Determination of effects of bacteria, mineral fertiliser and their combination on the plant growth of tulip (*Tulipa gesneriana* L.)

Melek Ekinci* and Atilla Dursun

Department of Horticulture,
Agriculture Faculty,
Atatürk University,
25240, Erzurum, Turkey
Email: ekincim@atauni.edu.tr
Email: atilladursun@atauni.edu.tr
*Corresponding author

Recep Kotan

Department of Plant Protection,
Agriculture Faculty,
Atatürk University,
25240, Erzurum, Turkey
Email: rkotan@atauni.edu.tr

Fazilet Parlakova Karagöz and Raziye Kul

Department of Horticulture,
Agriculture Faculty,
Atatürk University,
25240, Erzurum, Turkey
Email: f.parlakova@atauni.edu.tr
Email: raziye.kul@atauni.edu.tr

Soner Kazaz

Department of Horticulture,
Agriculture Faculty,
Ankara University,
06110, Ankara, Turkey
Email: skazaz@ankara.edu.tr

Adem Güneş

Department of Soil Science and Plant Nutrition,
Seyrani Agriculture Faculty,
Erciyes University,
Kayseri, Turkey
Email: ademgunes@erciyes.edu.tr

Abstract: Using biofertiliser in agricultural production has increased lately, in this context; we investigated the effects of four bacteria isolates (*Paenibacilluspolymyxa*-BI, *Pseudomonas putida*-BII, *Bacillus subtilis*-BIII and *Kluyveracryocrescens*-BIV) and 50% mineral fertilizer reduction with bacteria on plant growth of seven tulip cultivars. In the results, the effects of applications and cultivars were generally significant. With 1/2MF+BIII combination was ensured of shorter sprouting time. The bulb sprouting ratio was observed 97.33% (Jan Reus) and 99.78% (Parade) in varying proportions among the cultivars. The vegetation period had been longest with 1/2MF+BIII and American Dream cultivar. Treated applications showed the highest length and thickness of peduncle increased by 7.82% and 7.86% compared to control. The applications increased the plant height by 7.88% (BI) and the stem diameter by 6.06% (BIII) ratio. Dry matter in perianth increased by 6.30% with 1/2MF+BIV. As a result, the bacterial applications could be advised as fertiliser on plant growth of tulip.

Keywords: tulip; PGPB; plant growth; fertiliser.

Reference to this paper should be made as follows: Ekinci, M., Dursun, A., Kotan, R., Karagöz, F.P., Kul, R., Kazaz, S. and Güneş, A. (2017) ‘Determination of effects of bacteria, mineral fertiliser and their combination on the plant growth of tulip (*Tulipa gesneriana* L.)’, *Int. J. Sustainable Agricultural Management and Informatics*, Vol. 3, No. 3, pp.233–253.

Biographical notes: Melek Ekinci received her PhD from the Horticulture Department, Atatürk University. She still works at the same department as an Associate Professor.

Atilla Dursun received his PhD from the Horticulture Department, Atatürk University. He still works at the same department as a Professor Doctor.

Recep Kotan received his PhD from the Plant Protection Department, Atatürk University. He still works at the same department as a Professor Doctor.

Fazilet Parlakova Karagöz received her MSc from the Horticulture Department, Atatürk University. She still works at the same department as an Assistant Researcher.

Raziye Kul received her MSc from the Horticulture Department, Atatürk University. She still works at the same department as an Assistant Researcher.

Soner Kazaz received his PhD from the Horticulture Department, Adnan Menderes University. He works at Ankara University, Agriculture Faculty, Department of Horticulture as an Associate Professor.

Adem Güneş received his PhD from the Soil Science and Plant Nutrition Department, Atatürk University. He works at Erciyes University, Agriculture Faculty, Department of Soil Science and Plant Nutrition, (Kayseri, Turkey) as an Associate Professor.

This paper is a revised and expanded version of a paper entitled ‘Determination of effects of bacteria, mineral fertilizer and their combination on the plant growth of tulip (Tulipa gesneriana L.)’ presented at 2nd International Balkan Agriculture Congress (Agri Balkan 2017), Tekirdağ, Turkey, 16–18 May.

1 Introduction

Bulbous plants are increasing in their use as a cut flower, flowering potted plants and garden flowers using decorative, attractive look and sense of vitality day by day. These increased interests have increased in the trade of bulbous ornamental plants. More than 800 bulbous ornamental plants are being traded in the world. *Tulipa*, *Narcissus*, *Gladiolus*, *Iris*, *Lilium*, *Crocus* and *Hyacibus* are among the most popular species and cultivated of bulbous ornamental plants in the ornamental plants sector. Their shares of total bulbous ornamental plants are 90% (Alp et al., 2010; Benschop et al., 2010).

The tulip is a monocotyledonous plant in the *Liliaceae* family. It is stated that the major centre of origin for tulip is situated in Central Asia and its diversification take place from the region of Tien-Shan and Pamir–Altai to the north and northeast (Siberia, Mongolia and China), Turkey, the Caucasus, south to Cashmere and India, west to Afghanistan and Iran. Hundreds of tulip cultivars with a wide variation in flower colours and shapes have been reported from the throughout the world (Le Nard and De Hertogh, 1993; Juodkaitë et al., 2005; Asghari, 2014). Because of the availability of large number of cultivars, tulips can be easily planted in almost all climate zones of the world (Ohyama et al., 2006; Asghari, 2014). Tulip belongs to bulbous plants group and has a hard-brown shell covered with armband-shaped onions. They are spring-blooming perennials that grown from bulbs, so it needs a cold period to ensure flowering and development of sufficient stem length (Asghari, 2014). The annual replacement cycle of the tulip bulb is about an eight-month period that begins with planting of the bulb in the autumn and completes after flower senescence (Niedziela et al., 2015). Tulips can adaptate to place with mild springs and autumns, and want summers to be dry and warm (Sytsma and Rose, 2015).

The tulip is affected by internal factors (especially bulb formation) and environmental factors, cultural process such as fertilisation important one. Fertilising with phosphorus, potassium and other minerals is important for the healthy development of plant organs of tulip such as leaves, flowers, bulbs, etc (Niedziela et al., 2015). Since the development of tulip plants is as short as a few months, fertilisation is important in order to complete the development in the best way, growing bulbs and increasing in the number of bulbs. It is stated that 140–150 kg of nitrogen, 40–50 kg of phosphorus, 140–150 kg of potassium and 110–120 kg of calcium should be given in hectare for fertilisation of tulip. Fertilisers should be given as liquids to prevent root damage and granular fertilisers should be mixed with soil especially during the spring development period (Bakker, 1991; Niedziela et al., 2015). It is not the case that biological fertilisers by mixed into the soil are damage the roots in tulip cultivation.

Chemical inputs used in agriculture have caused environmental problems. For this reason, there has recently been increased in friendly interest in the environment, sustainable and organic agricultural practices in the world. One of them is plant growth promoting bacteria (PGPB) application in agricultural production. These bacteria are used as bio fertilisers including different genera such as *Azotobacterium*, *Azospirillum*, *Azotobacter*, *Arthrobacter*, *Alcaligenes*, *Bacillus*, *Burkholderia*, *Clostridium*, *Enterobacter*, *Flavobacterium*, *Pseudomonas*, *Serratia*, etc. (Adesemoye et al., 2008; Cakmakci, 2009; Nezarat and Gholami, 2009). PGPB are widely applied to agricultural crops to improve plant growth, enhance nutrient uptake by plants and reduce chemical inputs (such as fertiliser and pesticide) causing environmental degradation (Yildirim et al., 2008; Günes et al., 2009; Yildirim et al., 2011a; Adesemoye et al., 2010).

