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Effects of Compost, Fertilization, Rhizobacteria and Mycorrhiza Applications on Growth, Flowering and Bulb Quality of 'Jan van Nes' Tulip Varieties

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A B S T R A C T

Compost is usually made of biodegradable wastes. Today, compost, bio-agent bacteria and mycorrhizae are used as the key components of sustainable agriculture. This study was conducted to determine the effects of compost treatments alone and combined with bacteria, mycorrhiza and commercial fertilizers on growth, flower and bulb quality parameters of the 'Jan van Nes' tulip cultivar. Compost was made of grape pomace and set at different EC levels. Three different compost ratios (0%, 20% and 40%), three different EC levels (0.75, 1.10, and 1.45 dS/m) and combinations with or without bacteria and mycorrhizae were experimented. Flower stalk length, perianth length and vase life were identified as the most striking parameters for growth and flowering of tulip plants. The best outcomes in terms of flower stem length (34.20 cm), perianth length (44.85 mm) and vase life (7.00 days) were obtained from 0% compost treatments. Increasing compost ratios had adverse effects on plant growth and bacteria and mycorrhizae treatments alone did not provide any significant effects. However, combining with different compost ratios increased the effectiveness of bacteria and mycorrhiza. EC of 0.75 yielded better results than the other EC levels.

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Introduction

Tulip (*Tulipa gesneriana* L.) is a bulbous perennial plant with glamorous flowers. It is classified under *Tulipa* genus of Liliaceae family. Tulip is among the most important ornamental plants in the world (Kumar et al., 2013). Tulip cultivation is practiced primarily for quality flowers and bulbs. Bulb quality plays an essential role in growth and flowering of tulip (Carillo et al., 2022).

Agricultural and food processing operations generate large volumes of organic waste such as crop residues, animal manure and agricultural by-products. Worldwide solid waste generation is estimated to exceed 6 million tons per day by the year 2025 (Awasthi et al., 2018). This ratio will continue to increase as the demand for food increases. Most solid organic wastes are biodegradable but cannot be applied directly to the soil as uncontrolled degradation can damage the soil system (Hanc et al., 2019). Efficient treatment, use and recycling of these organic wastes reduce resource waste and prevent secondary pollution by reducing ammonia and greenhouse gas (GHG) emissions. Composting offers a reliable means of turning biodegradable organic wastes into fertilizer.

Biological conversion of agricultural and animal organic waste through composting process results in a product so called as 'compost' (Meng et al., 2019). Processing and reuse of agricultural and animal wastes are cost-effective and efficient practices (Wang et al., 2019; Liu et al., 2022). It is an efficient and environment-friendly method of managing and recycle of agricultural and animal waste. Compost is used as a growing medium and also used to enrich soil properties (Zhang et al., 2018; Ding et al., 2020). Farmers have used compost to meet their fertilizer needs. Sustainable and environment-friendly methods have been developed to protect plant health, increase quality and reduce production costs (Dash et al., 2018). In this sense, rhizobacteria and mycorrhiza improve the efficiency of compost.

Plant growth-promoting rhizobacteria (PGPR) are a group of microorganisms that directly or indirectly promote the growth of plants through colonizing in plant roots or free-living organisms of the roots (Abdel Motaleb et al., 2020). For instance, PGPR produce indole acetic acid, gibberellins and some unknown plant growth hormones and these substances increase root length, root surface area and number of root tips, leading to increased nutrient uptake and thus improved nutrient uptake under stress conditions. Inoculation with PGPR such as Bacillus and Pseudomonas can play a vital role in plants by increasing nutrient uptake and reducing adverse effects of abiotic stress factors through accumulating osmolytes (Osmo-protectors) such as soluble sugars, potassium, exopolysaccharide production (Abdelmoteleb et al., 2022). Arbuscular mycorrhizal fungi (AMF), living in between roots and soil, are a group of microorganisms that play a significant role in resource exchange between plants and soil (van der Heijden et al., 2015). They may form symbiotic relationships with the majority of crops (Smith and Read, 2008). AMF can mediate soil regeneration, nutrient cycling and microbial communities (Frey, 2019). Furthermore, mycorrhizal plants under drought stress accumulate less proline in their tissues than non-mycorrhizal plants, which indicates that mycorrhizal plants have increased drought resistance (Wu et al., 2017).

