato seedlings were planted in the second week of April (25.04.2022). Post-planting, drip irrigation pipes were affixed to the surface of the bags, with 200 ml of living water allocated to each plant. On the day of planting, only living water was administered to the plants, with the nutrient solution commencing from the subsequent day.

Pruning, a widely employed practice in tomato cultivation, was meticulously executed on the shoots emerging from the leaf axils and the lower old leaves, with the systematic removal of three leaves per week. Old leaves located beneath harvested clusters were systematically removed, ensuring the retention of five fruits per cluster. Subsequent green fruit clusters were pruned, with the removal of three leaves, leaving a total of 12 leaves on the plant. Throughout the cultivation period, a range of other maintenance, spraying and cultural procedures were applied as required. Armpit removal and pruning were executed on a weekly basis. According to the EDT (economic damage threshold) method, cultural precautions such as collecting pest leaves, placing pheromone water traps and sticky traps were carried out.

Measurements and observations on growing plants

In the present study, bio-fertilizer applications were initiated at the 6 cluster stage. However, given that the research was conducted within a commercial enterprise, measurements and observations were determined by following up until the end of cultivation. The fruit quality characteristics were evaluated on a scale of 1 to 5. The fruit samples were obtained from clusters 3–5.

The height of the plants was measured in centimetres from the root collar to the tip of the growth, with the aid of a tape measure. The stem diameter was measured in millimetres from the root collar using a digital calliper. The number of leaves was counted manually from the time of planting and recorded accordingly. The root dry weight was measured by washing and separating the roots so that there would be no root loss during the uprooting process. The separated roots were then placed in paper bags and placed in an oven at 80 °C. The drying process was carried out for a minimum of 48 hours. During this period, the weight change method was employed for the samples that had not yet completed drying, and the determination was made as to whether the drying process had been completed or not. Once it was established that the samples had undergone complete desiccation, their dry weights were determined by means of a balance with a sensitivity of 0.01 g. The number of cluster was determined by manual enumeration. The number of fruits per cluster was determined as the mean value by means of manual enumeration of the fruits in the cluster since planting. Measurements were taken at regular intervals, with each interval spanning a duration of 20 days. The final measurements were taken 9 months after planting the seedlings.

Throughout the growing season, all fruits that reached the pink stage were harvested and measured. The yield, weight and fruit diameter of each fruit were determined. The fruit weights were measured by means of a scale that was sensitive to 0.1 g. The fruit weight was determined in grams by averaging the obtained fruit weights. Finally, the yield per plant was calculated in kilograms by summing the weights of the harvested fruits (marketable product amount).

The colour of the fruit skin was determined in accordance with the CIE Chroma and Hue colour models. The colour of the fruit was measured using a colourimeter (Minolta, model CR-400, Tokyo, Japan) by taking a measurement from two opposite sides of the equatorial side of 10 fruits obtained from each repli-

cate of each treatment. Flesh firmness was measured by lifting the peel from two different sides of the equatorial part of 10 fruits in each treatment. A hand penetrometer (4301, Instron, USA) with a 7.9 mm tip was then used, and the force required to pierce the fruit was expressed in Newton (N) [Kılıç et al. 1991]. The water soluble solids content (SSC) was determined by shredding 10 fruit slices from each treatment in each replicate with an electric mixer, and the juice obtained was passed through cheesecloth. A sufficient volume of juice sample was collected, and the refractive index was measured using a digital refractometer (PAL-1, McCormick Fruit Tech, Yakima, USA). The results were expressed as a percentage. Titratable acidity was determined by diluting 10 mL of the juice sample with 10 mL of distilled water and titrating with 0.1 N sodium hydroxide (NaOH) until the pH reached 8.1. The results were expressed as citric acid (g citric acid 100 mL^{-1}) based on the amount of NaOH consumed in the titration. The extraction of vitamin C from 25 g of tomato fruits was achieved through a blending process involving 25 mL of oxalic acid (0.4%) with a blender, followed by filtration through filter paper. The amount of vitamin C (L-ascorbic acid) in the samples taken from this filtrate was measured with 2,6-dichloroindophenol using the titrimetric method AOAC [1995] at a wavelength of 518 nm in a spectrophotometer. The results were given as milligrams of vitamin C per 100 g of wet weight. The quality characteristics of the fruit were evaluated in samples obtained from the fourth to sixth cluster, three months after the seedlings were planted.