PGPB can indirectly facilitate plant growth by reducing plant pathogens, or directly by facilitating the uptake of nutrients from the environment, by influencing phytohormone production (e.g. auxin, cytokinin, or gibberellin), and/or by enzymatic lowering of plant ethylene levels (Azcon and Barea, 1976).

PGPB practices have been studied by different researchers and it was reported that inoculation of PGPB has significant enhance in yield and growth of crops (Garcia et al., 2003; Kokalis-Burelle et al., 2003; Dursun et al., 2008, 2010; Yildirim et al., 2008, 2011b; Ekinci et al., 2009; Misra et al., 2010; Ibiene et al., 2012), but PGPB application in the ornamental plants has generally not been studied yet. Tulip is one of the most grown plants in the world among the ornamental plants. For this reason, the effects of PGPB applications have been investigated on plant development of different tulips cultivars in this study. The effects of PGPBs on reducing the use of chemical fertilisers were also determined.

2 Materials and methods

2.1 Bacterial strain and bulb inoculation

Paenibacillus polymyxa (BI), *Pseudomonas putida* (BII), *Bacillus subtilis* (BIII) and *Kluyvera cryocrescens* (BIV) bacteria isolates were obtained from the Culture Collection Unit of the Department of Plant Production, Faculty of Agriculture, Ataturk University. These microorganisms were identificated by classic and molecular systems such as MIS and BIOLOG analysis. The isolate was tested for N2-fixing ability (Dobereiner et al., 1988) and phosphate solubilisation capacity and hormone (IAA, GA). The ability of bacterial isolates to grow on Dobereiner nitrogen-free culture medium was indicated by their N2-fixation ability. The phosphate solubilising capacity of isolates was tested qualitative in NBRI-BPB liquid medium according to Mehta and Nautiyal (2001). The bacterial colonies were selected, purified and inoculated to 5 mL NBRI-BPB medium (50 μL inoculum with approximately 1 to 2 × 10^9 cfu.mL^{-1}). Autoclaved, non-inoculated media was served as the control (Yildirim et al., 2008).

The bulbs of tulip were firstly disinfected ((3 min in a 3% sodium hypochlorite for sterilising and washing four times with distilled water (sd. H_2O)) to avoid the presence of any saprophytic and/or pathogenic microorganisms on the surface and after than bulbs were air-dried.

Bacteria were grown in 50 mL flasks containing 20 mL of Triptic Soy Broth (TSB) medium on a rotary shaker at 27°C for 24h. Absorbance of the bacterial suspensions was measured spectrophotometrically at 600 nm and appropriately diluted to 1 × 10^8 cfu.mL^{-1} in sd. H_2O. The bacterial suspension diluted 100 fold with chlorine-free well water and added sugar in a ratio of 1/40 (kg L^{-1}) as a glued and mixed thoroughly, allowed to stand one night. The bulbs were incubated in the basin during 4 h at 28ºC to coat the bulbs with the bacteria. After incubating, the bulbs were taken out and air-dried.

2.2 Experimental site, setup and treatments

The study trials were performed in the research garden of Horticulture Department of Atatürk University, Erzurum, Turkey ((29 to 55° N latitude and 41 to 16° E longitude, 1,850 m (6.070 ft) above sea levels). Average temperature was 7.4°C while total rainfall was 42.2 mm in the experimental area in 2015.

The experiment was initiated in late October 2014. The soil's physical and chemical properties are given in Table 1. To prepare the proper seed beds, the main plot was tilled twice with a tractor and divided subsequently into sub plots according to the treatments plan with a net plot size of 1.5 × 1.5 m. 15 bulb was used for each application parcel. Inoculated and non inoculated bulbs were planted to the field area in rows with the planting distance as 10 cm and intra row spacing of 10 cm and deep of 10–12 cm.

Table 1 The properties of soil in the experimental area

Parameters	*Values*	*Parameters*	*Values*
pH (1:2, 5)	6.9	Cu (ppm)	0.94
Organic matter (%)	2.48	Fe (ppm)	0.602
Lime (%)	1.04	Mn (ppm)	5.91
N (%)	0.002	Cd (ppm)	0.008
P (ppm)	23.62	Cr (ppm)	0.005
K (ppm)	996.45	Ni (ppm)	0.653
Ca (ppm)	2794	Pb (ppm)	0.064
Mg (ppm)	518.3	Hg (ppm)	Trace
Texture		Sandy – loamy	

The experimental design was randomised completed block designs with three replications. There were two factors. The first factor ((PGPB treatments and mineral fertilisation (MF) had four bacteria (*Paenibacillus polymyxa* (BI), *Pseudomonas putida* (BII), *Bacillus subtilis* (BIII) and *Kluyvera cryocrescens* (BIV)) and 50% reduction MF suggested with bacterial isolates (for each bacteria and 100% MF), and the second one had seven cultivars (Cassini-C, Banja Luca-BL, Golden Apeldoorn-GA, Ollioules-O, American Dream-AD, Parade-P and Jan Reus-JR). Also, there was control group for each cultivar that did not include bacteria or mineral fertilisers (Table 2). Mineral fertiliser was applied as ammonium nitrate (140 kg ha^{-1} N), triple super phosphate (40 kg ha^{-1} P_2O_5) and potassium sulphate (140 ha^{-1} K_2O) in 0 to 30 cm soil layer at planting.

Table 2 The explanations of applications in this study

Application	*Explanation*
Control	No bacteria and mineral fertiliser
BI	*Paenibacillus polymyxa*
BII	*Pseudomonas putida*
BIII	*Bacillus subtilis*
BIV	*Kluyvera cryocrescens*
MF	%100 mineral fertiliser
1/2MF + BI	%50 reduced mineral fertiliser with *Paenibacillus polymyxa*
1/2MF + BII	%50 reduced mineral fertiliser with *Pseudomonas putida*
1/2MF + BIII	%50 reduced mineral fertiliser with *Bacillus subtilis*
1/2MF + BIV	%50 reduced mineral fertiliser with *Kluyvera cryocrescens*

2.3 Plant growth parameters

Tulip bulbs were harvested in late June 2015 after the plants yellowing and drying. Before harvest, parameters such as bulb sprouting time and ratio (sprouting in spring), peduncle length, peduncle thickness, leaf number, plant height, stem diameter, tillering number, perianth fresh and dry weight, perinath dry matter (DM), perianth diameter and length plant height were measured on the plants during the vegetation period (plants is fresh, the perianths were occurred yet and before the flowers were fully opened). The plant materials were weighed for dry matter ratio and then dried in an oven at 70°C until a constant mass was reached.

2.4 Statistical analysis

SPSS program was used to evaluate the data (SPSS, 2010). Arcsin transformation was done for bulb sprouting ratio before statistical analysis. Data were subjected to analysis of variance (ANOVA) to compare the effects of applications and cultivars. The differences among the means were compared using the Duncan multiple tests ($P < 0.05$).

3 Results

In the results of this study, the effects of bacteria and mineral fertiliser on plant growth and development of tulip were given in Tables 3, 4, 5, 6 and 7.