This study was conducted to investigate the effects of bacteria, mycorrhiza and fertilizers on plant growth, flowering and bulb quality parameters of tulip plants grown in media with different compost ratios.

Material and Method

Location and Plant Material

This study was carried out in a glass-covered greenhouse (40°19’55"N 36°28’33" E) of Tokat Gaziosmanpaşa University Agricultural Research and Implementation Center in 2021.

Tulip cultivar of ‘Jan Van Nes’ was preferred as the plant material of the study. Tulip seeds were supplied from a private company.

Preparation and Application of Compost

Grape pulp (8 tons) was supplied from Tokat Dimes Food Processing Factory to prepare compost material. Other materials required for the composting process are straw bales (12 pieces of 10 kg), barn manure (1 ton), lime (25 kg) and urea (5 kg). For the composting process, the sequential heap-composting method (windrow method) and aerobic conditions were preferred. This system has an advantage for accelerating the composting process through aeration of compost piles (Durmuş and Kızılkaya, 2018). The batch was aerated by mixing it regularly, once a week with a mixing machine. After 4.5 months, the composting process was completed when the compost and outdoor temperature equalized. Compost was incorporated into growing media at different ratios (0%, 20% and 40%, in volume). Composition of compost material is provided in Table 1.

Preparation and Application of Bacterial Solution

Bacillus cereus and *Pseudomonas putida* bacteria were preferred due to their nitrogen fixation properties (Kayaaslan, 2021). Bacteria found as stock cultures were grown on nutrient Agar medium and grown for 24 hours at 25±2 °C. Growing bacteria were removed from the medium with distilled water and suspensions were prepared. Prepared bacterial suspensions were diluted with sterile distilled water and adjusted to 0.3 absorbance (abs) value in a spectrophotometer (PG Instruments T60 UV-Vis Spectrophotometer) at 600 nm wavelength, with a final concentration of 10^8 cells/ml. The prepared bacterial suspensions were applied to the bulbs by dipping them into the suspensions in 30 L buckets for 30 minutes and then planting them into the growing medium (Bayram and Belgüzar, 2021). The bacterial suspensions were diluted with sterile distilled water and the final concentration was adjusted to 108 (CFU/ ml) in the spectrophotometer at 600 nm wavelength and the measurements were made.

Preparation and Application of Mycorrhiza

Endo Roots Soluble, ERS, a mixed culture mycorrhiza product sold in Türkiye, was used. The density of mycorrhiza inoculant was adjusted to be 5000 ppm in 30 L buckets and the bulbs were kept in this solution for 10 seconds and planted into the growing medium.

Preparation and Application of Commercial Fertilizers in Different Ratios

Crate culture, one of the soilless farming methods, is the preferred farming method in this study. A fertilizer with two different EC levels (EC 1.10 - EC 1.45 ds/m) was prepared with mixtures of Magnesium Nitrate, Calcium Nitrate, 20-10-20 + TE, EDDHA Chelated Iron and Micro Element (Multi-Comb). Tap water (EC 0.75) was preferred as a control. Fertilization was started when the tulip shoots reached a length of 5-7 cm and ended when the tulips reached harvest maturity.

Observations on the Tulip Plants

Bulb output rate (%), flower stem length (cm), flower stem thickness (mm), branch weight (g), plant height (cm), perianth width (mm), perianth length (mm), vase life (days), bulb weight (g), bulb diameter (mm) and number of young bulbs (piece/head of bulb) were observed and measured. Vase life was measured as the time (days) elapsed from the day the flowers were placed into the vase to the day when the leaves began to turn yellow, the petals to fade and fall and the flower stalk to twist (Karunaratne et al., 1997).

Study Design and Data Analysis

Soilless agriculture was preferred in crates measuring 20 cm (depth) × 40 cm (width) × 60 cm (length). Experiments were conducted in randomized blocks – factorial experimental design with 3 replications. Experimental findings were subjected to analysis of variance with IBM SPSS Statistics 26.0 software. Significant means were compared with the use of Duncan’s test.