Statistical analysis

The study comprised four treatments: three biological fertilizers (*Aspergillus oryzae*, *Arthrobacter globiformis*, *Streptomyces griseus*) and one control. Experiments were conducted in a randomized plot design with three plot and with 18 plants in each replication. In total, 54 plants were measured for each treatment. The normality assumption of the data was examined using the Shapiro-Wilk test, and it was determined that the data met the normality assumption ($p > 0.05$). Furthermore, the Levene's test for variance homogeneity revealed that the variances were homogeneous ($p > 0.05$). According to these conditions, it was determined that the data were suitable for variance analysis, and statistical analyses were performed according to one-way analysis of variance (One Way ANOVA). Differences between groups were determined using the Duncan multiple comparison test. The OMU licensed SPSS 21 package programme was used in the analysis of the data.

RESULTS

The present study investigates the effects of different bio-fertilizers (Fungus: *Aspergillus oryzae* and Bacteria: *Arthrobacter globiformis*, *Streptomyces griseus*) on plant height, stem diameter, number of leaves and root dry weight in soilless tomato cultivation (Table 3). According to the results obtained, the effects of treatments on number of leaves and root dry weight were found to be significant ($p < 0.05$). While the highest root dry weight (20.3 g was obtained from

Table 3. The effect of biological fertilization with pure cultures of *Aspergillus oryzae, Arthrobacter globiformis* and *Streptomyces griseus* on tomato plant height, stem diameter, number of leaves and root dry weight

Applications	Plant height (cm)	Stem diameter (cm)	Number of leaves	Root dry weight (g)
Control	734.7	1.47	87.7 b	16.4 ab
Aspergillus oryzae	746.7	1.50	93.3 ab	11.8 b
Arthrobacter globiformis	753.5	1.53	97.5 a*	20.3 a*
Streptomyces griseus	758.0	1.53	94.3 ab	13.6 ab
SEM	*5.03*	*0.20*	*1.87*	*1.08*

Notes: Means in the same column followed by different letters were significantly different (* $p < 0.05$); SEM: standard error of the means

the *A. globiformis* bio-fertilizer application, it was determined that the control application with *S. griseus* was also in the same group. The application of *A. globiformis* resulted in the highest number of leaves (97.5). The lowest number of leaves was recorded in the control application, with a measurement of 87.7. While no statistical difference was detected, bio-fertilizers performed better than the control group on plant height and stem diameter, and bacterial treatment was more effective than fungal treatment. However, root dry weight values were similar between the bacterial and control groups. The study concluded that the effect of biological fungal fertilizers on root dry weight was limited.

It was determined that different bio-fertilizer (fungi and bacteria) applications had significant ($p < 0.05$) effects on the number of cluster, number of fruits in cluster and yield values in soilless tomato cultivation (Table 4). The *Streptomyces griseus* application demonstrated the highest number of cluster (28.3) and number of fruits per cluster (6.63). However, no significant differences were observed among the other bio-fertilizer applications. The lowest values were obtained from the control application. The *Streptomyces griseus* application yielded the highest yield of 58.6 t da^{-1}, while the *Aspergillus oryzae* application achieved similar values of 53 t da^{-1}. The lowest recorded yield values were measured at 47.6 t da^{-1} in the control application. No statistical differences were determined for the average fruit diameter and average fruit weight values.

The impact of diverse bio-fertilizers on fruit color (Chroma and Hue°), soluble solids content (SSC), titratable acidity and ascorbic acid was found to be sig-

Table 4. The effect of biological fertilization with pure cultures of *Aspergillus oryzae, Arthrobacter globiformis* and *Streptomyces griseus* on tomato cluster number, number of fruits per cluster, average fruit diameter, average fruit weight and yield in soilless tomato cultivation

Applications	Cluster number	Number of fruits per cluster	Average fruit diameter (cm)	Average fruit weight (g)	Yield (t da^{-1})
Control	26.3 b	3.38 b	6.63	116.8	47.6 b
Aspergillus oryzae	28.0 a	4.13 a	5.72	117.6	53.0 ab
Arthrobacter globiformis	27.3 ab	4.29 a	5.48	98.6	40.4 b
Streptomyces griseus	28.3 a*	4.63 a*	6.42	125.4	58.6 a*
SEM	*0.58*	*3.54*	*1.87*	*5.94*	*928.4*

Notes: as in Table 3

Table 5. The effect of biological fertilization with pure cultures of *Aspergillus oryzae, Arthrobacter globiformis* and *Streptomyces griseus* on tomato firmness, titratable acidity, SSC and vitamin C in soilless tomato cultivation