According to results, the highest bulb sprouting time was occurred in the control (157.42 day) and BIV (157.51 day) application. Interaction between cultivar and application was statistically significant ($P < 0,001$). Effects of application on bulb sprouting time were significant except for O, BL, P and GA cultivars. In terms of the bulb sprouting time, the application of BIII on C (155.64 day) and application of 1/2MF+BIII on JR (155.61 day) and AD (152.84 day) cultivars (Table 3) gave the best result. The effects of applications on bulb sprouting ratio were not significant, but it was determined that significant differences were determined among the cultivars. The interaction between cultivars and applications were not significant ($P > 0.05$). P cultivar of bulb sprouting ratio was significantly higher (99.78%) than the other cultivars (Table 3). It was determined that there were significant differences among applications and cultivars in the vegetation period. In terms of vegetation period, the effects of application were significant in cultivars except for BL, P and GA cultivars. In addition, interaction between cultivar and application was statistically significant ($P < 0.001$). According to average, the longest vegetation period was determined in 1/2MF+BIII (92.89 day) application and AD (94.17 day) cultivar. It was determined that the longest vegetation period was obtained from 1/2MF+BIV application in C (92.24 day) cultivar, BI application in O (93.87 day) cultivar, BIII application in JR (92.11 day) cultivar and 1/2MF+BIII application in AD (96.16 day) cultivar (Table 3).

Table 3 The effects of bacteria and mineral fertiliser on bulb sprouting time, bulb sprouting ratio and vegetation period of tulip

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
Application				*Bulb sprouting time (day)*				
BI	158.06 bc**	155.13 ^{ns}	157.08 cde***	158.24 ^{ns}	155.38 b***	156.34 ^{ns}	155.67 ^{ns}	156.56B***
BII	157.60 bcd	156.86	157.47 bcd	155.89	153.91 cde	156.47	157.26	156.49 B
BIII	155.64 d	155.44	156.55 de	157.16	153.31 de	155.58	156.18	155.69 C
BIV	157.51 bcd	157.33	158.54 abc	157.24	156.91 a	156.42	157.94	157.41 A
MF	159.14 ab	154.53	159.07 ab	156.75	155.51 b	156.91	155.65	156.79 AB
1/2MF+BI	157.53 bcd	156.99	156.92 cde	157.61	154.36 bcd	155.91	155.71	156.43 B
1/2MF+BII	158.20 bc	157.40	157.45 bcd	159.13	154.73 bc	155.47	157.32	157.10 AB
1/2MF+BIII	156.46 cd	157.40	155.61 e	156.87	152.84 e	154.02	155.91	155.59 C
1/2MF+BIV	156.76 cd	157.09	157.88 a-d	157.89	155.48 b	157.42	155.48	156.86 AB
CONTROL	160.23 a	156.53	159.24 a	158.58	155.35 b	155.42	156.62	157.42 A
CUL. MEAN	157.71 A***	156.47 B	157.58 A	157.53 A	154.78 C	156.00B	156.37 B	
				Bulb sprouting ratio (%)				
BI	95.56 ^{ns}	100.00 ^{ns}	97.78 ^{ns}	93.33 ^{ns}	100.00 ^{ns}	97.78 ^{ns}	100.00 ^{ns}	97.78 ^{NS}
BII	100.00	100.00	97.78	97.78	100.00	100.00	97.78	99.05
BIII	100.00	100.00	95.56	97.78	100.00	100.00	97.78	98.73
BIV	100.00	100.00	97.78	100.00	100.00	100.00	95.56	99.05
MF	97.78	100.00	93.33	100.00	100.00	100.00	95.56	98.10
1/2MF+BI	100.00	97.78	97.78	97.78	100.00	100.00	95.56	98.41
1/2MF+BII	100.00	100.00	100.00	97.78	100.00	100.00	97.78	99.37
1/2MF+BIII	100.00	97.78	97.78	100.00	100.00	100.00	97.78	99.05
1/2MF+BIV	97.78	100.00	95.56	100.00	97.78	100.00	97.78	98.41
CONTROL	95.56	100.00	100.00	100.00	97.78	100.00	97.78	98.73
CUL. MEAN	98.67 AB***	99.56 A	97.33 C	98.44 AB	99.56 A	99.78 A	97.33 C	

Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $^{ns}P > 0.05$, differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 3 The effects of bacteria and mineral fertiliser on bulb sprouting time, bulb sprouting ratio and vegetation period of tulip (continued)

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
					Vegetation period (day)			
BI	90.03 bc**	93.87 a**	91.58 ab*	90.76 ^{ns}	93.62 d***	91.99 ^{ns}	91.33 ^{ns}	91.88 BC***
BII	88.40 c	92.13 abc	90.53 abc	90.66	95.09 abc	92.53	91.08	91.49 CD
BIII	91.22 ab	93.55 a	92.11 a	91.84	95.69 ab	92.42	92.82	92.81 A
BIV	91.42 ab	90.33 c	89.79 bc	91.76	91.42 e	91.91	91.06	91.10 D
MF	89.86 bc	93.13 ab	89.93 bc	92.25	93.49 d	90.76	92.35	91.68 BCD
1/2MF+BI	90.87 ab	92.25 abc	90.74 ab	90.39	94.64 bcd	92.42	92.29	91.94 BC
1/2MF+BII	89.80 bc	91.27 bc	90.22 abc	89.87	94.27 cd	92.20	91.68	91.33 CD
1/2MF+BIII	91.53 ab	90.93 c	91.38 ab	92.13	96.16 a	94.98	93.09	92.89 A
1/2MF+BIV	92.24 a	91.24 bc	88.66 c	91.11	93.52 d	91.58	91.40	91.39 CD
CONTROL	90.44 ab	93.60 a	89.76 bc	91.76	93.83 cd	93.91	92.38	92.24 AB
CUL. MEAN	90.58D***	92.23 B	90.47 D	91.25 B	94.17 A	92.47B	91.95 B	

Notes: *P < 0.05; **P < 0.01; ***P < 0.001; ^{ns}P > 0.05, differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 4 The effects of bacteria and mineral fertiliser on peduncle length, peduncle thickness and leaf number of tulip

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
Application				*Peduncle length (cm)*				
BI	14.52 b-e ***	17.61 ^{ns}	18.32 a*	17.42 e**	20.11 a*	20.42 ^{ns}	20.00 ^{ns}	18.34 ABC*
BII	15.45 a-d	18.77	17.35 ab	17.69 de	20.59 a	21.71	18.83	18.63 AB
BIII	16.85 abc	19.16	15.54 b	19.35 a-d	17.53 b	21.27	20.08	18.54 AB
BIV	16.94 ab	18.42	17.31 ab	20.68 a	17.49 b	21.75	18.73	18.76 A
MF	14.31 de	16.64	16.34 ab	17.92 cde	19.05 ab	20.53	19.19	17.71 BC
1/2MF+BI	12.83 e	19.06	18.16 a	19.44 abc	19.30 ab	21.54	19.65	18.57 AB
1/2MF+BII	14.45 cde	19.42	17.50 ab	18.06 b-e	17.09 b	21.11	19.44	18.15 ABC
1/2MF+BIII	16.49 a-d	17.83	16.41 ab	19.70 ab	17.28 b	20.18	17.75	17.95 ABC
1/2MF+BIV	17.54 a	17.53	16.45 ab	18.36 b-e	17.42 b	21.14	19.26	18.24 ABC
CONTROL	12.13 e	18.75	15.32 b	18.11 b-e	17.69 b	21.02	18.79	17.40 C
CUL. MEAN	15.15 E***	18.32 C	16.87 D	18.67 BC	18.35 C	21.07 A	19.17 B	
				Peduncle thickness (mm)				
BI	5.04 abc***	6.31 bcd**	6.10 ^{ns}	5.98 ^{ns}	7.04 a*	6.07 ^{ns}	5.72 c**	6.04 A***
BII	5.34 a	6.55 abc	5.77	5.76	6.94 a-d	6.07	5.67 c	6.01 AB
BIII	4.84 bc	6.78 ab	5.69	5.96	6.59 d	5.73	5.97 a	5.94 AB
BIV	5.22 ab	6.39 a-d	5.78	6.02	6.89 a-d	5.80	5.78 bc	5.98 AB
MF	4.71 cd	6.14 cd	5.47	5.92	7.07 a	5.82	5.92 ab	5.86 AB
1/2MF+BI	5.22 ab	6.82 ab	5.58	5.91	6.95 abc	5.69	5.60 c	5.97 AB
1/2MF+BII	5.11 abc	6.86 a	5.95	5.79	6.76 a-d	5.89	5.63 c	6.00 AB
1/2MF+BIII	4.87 bc	6.44 abc	5.95	5.85	6.67 bcd	5.55	5.67 c	5.86 B
1/2MF+BIV	5.21 ab	6.36 a-d	5.55	6.06	6.99 ab	6.13	5.73 c	6.00 AB
CONTROL	4.43 d	5.91 d	5.29	5.85	6.61 cd	5.46	5.68 c	5.60 C
CUL. MEAN	5.00 E***	6.46 B	5.71 D	5.91 C	6.85 A	5.82 CD	5.74 D	