Results

Effects of different compost ratios on investigated parameters are provided in Table 2. Significant ($P<0.05$) differences were seen in flower stalk length, plant height, perianth length, branch weight, bulb diameter, bulb weight and number of young bulbs. Better outcomes were seen in 0% compost treatments (Table 2).

Effects of mycorrhiza applications on some quality criteria of tulip plant were not found to be significant ($P>0.05$). However, better outcome for all parameters, except for perianth width and vase life, were obtained from mycorrhiza treatments.

Table 1. Composition of compost material

Parameters	Analysis Method	Quantity
Humidity (%)	A.O.A.C., 1995	48.77
Organic Matter (%)	AOAC 967.03-04-05	68.82
pH	1/10 Potentiometric	8.52
EC (ds/m)	1/10 Potentiometric	2.51
Nitrogen (N) (%)	TL 7.02-02 (Rev:4)	2.71
Potassium (K) (%)	Kacar and Kütük, 2009	3.26
Copper (Cu) (ppm)	GPGDY Ek-3 9.1/10.1	31.66
Phosphorus (P) (%)	Kacar and Kütük, 2009	0.58
Calcium (Ca) (%)	GPGDY Ek-3 9.1/10.1	3.54
Magnesium (Mg) (%)	GPGDY Ek-3 9.1/10.1	0.72
Iron (Fe) (%)	GPGDY Ek-3 9.1/10.1	0.71
Manganese (Mn) (ppm)	GPGDY Ek-3 9.1/10.1	204.45
Zinc (Zn) (ppm)	GPGDY Ek-3 9.1/10.1	76.65
Bacteria Count (cfu/g)	TS EN ISO 4833-2	4.75×10^6

Table 2. Effects of different compost ratios on quality parameters of tulip

Compost Ratio (%)	Bulb Emergence Rate (%)	Flower Stalk Length (cm)	Flower Stem Thickness (mm)	Plant Height (cm)	Perianth Width (mm)	Perianth Length (mm)
0	69.05	34.20^a	8.77	38.68^a	20.96	44.85^a
20	70.35	32.31^b	8.93	36.59^b	21.05	43.42^b
40	67.50	28.69^c	8.79	32.67^c	19.71	42.41^b
Significance coefficient	0.055^{ns}	0.000**	0.373^{ns}	0.000**	0.166^{ns}	0.000**

Compost Ratio (%)	Branch Weight (g)	Vase Life (Day)	Bulb Diameter (mm)	Bulb Weight (g)	Number of young bulbs (bulb/piece)
0	22.05^a	7.00	27.21^a	11.18^a	2.50^a
20	21.63^a	6.57	27.17^a	10.87^{ab}	2.27^a
40	19.41^b	6.20	26.56^b	10.50^b	1.98^b
Significance coefficient	0.001**	0.105^{ns}	0.042*	0.041*	0.000**

:** P<0.05, *:** P<0.01. **ns:** Not significant (P>0.05).

Table 3. Effects of different fertilizer EC levels on quality parameters of tulip

Fertilization (EC)	Bulb Emergence Rate (%)	Flower Stalk Length (cm)	Flower Stem Thickness (mm)	Plant Height (cm)	Perianth Width (mm)	Perianth Length (mm)
0.75	70.78^a	32.02	8.67^b	36.28	21.43	43.59
1.10	69.33^a	32.30	8.83^{ab}	36.46	20.03	43.59
1.45	66.80^b	31.45	9.00^a	35.81	20.37	43.71
Significance coefficient	0.003*	0.659^{ns}	0.035*	0.784^{ns}	0.159^{ns}	0.976^{ns}

Fertilization (EC)	Branch Weight (g)	Vase Life (Day)	Bulb Diameter (mm)	Bulb Weight (g)	Number of young bulbs (bulb/piece)
0.75	21.11	6.63	26.99	10.76	2.36
1.10	21.51	6.77	26.83	10.69	2.16
1.45	20.77	6.67	27.13	11.11	2.22
Significance coefficient	0.601^{ns}	0.922^{ns}	0.590^{ns}	0.261^{ns}	0.270^{ns}

:** P<0.05, *:** P<0.01, **ns:** Not significant (P>0.05).