Applications	Chroma	Hue°	Firmness (N)	Titratable acidity (g citric acid 100 mL^{-1})	SSC (%)	Vitamin C (mg 100 g^{-1})
Control	25.6	55.7 a*	17.74	0.21 b	4.25 c	23.1 a*
Aspergillus oryzae	23.1	51.9 b	18.15	0.24 b	4.48 bc	19.3 b
Arthrobacter globiformis	26.7	54.2 ab	18.93	0.26 a	4.65 b	15.5 c
Streptomyces griseus	26.9	54.1 ab	19.82	0.28 a*	4.85 a*	11.8 d
SEM	*4.72*	*2.31*	*0.78*	*0.012*	*0.05*	*0.01*

Notes: as in Table 3; SSC: soluble solids content

nificant ($p < 0.05$). The most effective coloration was observed in the bio-fertilizer treatments, while *Aspergillus oryzae* bio-fertilizer application was notable for its impact on SCC (4.85%) and titratable acidity (0.28 g citric acid 100 mL^{-1}). Similar values were obtained in titratable acid values with *Arthrobacter globiformis* bio-fertilizer application of 0.26 g citric acid 100 mL^{-1}. The highest vitamin C content (23.07 mg 100 g^{-1}) was determined in the control treatment (Table 5).

DISCUSSION

The microbial content and diversity of the plant root zone (rhizosphere) plays a pivotal role in the suppression of soil-borne plant pathogens, thereby enhancing the natural suppressive capacity of the soil. Indeed, the rhizosphere is home to a plethora of species with beneficial properties that influence plant growth. Consequently, the rhizosphere provides plant health and protection against harmful soil-borne plant pathogens [Mendes et al. 2011, 2013, Anzalone et al. 2022]. The use of fungal and bacterial microorganisms in the root zone for biocontrol purposes is emerging as a new approach to combating diseases. Various *Bacillus* and *Trichoderma* species with strong biocontrol potential are widely used to control many plant diseases in tomatoes [Mazrou et al. 2020, Stracquadanio et al., 2020, Castro-Restrepo et al. 2022, Narware et al. 2023, Abo-Elyousr et al. 2022, Imran et al. 2023].

In a study investigating the effects of root microbiome in soilless tomato cultivation in greenhouses, microorganisms (bacteria and fungi) taken from soil were applied to cocopeat media. It has been determined that fungi form a more effective growth and network in the root zone, while the amount and diversity of bacteria decrease over time. Nevertheless, a multitude of bacterial species have been identified as exerting a favourable influence on biological control and root development of the plant [Jacobsen et al. 2004, Anzalone et al. 2022]. In the present study, it was established that the application of bacteria led to an augmentation in root dry weight. In many studies carried out on soilless tomato cultivation, it has been determined that similar results were obtained in growth and yield values when the same growing periods were considered [Öztekin et al., 2017, Orta-Guzmán 2021, Cela et al. 2024, Erdal et al. 2024]. In a separate study, it was reported that bacterial applications yielded higher values than mineral fertilizers and fungal biological fertilizers [Dasgan et al. 2023]. The present study investigated the effects of two different microbial fertilizers on the cultivation of soilless lettuce (*Lactuca sativa* L.) and celery (*Apium graveolens* L.). The findings demonstrated that microbial fertilizer applications led to substantial enhancements in several key parameters, including aboveground fresh weight, belowground fresh weight, root length, leaf length, and leaf number, in both lettuce and celery. Furthermore, Wang et al. [2023] reported significant enhancements in root activity, net photosynthesis rate, stomatal conductance and total chlorophyll content in both lettuce and celery. The study demonstrated that bio-fertilizers promote leaf photosynthesis by enhancing root development and root nutrient uptake [Wang et al. 2023].