Notes: *P < 0.05; **P < 0.01; ***P < 0.001; ^{ns}P > 0.05. Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 4 The effects of bacteria and mineral fertiliser on peduncle length, peduncle thickness and leaf number of tulip (continued)

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
				Leaf number				
BI	3.34 ^{ns}	3.09 ^{ns}	3.57 ^{ns}	3.07 ^{ns}	3.07 ^{ns}	3.51 ^{ns}	3.23 b-e***	3.27 ABC**
BII	3.32	3.05	3.64	3.02	3.05	3.58	3.51 a	3.31 A
BIII	3.18	3.04	3.46	3.10	3.04	3.52	3.09 de	3.21 C
BIV	3.17	3.07	3.74	3.02	3.03	3.52	3.12 de	3.24 ABC
MF	3.21	3.10	3.77	3.09	3.02	3.57	3.27 bcd	3.29 AB
1/2MF+BI	3.34	3.10	3.71	3.04	3.08	3.33	3.20 cde	3.26 ABC
1/2MF+BII	3.38	3.00	3.78	3.07	3.02	3.57	3.35 abc	3.31 A
1/2MF+BIII	3.24	3.09	3.67	3.00	3.04	3.46	3.39 ab	3.27 ABC
1/2MF+BIV	3.24	3.10	3.66	3.07	3.05	3.37	3.10 de	3.23 BC
CONTROL	3.21	3.02	3.49	3.07	3.04	3.53	3.05 e	3.20 C
CUL. MEAN	3.26 C***	3.07 D	3.65 A	3.06 D	304 D	3.50 B	3.23 C	

Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $^{ns}P > 0.05$. Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 5 The effects of bacteria and mineral fertiliser on plant height, stem diameter and tillering number of tulip

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
Application				*Plant height (cm)*				
BI	20.13 a*	27.27 ab*	23.49 ^{ns}	22.89 ^{ns}	28.63 a***	22.37 ^{ns}	23.05 ^{ns}	23.97 A***
BII	20.80 a	25.58 bcd	22.68	21.87	26.69 bc	22.98	22.19	23.25 AB
BIII	20.20 a	26.65 abc	21.51	23.06	23.26 d	23.49	24.98	23.31 AB
BIV	20.27 a	25.71 a-d	22.87	23.40	25.34 c	24.55	22.97	23.59 AB
MF	18.96 a	25.22 cd	21.51	23.56	27.35 ab	23.67	23.03	23.33 AB
1/2MF+BI	19.97 a	27.64 a	23.70	23.34	26.28 bc	23.67	22.75	23.91 AB
1/2MF+BII	19.85 a	26.18 a-d	23.18	22.76	25.39 c	23.85	22.55	23.39 AB
1/2MF+BIII	20.22 a	25.80 a-d	22.38	24.25	23.27 d	23.34	23.49	23.25 AB
1/2MF+BIV	19.87 a	25.22 cd	21.14	23.55	25.52 bc	24.87	21.92	23.16 B
CONTROL	16.28 b	24.56 d	21.28	22.73	25.30 c	22.27	23.10	22.22 C
CUL. MEAN	19.65 D***	25.98 A	22.37 C	23.14 B	25.70 A	23.51 B	23.00 B	
				Stem diameter (mm)				
BI	8.48 ^{ns}	10.22 bc**	10.48 ^{ns}	11.01 ^{ns}	11.68 ^{ns}	9.87 ^{ns}	10.21 a-d*	10.28 A***
BII	8.74	10.44 b	10.63	10.39	11.54	10.51	10.23 a-d	10.35 A
BIII	8.53	10.89 a	10.70	10.33	11.41	10.34	10.77 a	10.42 A
BIV	8.21	10.07 bc	10.67	10.40	11.60	9.87	10.54 ab	10.19 A
MF	8.19	9.88 c	10.26	10.13	11.00	10.03	9.62 d	9.88 B
1/2MF+BI	8.53	10.22 bc	10.60	10.31	11.51	10.31	10.43 abc	10.27 A
1/2MF+BII	8.31	10.24 bc	10.67	10.26	11.69	10.28	10.85 a	10.33 A
1/2MF+BIII	8.56	10.44 b	11.25	10.72	11.12	10.09	10.36 a-d	10.36 A
1/2MF+BIV	8.74	10.43 b	10.81	10.44	11.18	10.61	10.00 bcd	10.32 A
CONTROL	7.86	10.02 bc	10.12	10.03	10.72	10.37	9.70 cd	9.83 B
CUL. MEAN	8.42 D***	10.28 C	10.62 B	10.40 C	11.35 A	10.23 C	10.27 C	

Notes: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $^{ns}P > 0.05$. Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 5 The effects of bacteria and mineral fertiliser on plant height, stem diameter and tillering number of tulip (continued)

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
				Tillering number				
BI	3.12 abc***	2.05 a**	1.13 a*	2.83 ^{ns}	0.43 cd**	2.56 bcd***	2.53 ^{ns}	2.09 A***
BII	3.02 a-d	1.57 abc	1.10 ab	2.69	0.79 a	2.49 cd	2.37	2.00 AB
BIII	3.20 ab	1.22 cd	0.80 cd	2.55	0.33 d	2.85 abc	2.61	1.94 AB
BIV	3.52 a	1.13 cd	0.73 d	2.78	0.42 cd	2.70 abc	2.55	1.98 AB
MF	2.63 cde	1.26 cd	0.72 d	2.62	0.76 ab	2.96 ab	2.44	1.91 B
1/2MF+BI	3.14 ab	1.45 bc	0.88 a-d	2.63	0.68 abc	2.97 ab	2.20	1.99 AB
1/2MF+BII	3.16 ab	1.83 ab	1.05 abc	2.67	0.43 cd	2.17 de	2.36	1.96 AB
1/2MF+BIII	2.56 de	1.54 abc	0.83 bcd	2.55	0.36 d	2.57 bcd	2.73	1.88 B
1/2MF+BIV	2.99 bcd	1.33 bc	0.69 d	2.70	0.45 cd	3.09 a	2.54	1.97 AB
CONTROL	2.22 e	0.79 d	0.77 cd	2.30	0.49 bcd	1.97 e	2.33	1.55 C
CUL. MEAN	2.96 A***	1.42 D	0.87 E	2.63 B	0.51 F	2.63 B	2.47 C	