Effects of fertilizers with different EC levels on development, flowering, and bulb quality parameters of tulip plant are provided in Table 3. Significant (P<0.05) differences were observed in bulb emergence rate and flower stem thickness parameters. The best results for bulb emergence rate and flower stem thickness were respectively obtained from EC 0.75 (70.78%) and EC 1.45 (9.00 mm) treatments.

Effects of different compost ratios and bacteria applications on some quality criteria of tulip plants are provided in Table 4. Compost ratio x bacteria interactions were found to be significant (P<0.05). The best results for bulb emergence rate, flower stalk length, plant height, branch weight, and number of young bulbs were obtained from 0% compost ratio without bacteria (0 × BU) treatments. The best perianth length and bulb weight parameters were obtained from 0% compost ratio with bacteria (0 × BA) treatments. The best results for bulb diameter were obtained from 20% compost ratio without bacteria (20 × BU) treatments.

Table 4. Effects of different compost ratios and bacterial applications on some quality characteristics

Compost ratio (%) × Bacteria	Bulb Emergence Rate (%)	Flower Stalk Length (cm)	Flower Stem Thickness (mm)	Plant Height (cm)	Perianth Width (mm)	Perianth Length (mm)
0 × BA	68.20^{ab}	33.81^{a}	8.77	38.39^{ab}	21.53	44.94^{a}
0 × BU	69.90^{a}	34.57^{a}	8.76	38.94^{a}	20.43	44.77^{ab}
20 × BA	70.00^{a}	32.31^{a}	8.90	36.61^{b}	21.88	43.11^{bc}
20 × BU	70.70^{a}	32.31^{a}	8.96	36.58^{b}	20.17	43.74^{ab}
40 × BA	69.30^{a}	28.05^{b}	8.77	31.98^{c}	19.73	42.03^{c}
40 × BU	65.70^{b}	29.37^{b}	8.80	33.40^{c}	19.68	42.81^{c}
Significance coefficient	0.038^{*}	0.000^{**}	0.837^{ns}	0.000^{**}	0.195^{ns}	0.004^{**}

Compost ratio (%) × Bacteria	Branch Weight (g)	Vase Life (Day)	Bulb Diameter (mm)	Bulb Weight (g)	Number of young bulbs (bulb/piece)
0 × BA	22.05^{a}	6.80	27.44^{ab}	11.61^{a}	2.43^{ab}
0 × BU	22.05^{a}	7.18	26.99^{abc}	10.75^{b}	2.56^{a}
20 × BA	21.78^{a}	6.80	26.75^{abc}	10.73^{b}	2.13^{bc}
20 × BU	21.46^{a}	6.36	27.59^{a}	11.02^{ab}	2.42^{ab}
40 × BA	18.58^{b}	6.00	26.67^{bc}	10.63^{b}	2.07^{c}
40 × BU	20.30^{ab}	6.29	26.45^{c}	10.38^{b}	1.89^{c}
Significance coefficient	0.003^{**}	0.279^{ns}	0.031*	0.025^{*}	0.000^{**}

BA: Bacteria available, BU: Bacteria unavailable. ***:** P<0.05, ****:** P<0.01, ns: Not significant (P>0.05)

Table 5. Effects of different compost ratios and mycorrhiza applications on tulip quality

Compost ratio (%) × Mycorrhiza	Bulb Emergence Rate (%)	Flower Stalk Length (cm)	Flower Stem Thickness (mm)	Plant Height (cm)	Perianth Width (mm)	Perianth Length (mm)
0 × MA	68.35^{ab}	34.28^{a}	8.76	38.93^{a}	20.88	45.19^{a}
0 × MU	69.75^{a}	34.13^{ab}	8.78	38.44^{a}	21.03	44.54^{ab}
20 × MA	69.80^{a}	32.76^{ab}	8.98	37.05^{ab}	20.83	43.92^{ab}
20 × MU	70.90^{a}	31.84^{b}	8.88	36.11^{b}	21.28	42.89^{b}
40 × MA	69.30^{a}	29.20^{c}	8.93	33.15^{c}	19.33	43.41^{b}
40 × MU	65.70^{b}	27.97^{c}	8.58	31.99^{c}	20.24	40.99^{c}
Significance coefficient	0.039^{*}	0.000^{**}	0.352^{ns}	0.000^{**}	0.500^{ns}	0.000^{**}