The present study set out to investigate the effects of bio-fertilizer application on tomato yield in hydroponic systems. The study established that the application of bio-fertilizer (0%, 25%, 50%, 75% and 100%) in conjunction with the control (100% inorganic fertilizer) led to an augmentation in the population of endophytic bacteria, *Azotobacter* sp., *Azospirillum* sp., phosphate solubilizing bacteria and nitrogen content. It was determined that different bio-fertilizer combinations did not change the phosphorus and potassium content compared to the control, but increased fruit quality. In particular, the combination of inorganic fertilizer and bio-fertilizer resulted in a significant increase in fruit weight compared to the control group [Setiawati et al. 2023]. Soilless systems represent a popular cultivation technique that aims to maximize plant productivity whilst minimizing resource use. Nevertheless, the absence of a soil matrix gives rise to challenges that necessitate precise management of nutrients, effective control of salinity stress and proactive strategies to specialize in disease management. The utilization of plant growth-promoting microorganisms has emerged as a promising solution to address these challenges. The utilization of microbial inoculation in soilless growing systems has been demonstrated to enhance nutrient management, disease control and the mitigation of salinity issues [Mourouzidou et al. 2023]. A study was conducted in which four distinct treat-

ments were investigated: 1) poultry manure, 2) poultry manure + effective microorganisms, 3) leaf compost, 4) leaf compost + effective microorganisms. These treatments were applied in soilless tomato cultivation using an organic substrate and effective microorganisms. It is stated that the application of microorganisms in combination with different animal manures has a significant effect on yield and quality [Sajid et al. 2023].

In a study comparing organic and chemical fertilizers in soilless tomato cultivation, organic and chemical fertilization were used to determine the values of SCC (organic: 5.9% and chemical: 5.9%), titratable acidity (organic: 1.5 mg/100 g and chemical: 1.3 mg/100 g) and vitamin C (organic: 15.3 mg/100 mL and chemical: 23.1 mg/100 mL) [Bozköylü and Daşgan 2010]. The study revealed significant variations in vitamin C levels in organic and chemical fertilizations, with comparable outcomes observed in our study. In a separate study, the effects of various organic and inorganic growing media on soilless tomato cultivation were investigated, and fruit flesh firmness was measured as 11.96–12.46 N, SCC 3.75–4.01%, titratable acidity 2.92–3.85%, and vitamin C 12–20 mg/100 g [Tzortzakis and Economakis 2008]. In a study investigating the effects of growing media as an alternative to coconut fiber in soilless tomato cultivation, the values of 5.2–5.9% titratable acidity and 0.41–0.52 mg/100 g vitamin C were determined [Kartal and Geboloğlu 2023]. In a separate study investigating the effects of different growing media (perlite and cocopeat) on tomato yield and fruit quality in soilless tomato cultivation, chroma (32–39), hue° (61–62), titratable acidity (5.1–6.9 mval/100 mL), SCC (4.5–5.58%) and vitamin C (21–22.6 mg/100 mL) values were determined [Kartal and Geboloğlu 2023]. In the study, cocopeat was found to yield superior results in terms of quality [Toprak and Gül 2013]. In the study in which effective microorganisms were used in soilless tomato cultivation, the values of SSC ranged between 3.90% and 4.56%, with the highest value being determined with microorganism application [Sajid et al. 2023]. In the present study, titratable acidity values, which have been demonstrated to exert significant influence on fruit quality, taste and aroma in soilless tomato cultivation with the use of different bio-fertilizers, yielded analogous results with the exception of titratable acidity values.

CONCLUSION

In our study, it was determined that the use of commercial bio-fertilizers of different origin (fungi and bacteria) significantly affected the yield and quality in soilless tomato cultivation. The highest yield (58.6 t da^{-1}) and fruit quality (SSC = 4.85%, acidity = 0.28 g citric acid 100 mL^{-1}) values were obtained from the *Streptomyces griseus* application. It is a bacterial bio-fertilizer-derived from *Streptomyces griseus*. The study concludes that microbial inoculation enhances yield and quality in soilless tomato cultivation. This is supported by the fact that another bacterial biological fertilizer, *Arthrobacter globiformis* significantly increased (20.3 g) root dry weight. Bacteria-based biological fertilizers have been demonstrated to promote plant growth, with a particular emphasis on root development. Furthermore, it is acknowledged that these fertilizers assist plants in combating diseases by counteracting pathogens. Consequently, the utilization of microorganisms as fertilizers will emerge as a pivotal alternative for transitioning to a sustainable and environmentally friendly production model in soilless tomato cultivation.

The incorporation of plant growth-promoting microorganisms into the growing medium has emerged as a promising solution to address the existing challenges in soilless vegetable cultivation. Future studies should therefore concentrate on increasing the diversity of microorganisms in growing media and on the use of microorganisms with high adaptation to saline conditions. In addition, it is known that the use of organic growing media helps microorganisms to live and multiply. Therefore, the use of different plant residues that could be alternatives to cocopeat substrate could be an important step towards zero waste.

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