Notes: $*P < 0.05$; $**P < 0.01$; $***P < 0.001$; $^{ns}P > 0.05$. Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 6 The effects of bacteria and mineral fertiliser on perianth fresh weight, perianth dry weight and perianth dry matter (DM) of tulip

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
Application				*Perianth fresh weight (g)*				
BI	1.95 ^{ns}	4.41 ^{ns}	3.29 ^{ns}	3.76 ^{ns}	4.81 ^{ns}	3.13 ^{ns}	3.72 ^{ns}	3.58 ^{NS}
BII	2.07	4.27	3.04	3.59	4.58	3.86	3.11	3.51
BIII	1.94	4.27	2.39	3.82	4.34	3.87	4.14	3.54
BIV	2.07	4.19	2.73	4.32	4.26	3.58	3.23	3.48
MF	1.75	4.12	2.44	3.89	4.68	3.46	3.87	3.46
1/2MF+BI	1.93	4.25	2.82	4.03	4.84	3.57	3.63	3.58
1/2MF+BII	1.94	4.32	3.11	3.70	4.34	3.61	3.44	3.49
1/2MF+BIII	2.18	4.06	2.83	3.91	4.58	3.70	3.42	3.52
1/2MF+BIV	2.02	3.93	2.59	4.12	4.25	3.90	4.72	3.65
CONTROL	1.61	4.44	2.79	3.78	4.65	3.85	3.87	3.57
CUL. MEAN	1.94 F***	4.23 B	2.80 E	3.89 C	4.53 A	3.65 D	3.71 CD	
				Perianth dry weight (g)				
BI	0.31 ab*	0.58 ^{ns}	0.43 ^{ns}	0.53 ^{ns}	0.72 ^{ns}	0.46 ^{ns}	0.58 ^{ns}	0.52 ^{NS}
BII	0.34 a	0.66	0.44	0.52	0.67	0.52	0.50	0.52
BIII	0.32 ab	0.60	0.39	0.51	0.67	0.52	0.56	0.51
BIV	0.33 ab	0.58	0.47	0.58	0.62	0.57	0.49	0.52
MF	0.27 bc	0.57	0.41	0.55	0.68	0.51	0.53	0.50
1/2MF+BI	0.32 ab	0.60	0.43	0.56	0.72	0.53	0.52	0.53
1/2MF+BII	0.35 a	0.59	0.44	0.55	0.62	0.52	0.52	0.51
1/2MF+BIII	0.32 ab	0.59	0.42	0.54	0.73	0.51	0.54	0.52
1/2MF+BIV	0.34 a	0.59	0.42	0.56	0.65	0.57	0.65	0.54
CONTROL	0.24 c	0.57	0.42	0.56	0.67	0.51	0.55	0.50
CUL. MEAN	0.31 E***	0.59 B	0.43 D	0.55 C	0.68 A	0.52 C	0.54 C	

Notes: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; $^{ns}P > 0.05$, Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 6 The effects of bacteria and mineral fertiliser on perianth fresh weight, perianth dry weight and perianth dry matter (DM) of tulip (continued)

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN*
				Perianth DM (%)				
BI	16.25 ^{ns}	13.43 ^{ns}	13.54 ^{ns}	14.21 ^{ns}	14.89 ^{ns}	14.71 ^{ns}	15.56 ^{ns}	14.65 ^{NS}
BII	16.58	15.55	14.94	14.39	14.63	13.60	16.14	15.12
BIII	16.56	14.18	16.17	13.39	15.40	13.50	13.55	14.68
BIV	15.97	13.75	17.21	13.55	14.58	16.12	15.28	15.21
MF	15.32	14.11	16.90	14.06	14.69	14.70	13.63	14.77
1/2MF+BI	16.68	14.06	15.33	13.82	14.94	14.98	14.41	14.89
1/2MF+BII	18.36	13.60	14.59	14.91	14.39	14.37	15.24	15.07
1/2MF+BIII	14.47	14.62	14.70	13.93	15.98	13.72	15.71	14.73
1/2MF+BIV	16.88	15.23	16.11	13.59	15.38	14.67	14.40	15.18
CONTROL	15.39	12.82	15.15	14.76	14.39	13.37	14.11	14.28
CUL. MEAN	16.25 A***	14.13 C	15.46 AB	14.06 C	14.93 BC	14.37 C	14.80 BC	

Notes: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; $^{ns}P > 0.05$, Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

Table 7 The effects of bacteria and mineral fertiliser on perianth diameter and perianth length of tulip

Cultivar	*C*	*O*	*JR*	*BL*	*AD*	*P*	*GA*	*APP. MEAN.*
Application				*Perianth diameter (mm)*				
BI	15.61 a**	23.23 ^{ns}	19.23bcd***	21.79 bc**	23.44 a*	20.47 bc*	21.37 ^{ns}	20.74 AB***
BII	15.49 a	22.83	20.40 abc	21.18 c	22.24 abc	22.85 a	19.94	20.70 AB
BIII	14.08 bcd	22.99	17.85 d	21.74 bc	22.34 abc	22.85 a	21.54	20.48 AB
BIV	14.51 abc	22.69	18.76 cd	21.60 bc	20.96 c	21.53 abc	20.39	20.06 BCD
MF	13.64 cd	21.38	18.65 d	22.27 abc	21.24 bc	19.41 c	21.62	19.74 CD
1/2MF+BI	14.43 a-d	23.96	20.88 ab	23.67 a	23.62 a	20.36 bc	21.08	21.14 A
1/2MF+BII	13.98 bcd	23.51	21.40 a	20.84 c	22.06 abc	21.32 abc	20.74	20.55 AB
1/2MF+BIII	15.07 ab	22.05	18.43 d	23.06 ab	22.64 ab	21.99 ab	19.48	20.39 BC
1/2MF+BIV	15.17 ab	22.94	18.43 d	22.42 abc	22.28 abc	20.63 abc	20.44	20.33 BC
CONTROL	13.11 d	22.49	17.60 d	21.33 c	21.69 bc	20.04 bc	20.84	19.59 D
CUL. MEAN	14.51 E ***	22.81 A	19.16 D	21.99 B	22.25 B	21.15 C	20.74 C	
				Perianth lenght (mm)				
BI	41.72 ab***	45.86 ab**	40.19 ab*	49.03 bc*	53.86 ab**	46.59 ^{ns}	49.61 ^{ns}	46.69 AB***
BII	42.26 ab	45.28 abc	41.31 a	48.38 c	53.89 ab	51.76	48.51	47.34 A
BIII	41.28 bc	44.24 bc	36.64 c	49.85 abc	51.35 d	50.61	51.37	46.48 AB
BIV	42.60 ab	44.67 bc	39.43 abc	51.87 a	50.23 d	50.23	49.56	46.94 A
MF	39.76 cd	42.91 c	38.24 bc	49.61 bc	51.89 a-d	48.91	49.11	45.77 BC
1/2MF+BI	39.91 cd	47.51 a	40.54 ab	49.98 abc	54.12 a	49.12	49.42	47.23 A
1/2MF+BII	42.50 ab	46.30 ab	39.26 abc	48.36 c	51.27 d	49.59	49.30	46.65 AB
1/2MF+BIII	43.46 a	44.71 bc	39.31 abc	49.64 bc	53.62 abc	49.79	48.39	46.99 A
1/2MF+BIV	42.54 ab	44.40 bc	38.71 abc	50.75 ab	51.83 bcd	50.57	47.76	46.65 AB
CONTROL	38.50 d	43.07 c	36.49 c	49.12 bc	51.59 cd	49.65	49.57	45.43 C
CUL. MEAN	41.45 D***	44.89 C	39.01 E	49.66 B	52.37 A	49.68 B	49.26 B	

Notes: *P < 0.05; **P < 0.01; ***P < 0.001; ^{ns}P > 0.05. Differences in each cultivar were given in small letters, and differences among the applications and cultivars mean were given in capital letters.
C: Cassini, O: Ollioules, JR: Jan Reus, BL: Banja Luca, AD: American Dream, P: Parade and GA: Golden Apeldoorn.