Compost ratio (%) × Mycorrhiza	Branch Weight (g)	Vase Life (Day)	Bulb Diameter (mm)	Bulb Weight (g)	Number of young bulbs (bulb/piece)
0 × MA	22.48^{a}	7.00	27.17^{ab}	11.21	2.48^{a}
0 × MU	21.64^{ab}	7.00	27.25^{ab}	11.15	2.51^{a}
20 × MA	22.01^{ab}	6.36	27.59^{a}	11.11	2.32^{ab}
20 × MU	21.21^{ab}	6.80	26.76^{ab}	10.64	2.23^{abc}
40 × MA	20.08^{bc}	5.83	26.42^{b}	10.33	1.94^{c}
40 × MU	18.47^{c}	6.75	26.70^{b}	10.68	2.02^{bc}
Significance coefficient	0.002^{**}	0.193^{ns}	0.050^{*}	0.114^{ns}	0.003^{**}

MA: Mycorrhiza available, MU: Mycorrhiza unavailable. ***:** P<0.05, ****:** P<0.01. ns: Not significant (P>0.05).

Table 6. Effects of different compost ratios and fertilizer EC levels on some quality characteristics

Compost ratio (%) × Fertilization (EC)	Bulb Emergence Rate (%)	Flower Stalk Length (cm)	Flower Stem Thickness (mm)	Plant Height (cm)	Perianth Width (mm)	Perianth Length (mm)
0 × 0.75	69.75^{abc}	34.46^{a}	8.71	39.16^{a}	22.33	44.73^{ab}
0 × 1.10	72.68^{a}	34.65^{a}	8.62	38.96^{a}	21.13	45.24^{a}
0 × 1.45	64.73^{d}	33.52^{a}	8.98	37.96^{a}	19.54	44.58^{ab}
20 × 0.75	72.30^{ab}	33.30^{ab}	8.85	37.66^{a}	21.88	44.42^{ab}
20 × 1.10	70.20^{abc}	32.90^{ab}	9.00	37.35^{a}	19.28	42.99^{abc}
20 × 1.45	68.55^{bcd}	30.59^{bc}	8.94	34.61^{b}	22.07	42.80^{bc}
40 × 0.75	70.28^{abc}	28.17^{c}	8.44	31.89^{c}	20.04	41.54^{c}
40 × 1.10	65.10^{d}	27.88^{c}	8.89	31.39^{c}	19.49	42.01^{c}
40 × 1.45	67.13^{cd}	29.91^{c}	9.09	34.54^{b}	19.51	43.68^{abc}
Significance coefficient	0.000^{**}	0.000^{**}	0.069^{ns}	0.000^{**}	0.064^{ns}	0.002^{**}

:** P<0.05, *:** P<0.01. **ns:** It was not found to be statistically significant (P>0.05).

Table 6. Effects of different compost ratios and fertilizer EC levels on some quality characteristics

Compost ratio (%) × Fertilization (EC)	Branch Weight (g)	Vase Life (Day)	Bulb Diameter (mm)	Bulb Weight (g)	Number of young bulbs (bulb/piece)
0 × 0.75	22.04[ab]	7.00	27.18	11.02	2.68[a]
0 × 1.10	22.14[ab]	6.86	27.09	10.89	2.41[ab]
0 × 1.45	21.97[ab]	7.20	27.37	11.64	2.40[ab]
20 × 0.75	22.67[a]	6.64	27.37	10.94	2.41[ab]
20 × 1.10	22.13[ab]	7.00	26.62	10.53	2.17[bc]
20 × 1.45	19.94[bc]	6.17	27.53	11.15	2.24[abc]
40 × 0.75	18.49[c]	5.75	26.41	10.32	2.00[bc]
40 × 1.10	19.65[bc]	6.00	26.78	10.66	1.91[c]
40 × 1.45	20.24[abc]	6.75	26.50	10.53	2.02[bc]
Significance coefficient	0.003**	0.398[ns]	0.204[ns]	0.163ns	0.006**

Table 7. Correlation coefficients among examined traits.