The effects of bacteria and mineral fertiliser on peduncle length, peduncle thickness and leaf number of tulip were given in Table 4. According to average data, the difference among cultivar ($P < 0.001$) and applications ($P < 0.05$) was statistically significant on peduncle length. The impact on the application of varieties was important except for O, P and GA cultivars. The longest peduncle was obtained from BIV (18.76 cm) application and P (21.07 cm) cultivar. The peduncle length was increased in 1/2MF+BIV application in C (17.54 cm), BI application in JR (18.32 cm), BIV application in BL (20.68 cm) and BII application in AD (20.59 cm). It was found that the interaction between cultivars and applications were significant in this study ($P < 0.001$) (Table 4). The effects of application on the peduncle thickness were statistically significant except for JR, BL and P cultivars. The interaction between cultivars and applications were statistically significant ($P < 0.01$). The thickest peduncle has been identified in the BI application (6.04 mm) and AD (6.85 mm) cultivar. The highest values were obtained from BII in C (5.34 mm), 1/2MF+BII in O (6.86 mm), MF in AD (7.07 mm) and BIII in GA (5.97 mm) (Table 4). The applications effects on the number of leaf were not statistically significant except for GA cultivar. However, significant differences occurred among the applications and cultivars according to average data. In addition, the interaction between cultivars and applications were significant ($P < 0.05$). According to average, the maximum leaf number (3.31) was found in BII and 1/2MF+BII applications and JR (3.65) cultivars (Table 4).

The effects of bacteria and mineral fertiliser on plant height, stem diameter and tillering number of tulip were given in Table 5. It was found that the interaction between cultivars and applications were significant ($P < 0.001$) in terms of plant height. And also, according to average data, the differences of among cultivars and application were significant. The effects of applications on plant height were statistically significant in the C, O and AD cultivars. The highest plant height was determined with BII application in C (20.80 cm) cultivar, 1/2MF+BI application in O (27.64 cm) cultivar and BI application in AD (28.63 cm) cultivar (Table 5). According to averages, it was found significant differences among cultivars and applications in the stem diameter. Also, the effects of applications on stem diameter were significant in O and GA cultivars. The interaction between cultivars and applications were not significant. According to averages, the highest stem diameter was occurred in BIII and 1/2MF+BII applications in O (10.89 mm) and GA (10.77 mm) cultivars, respectively (Table 5). The effects of applications on tillering number of tulip were significant in all cultivars except for BL and GA. Likewise, the interaction between cultivars and applications were statistically significant at levels of $P < 0.001$. According to average data, the tillering number was more in C (2.96) cultivar and BI (2.09) application. The highest tillering number was occurred from BI application in O (2.05) and JR (1.13) cultivars, BIV application in the C (3.52), BIII application in AD (0.79) and 1/2MF+BIV application in P (3.09) cultivar (Table 5).

The effects of bacteria and mineral fertiliser on perianth fresh and dry weight and perianth dry matter (DM) of tulip were given in Table 6. The effects of applications on perianth fresh and dry weight were not statistically significant except for C for dry weight. Also, the interaction was not significant between cultivars and applications. Nevertheless, the differences among cultivars were significant and the highest perianth fresh (4.53 g) and dry weight (0.68 g) was obtained from AD cultivar (Table 6). The effects of applications and interactions between cultivars and applications on perianth DM were not statistically significant. The highest DM was determined in C (16.25%) cultivar (Table 6).

The effects of application on perianth diameter were significant in all the cultivars except for O and GA. The highest perianth diameter was measured in C cultivars with BI application (15.61 mm), JR cultivar with 1/2MF+BII application (21.40 mm), BL (23.67 mm) and AD (23.62 mm) cultivars with 1/2MF+BI and P (22.85 mm) cultivar with BII and BIII applications. Generally, the highest values were obtained from 1/2MF+BI (21.14 mm) application and O (22.81 mm) cultivar. Also, the interaction was significant ($P < 0.001$) between cultivars and applications in terms of perianth diameter (Table 7). The effects of application on perianth length were significant in all the cultivars except for P and GA. The highest perianth length was obtained from 1/2MF+BIII, 1/2MF+BI, BII, BIV and 1/2MF+BI applications in the C, O, JR, BL and AD cultivars, respectively. According to average values, BII (47.34 mm) application and AD (52.37 mm) gave the highest perianth length. It was determined significant differences among the cultivars, applications and the interaction was statistically significant ($P < 0.001$) (Table 7).

4 Discussions and conclusions

Effects of the bacteria, mineral fertilisers and their combinations on plant growth of tulip were examined in this study. Results showed significant effects both applications and tulip cultivars. Generally, the applications had shortened the period in bulb sprouting in spring. This period was 2% earlier than control (Table 3). The longer time of bulb sprouting was realised in C cultivar. Although all cultivation conditions were the same, differences between cultivars was due to genetic and climatic factors. Thus, Le Nard and De Hertogh (1993) and Rees (1992) emphasised that water is important factor of in the healthy development and growth of the tulip plant and bulb. 1/2MF+BIII combination provided in the shorter sprouting time that is the importance of fertilisation in tulip production. Similarly, Hetman and Laskowska (1992), Rees (1992) and Le Nard and De Hertogh (1993) reported that the fertilisation very important in the production of the tulip plant and their bulb. Also, with bacteria and mineral fertiliser combination show that it could less using of chemical fertilisers being potentially pollutants (Cakmakcı et al., 2001) and PGPB is used as biological fertiliser (Burdman et al., 2000) in the cultivation of tulips. Smilarly, Bhat Zahoor et al. (2016) reported that the biofertiliser treatment with *Azospirillum* was significantly increased in plant height, flower size, florets fresh weight and sprouting of tulip. Likewise, El-Mokadem Hoda and Mona (2014) investigated the effects of *Azospirillum lipoferum* and *Bacillus polymxa* and their mixture with/or not $19N:19P_2O_5:19K_2O$ on petunia plant growth. They reported that both bacterial inoculants and their mixture increased vegetative growth and flower parameters when compared to control.

The interaction between cultivar and application was significant on bulb sprouting ratio. The effects of application on bulb sprouting ratio were not significant when compared to the control. The bulb sprouting ratio changed from 97.33% in JR to 99.78% in P (Table 3). The reason for higher sprouting rates is the completion of the development of the remaining bulbs in the ground during winter period, achieve the proper moisture capacity with rains, and the bulb germination and sprouting are stronger.

In our study, the vegetation period was longest with 1/2MF+BIII application and AD cultivar. Local climate conditions may affect on the quality and bulbs of tulip. Extension of vegetation time depends on tulip cultivars and the region's climatic conditions, these situation can affect on quality bulb of tulip. It was determined in previous studies, vegetation period of prolonged allowed to the growth of the bulb and it was bigger in areas with moderate cool summers (Ürgenç, 1998). Likewise, in a study conducted in marigold, combination of vermicompost (12,5% N), poultry manure (12,5% N), *Azospirillum spp.* (200 g) and 75% RDN (combination mixture to be 75% N) have given in the early beginning of flowering and the longest bloom period with 50% flowering (Shubha, 2006). Ali et al. (2014) determined that humic acid with NPK treatment ensured earliest sprouting and flowering in tulip. Also, the researchers established that early growth and the maximum germination percentage of tulip bulbs in combined application of humic acid and NPK.

Both bacteria and combination with mineral fertiliser showed the highest length and thickness of peduncle with increase in ratio of 7.82% and 7.86% compared to control, respectively. Besides, the highest peduncle length and peduncle thickness were obtained from P and AD cultivars, respectively (Table 4). Similarly, Shubha (2006) reported that combination of vermicompost, poultry manure, *Azospirillum spp.* and 75% RDN increased in peduncle, number of petals per flower, yield of flower per plant and yield of xanthophylls in marigold. Although the number of leaf is varieties feature, composed of average of the leaf was 3 leaves of all the cultivars of tulips during the production period (Table 4). Zulueta-Rodriguez et al. (2014) determined that *Pseudomonas putida* enhanced leaf number and leaf area of poinsettia.

In terms of the plant height and stem diameter among cultivars and applications, there were significant differences. The applications increased in ratio of 7.88% (BI) plant height and ratio of 6.06% (BIII) in stem diameter (Table 5). These increases have been indirectly affected on plant growing bulb.

Tillering occurs depending on the cultivar of feature while number of tillering has been more in C cultivar (Table 5). Tillering is visually preferred particularly due to the abundant formation of flowers. Generally, plant height, stem length and bulbs diameter vary between 15–60 cm, 5–50 cm 2,5–4 cm in tulip plants, respectively (Gezgin, 2007). In a study, investigated of the effects of DAP (diammonium phosphate) fertilisation on tulip; it was defined that significant effect on number of days to flowering (108.0) and leaf length (22.50 cm), when applied 3.0 g plot^{-1} DAP (Sajid et al., 2013). Though differences occurring in terms of plant characteristics are cultivar of property, it is seen that applications can act on different proportions on the development of the plant. The plant parameters, of which we evaluated in above, have an impact on the formation of bulb. Thus, it is expressed that number of flower per plant, stem length, discoloration and peduncle bending are some of the quality criteria that impact on formation of tulip bulb (Muisers et al., 2001).

Although the effects of application were significant on perianth fresh and dry weight, periant diameter and length, in generally, the values of these properties were similar. These are because of flower buds, it was rupture with the coloration of begins to encourage the formation of bulb and the realisation of this process in almost the same size in the perianth. The perianth size of C cultivar has been in smaller than compared to the others. Application increased in perianth DM with ratio 6,30% (1/2MF+BIV) (Tables 6 and 7). It is known that fertilisers may have important effects on plant growth in tulips. In a fertilisation study conducted in tulip, Ali et al. (2014) determined that humic acid and NPK applications increased plant height, leaf area, stem diameter, leaf chlorophyll contents, stalk length, vase life, fresh and dry flower of tulip.

In conclusion, PGPB application in tulip growing increased in plant development of the cultivars. It is stated that especially decreasing in 50% of chemical fertiliser could be inhibited to use much chemical fertiliser. Besides the biofertiliser with PGPB have been improved the plant growth and development of tulip, also they have increased the efficiency of reduced chemical fertiliser application. It is thought that the use of bacteria as a biofertiliser in tulip cultivation can be an advantage in terms of bulb production especially increasing in plant development. In terms of environmental pollution, the extreme use of chemical fertilisers, and the high costs of mineral fertiliser production, the bacteria can be evaluated that they might be used with mineral fertilisers or alone to achieve ecological and sustainable ornamental production. As a result of this study, we think that bacteria can be used as biofertiliser in ornamental plant cultivation as well as in tulip cultivation.

Acknowledgements

We are very grateful to TUBITAK (The Scientific and Technological Research Council of Turkey) for generous financial support (Project Number TOVAG- 113O957).

References

Adesemoye, A.O., Obini, M. and Ugoji, E.O. (2008) 'Comparison of plant growth-promotion with Pseudomonas aerugınosa and Bacıllus subtilis in three vegetables', *Brazilian Journal of Microbiology*, Vol. 39, No. 1, pp.423–426.

Adesemoye, A.O., Torbert, H.A. and Kloepper, J.W. (2010) 'Increased plant uptake of nitrogen from 15N-depleted fertilizer using plant growth-promoting rhizobacteria', *Applied Soil Ecology*, Vol. 46, Nos. 2–3, pp.54–58.

Ali, A., Rehman, S.U., Raza, S. and Allah, S.U. (2014) 'Combined effect of humic acid and NPK on growth and flower development of Tulipa gesneriana in Faisalabad, Pakistan', *Journal of Ornamental Plants*, Vol. 4, No. 4, pp.39–48.

Alp, S., Keskin, S. and Türkoğlu, N. (2010) *Bazı iklim verileri kullanılarak soğanlı bitki yetişitiriciliği açısından ülkemizde en uygun bölgenin belirlenmesi üzerine bir araştırma*, IV, Süs Bitkileri Kongresi (20–22 Ekim-Mersin) Bildiri Kitabı, pp.296–301, in Turkish.

Asghari, R. (2014) 'Effect of cold treatment (below 5°C) and different growth medium on flowering period and characteristics of tulip (Tulipa gesneriona L.)', *Journal of Experimental Biology and Agricultural Sciences*, Vol. 2, No. 4, pp.428–431.

Azcon, R. and Barea, J.M. (1976) 'Synthesis of auxins, gibberrellins and cytokinins by Azotobacter vinelandii and Azotobacter beijerinckii related to effects produced on tomato plants', *Plant Soil*, Vol. 43, No. 4, pp.609–613.

Bakker, M. (1991) *Teelt Information*, Vol. 9, CNB Information, Lisse, The Netherlands.

Benschop, M., Kamenetsky, R., Nard, M.L., Okubo, H. and De Hertogh, A. (2010) 'The global flower bulb industry: production, utilization, research', *Horticultural Reviews*, Vol. 36, pp.1–115.

Bhat Zahoor, A., Sheikh, M.Q. and Baba, Z.A. (2016) 'Influence of biofertilizers on vegetative growth, flower quality, bulb yield and nutrient uptake in tulip (Tulipa gesneriana L.)', *Indian Horticulture Journal*, Vol. 6, No. 2, pp.257–260.

Burdman, S., Jurkevitch, E. and Okon, Y. (2000) 'Recent advances in the use of plant Growth promoting rhizobacteria (PGPR) in agriculture', in *Microbiol Interactions in Agriculture and Forestry*, Vol II, Subba-Rao, N. and Dommergues Y.R. (Eds.) Chapter 10 Pub. Inc. UK, pp.29–250.

Cakmakci, R. (2009) 'Promoting of plant growth by ACC deaminase-producing plant promoting bacteria under stress conditions', *Atatürk Uni. Journal of Agriculture Faculty*, Vol. 40, No. 1, pp.109–125.

Cakmakcı, R., Kantar, F. and Sahin, F. (2001) 'Effect of N2-fixing bacterial inoculations on yield of sugar beet and barley', *Journal of Plant Nutrition and Soil Science*, Vol. 164, No. 5, pp.527–531.

Dobereiner, J., Reis, V.M. and Lazarini, A.C. (1988) 'New N2 fixing bacteria in association with cereals and sugar cane', in Bothe, H., Bruijn, F.J. and Newton, W.E. (Eds.): *Nitrogen Fixation: A Hundred Years After*, Stuttgart, pp.717–722, Fischer, Germany.