Variables	BER	FSL	FST	PH	PW	PL	BW	VL	BD	BW	NYB
BER		0.069	-0.161	0.063	0.056	0.015	-0.024	0.041	0.052	-0.100	0.006
FSL	0.069		0.138	0.985**	0.366**	0.722**	0.797**	0.183	0.104	0.071	0.217*
FST	-0.161	0.138		0.149	0.215*	0.398**	0.444**	-0.079	0.094	0.083	-0.084
PH	0.063	0.985**	0.149		0.388**	0.730**	0.801**	0.224*	0.108	0.083	0.225*
PW	0.056	0.366**	0.215*	0.388**		0.419**	0.440**	-0.152	0.147	0.117	0.002
PL	0.015	0.722**	0.398**	0.730**	0.419**		0.801**	0.083	0.085	0.037	0.109
BW	-0.024	0.797**	0.444**	0.801**	0.440**	0.801**		0.119	0.108	0.085	0.045
VL	0.041	0.183	-0.079	0.224*	-0.152	0.083	0.119		0.012	0.073	0.064
BD	0.052	0.104	0.094	0.108	0.147	0.085	0.108	0.012		0.784**	0.095
BW	-0.100	0.071	0.083	0.083	0.117	0.037	0.085	0.073	0.784**		-0.011
NYB	0.006	0.217*	-0.084	0.225*	0.002	0.109	0.045	0.064	0.095	-0.011	

*: P<0.05, **: P<0.01. BER: Bulb Emergence Rate (%), FSL: Flower Stalk Length (cm), FST: Flower Stem Thickness (mm), PH: Plant Height (cm), PW: Perianth Width (mm), PL: Perianth Length (mm), BW: Branch Weight (g), VL: Vase Life (Day), BD: Bulb Diameter (mm), BW: Bulb Weight (g), NYB: Number of young bulbs (bulb/piece).

Effects of different compost ratios and mycorrhiza applications on quality criteria of tulip plants are provided in Table 5.

Significant (P<0.05) differences were observed in bulb emergence rate, flower stalk length, plant height, perianth length, branch weight, bulb diameter and number of young bulbs. The best results for bulb emergence rate were obtained from 20% compost ratio with mycorrhiza (20 × MA) treatments. The best results for plant height, flower stalk length, perianth length and branch weight were obtained from 0% compost ratio with mycorrhiza (0 × MA) treatments. On the other hand, the best results for bulb diameter were obtained from 20% compost ratio with mycorrhiza (20 × MA) treatments.

Effects of different compost ratios and fertilizer EC levels on quality parameters of tulip plants are provided in Table 6. Significant (P<0.05) differences were seen in bulb emergence rate, flower stalk length, plant height, perianth length, branch weight and number of young bulbs. The best results for bulb emergence rate, flower stalk length and perianth length were obtained from 0% compost and EC 1.10 (0 × 1.10) treatments. The best outcomes for plant height and number of young bulbs were obtained from 0% compost and EC 0.75 (0 × 0.75) treatments. The best result for branch weight were obtained from 20% compost and EC 0.75 (20 × 0.75) treatments (Table 6).

Correlation matrix for the effects of different compost ratios, bacteria, mycorrhiza applications and different fertilizer EC levels on quality parameters of tulips is provided in Table 7. The highest correlation was found between PD and FSL (r=0.985, P<0.01), while the lowest correlation was found between FST and BER (r=-0.161, P>0.05).

Discussion

In ornamental plant industry, use of organic media rich in various substances is encouraged to improve flower growth and reduce the material load of the substrate input (Wani et al., 2018; Altaf et al., 2021). In this study, growing media with different compost ratios, bacteria and mycorrhiza applications and different fertilizer EC levels were prepared and effects of different growing media compositions on quality parameters of tulips were examined. With increasing compost ratios, decreases were encountered in quality parameters. Similarly, Riberio et al. (2000) indicated that environments with low compost content (10-20%) had higher plant growth parameters of geranium plants. Fitzpatrick (1998)) also reported linear decrease or increase in quality traits of tulips with increasing or decreasing compost ratios. Such a case could be attributed to high salinity, high pH level, heavy metal toxicity or phytotoxicity of the compost (Klock-Moore, 2000). Present compost samples had a high pH level (Table 1). With increasing compost ratios, greater and negative effects of pH on plant growth were encountered. Altaf et al. (2021) indicated that increasing substrate ratios could improve biophysical and chemical properties of the soils, thus increase water and nutrient uptake and oxygen transport rates, all ultimately improving plant growth and development. It was also determined that excessive compost ratios added a weight onto the growing medium and inhibited emergence power of the plants. Plants with weakened emergence power develop more slowly.

Bacteria and mycorrhiza applications alone could not significantly affect the quality parameters. It was mostly because of temperature and humidity conditions of the growing environment. Present experiments were conducted at 12-15°C temperatures and 60% relative humidity. These temperature and humidity values are estimated to limit the growth of bacteria and mycorrhizae. It was reported that ongoing conditions that prevent the active growth of microbial population in compost may have an antagonistic effect. In such cases, pathogens may be effective against these microorganisms (Finstein et al., 1980). Surface interaction of compost microorganisms may also inhibit the development of microbial enzymes or high pH values (8.52) may have adversely affected the microbial-mediated transformation of nutrients. Similar findings were also reported by Xiang et al. (2017) and Altaf et al. (2021). On the other hand, bacteria and mycorrhiza applications were more effective when they were combined with different compost ratios and EC levels. It was mostly because of sufficient nutrients, ambient temperature and rich microorganism diversity of compost-containing environments (Coventry et al., 2002). Necessary environmental conditions for bacteria and mycorrhizae were probably met in this study. Plant response varies with type and ratio of compost used in growing media (Moore, 2005).

When different compost ratios and different EC levels are compared, it was seen that better results were obtained from the growing media with low compost ratios. Table 6 shows that compost ratios suppressed the effect of fertilization through bilateral interaction. Still, it had a negative effect as this ratio increases. In hydroponic culture of ornamental plants, fertilization and chemical properties of aquatic media play an important role; however, excessive N, P or K nutrients can affect the quality of plant materials (Tseng et al., 2022). In this study, increasing organic matter-ratios and fertilizer EC levels limited plant growth and development. Similar results were also reported by Cai et al. (2014). In addition, when compost was used together with fertilizers, it caused an increase in EC values and salt content of the environments (Citak and Sönmez, 2011). On the other hand, decreasing EC values, as it was in the control group, improved plant growth and development by promoting nutrient absorption of plants. It was reported that EC was a handy parameter to control the salinity level of compost and was also responsible for phytotoxic effects (Sharma and Yadav, 2017). Compost high salinity levels can damage the roots, affect nutrient uptake, limit the water that the plant can use, or inhibit bulb emergence (Lim et al., 2016; Sharma and Yadav, 2017). The high EC (2.51) and pH (8.52) values given in Table 1 may also prove these negative effects. In this study, plants grown in 0% compost exhibited better growth than those in the other applications. Effects of growing media on flowering process and plant growth are highly dependent on species, compost composition and percentage (Wolna-Maruwka et al., 2017; Zawadzińska et al., 2021; Schroeter-Zakrzewska et al., 2021).

Phenol and flavonoids are thought to be the other parameters that may be effective in plant growth and development of tulips. Phenols and flavonoids are important secondary metabolites in plants and are associated with plant resistance to environmental stress (Wills et al., 2000). It was reported in studies that fertilization at proper doses increases the total phenolic and total flavonoid content of plants (Redovniković et al., 2012; Amarowicz et al., 2020), but excessive fertilization may cause a decrease in key enzyme activity of N uptake, which may result in a decrease in the essential enzyme activity of N uptake. However, phytochemical analyses were not conducted in this study and it is thought that the retarding effects in the plants were probably due to the high phenolic contents, as well as the differences in agricultural practices and environmental conditions.

Conclusion

Present findings revealed that increasing compost ratios restricted plant growth and development and had adverse effects. Increasing compost ratios also suppressed quality criteria. Within the scope of the study, while the use of bacteria and mycorrhizae alone did not significantly affect quality parameters, combining them with different compost ratios increased the effectiveness of bacteria and mycorrhizae. In terms of different fertilizer EC levels, EC 0.75 yielded better outcomes than the other levels. The best results for flower stem length (34.20 cm), perianth length (44.85 mm) and vase life (7.00 days) were obtained from 0% compost ratio. The newly-produced compost may not positively affect the tulip plant, but further research is recommended with different compost ratios and combinations.

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