Dursun, A., Ekinci, M. and Dönmez, M.F. (2008) 'Effects of inoculation bacteria on chemical content, yield and growth in rocket (Eruca vesicaria subsp. sativa)', *Asian Journal of Chemistry*, Vol. 20, No. 4, pp.3197–3202.

Dursun, A., Ekinci, M. and Dönmez, M.F. (2010) 'Effects of foliar application of plant growth promoting bacterium on chemical contents, yield and growth of tomato Lycopersıcon esculentum L.) and cucumber (Cucumıs satıvus L.)', *Pakistan Journal of Botany*, Vol. 42, No. 5, pp.3349–3356.

Ekinci, M., Dursun, A., Dönmez, M.F. and Eminag□aog□lu, H. (2009) 'Effects of different inoculation bacteria on yield and growth in cauliflower (Brassica oleracea var. botrytis)', *International Rural Development Symposium*, Ispir–Erzurum, Turkey, 25–27 September, No. 7, pp.88–91.

El-Mokadem Hoda, E. and Mona, S. (2014) 'Effect of bio and chemical fertilizers on growth and flowering of Petunia hybrid plants', *American Journal of Plant Physiology*, Vol. 9, No. 2, pp.68–77.

Garcia, L.J.A., Probanza, A., Ramos, B. and Manero, F.J.G. (2003) 'Effects of three plant growth-promoting rhizobacteria on the growth of transplants of tomato and pepper in two different sterilized and nonsterilized peats', *Archives Agronomy and Soil Science*, Vol. 49, pp.119–127.

Gezgin, B. (2007) *The Effects of Different Pot Size on the Formation and Characteristics of Tulip Bulb at the Ring Culture*, Master Thesis, Ankara University Graduate School of Natural and Applied Sciences Department of Horticulture, p.49.

Günes, A., Ataoglu, N., Turan, M., Esitken, A. and Ketterings, Q.M. (2009) 'Effects of phosphate-solubilizing microorganisms on strawberry yield and nutrient concentrations', *Journal of Plant Nutrition and Soil Science*, Vol. 172, pp.385–392.

Hetman, J. and Laskowska, H. (1992) 'The influence of leaf fertiliziation and yield of tulip bulbs', *V. İnternational Symposium on Flower Bulbs*, ISHS Acta Horticulture 325-pub, Date: 01.12.1992.

Ibiene, A.A., Agogbua, J.U., Okonko, I.O. and Nwachi, G.N. (2012) 'Plant growth promoting rhizobacteria (PGPR) as biofertilizer: effect on growth of Lycopersicum esculentus', *Journal of American Science*, Vol. 8, No. 2, pp.318–324.

Juodkaitë, R., Naujalis, J.R., Navalinskienë, M. and Samuitienë, M. (2005) 'Evaluation of tulip (Tulipa L.) decorative capacities and resistance to tulip breaking potyvirus in the tulip collection of the Botanical Garden of Vilnius University', *Biologija*, Vol. 4, pp.64–70.

Kokalis-Burelle, N., Vavrina, C.S., Reddy, M.S. and Kloepper, J.W. (2003) 'Amandment of muskmelon and watermelon transplant media with plant growth promoting rhizobacteria: effects on transplant quality, disease, and nematode resistance', *HortTechnology*, Vol. 13, No. 3, pp.476–482.

Le Nard, M. and De Hertogh, A.A. (1993) 'Tulipa, The physiology of flowerbulbs', in De Hertogh, A. and Le Nard, M. (Eds.): *A Comprehensive Treatise on the Physiology and Utilization Ornamental Flowering Bulbous and Tuberous Plants*, pp.617–682, Elsevier, Amsterdam.

Mehta, S. and Nautiyal, C.S. (2001) 'An efficient method for qualitative screening of phosphatesolubilising bacteria', *Current Microbiology*, Vol. 43, pp.51–56.

Misra, M., Kumar, U., Misra, P.K. and Prakash, V. (2010) 'Efficiency of plant growth promoting rhizo- bacteria for the enhancement of Cicer arietinum L. growth and germination under salinity', *Advantage Biological Research*, Vol. 4, No. 2, pp.92–96.

Muisers, J.J.M., Oeveren, J.C. and Tuyl, J.M. (2001) 'Breeding as a tool for İmproving postharvest quality characters of lily and tulip flowers', *ISHS Acta Horticulturae 430: VII International Symposium on Flowerbulbs*, 10.17660/ActaHortic.1997.430.91.

Nezarat, S. and Gholami, A. (2009) 'Screening plant growth promoting rhizobacteria for improving seed germination, transplant growth and yield of maize', *Pakistan Journal of Biological Science*, Vol. 12, No. 1, pp.26–32.

Niedziela Jr., C.E., Nelson, P.V. and Dickey, D.A. (2015) 'Growth, development, and mineral nutrient accumulation and distribution in tulip from planting through postanthesis shoot senescence', *Hindawi Publishing Corporation International Journal of Agronomy*, Article ID 341287, p.11 [online] http://dx.doi.org/10.1155/2015/341287.

Ohyama, T., Komiyama, S., Ohtake, N., Sueyoshi, K., Teixeira da Silva, J.A. and Ruamrungsri, S. (2006) 'Physiology and genetics of carbon and nitrogen metabolism in tulip', *Floriculture, Ornamental and Plant Biotechnology*, Volume III Global Science Books, pp.12–25.

Rees, A.R. (1992) 'Ornamental bulbs, corms and tubers', *C.A.B. International*, p.220, Wallingford, UK.

Sajid, M., Rab, A., Amin N., Khan, A., Mateen, A., Ahmad, N. and Amanatullah, W.F. (2013) 'Effect of diammonium phosphate (DAP) on flowers and bulb production of Tulip's cultivars', *Pure and Applied Biology*, Vol. 2, No. 2, pp.48–52.

Shubha, B.M. (2006) *Intergrated Nutrient Management for Growth, Flowering and Xanthophyll Yield of Marigold (Tagetes erecta. L)*, p.77, Master Thesis, University of Agricultural Sciences.

SPSS Inc. (2010) SPSS® 18.0 Base User's Guide, Prentice Hall.

Sytsma, K. and Rose, J. (2015) *Plant Geography*, University of Wisconsin Botany, Madison, WI.

Ürgenç, S.İ. (1998) 'Ağaç ve Süs Bitkileri Fidanlık ve Yetiştirme Tekniği' İstanbul Üniversitesi Orman Fakültesi Yayınları, Fakülte Yayın No: 442, ISBN: 975-404-445-7, İstanbul, in Turkish.

Yildirim, E., Dönmez, F. and Turan, M. (2008) 'Use of bioinoculants in ameliorative effects on radish (Raphanus sativus L.) plants under salinity stress', *Journal of Plant Nutrition*, Vol. 31, No. 8, pp.2059–2074.

Yildirim, E., Turan, M., Ekinci, M., Dursun, A. and Cakmakci, R. (2011a) 'Plant growth promoting rhizobacteria ameliorate deleterious effect of salt stress on lettuce', *Scientific Research Essays*, Vol. 6, No. 20, pp.4389–4396.

Yildirim, E., Karlidag, H., Turan, M., Dursun, A. and Goktepe, F. (2011b) 'Growth, nutrient uptake and yield promotion of broccoli by plant growth promoting rhizobacteria with manure', *HortScience*, Vol. 46, No. 6, pp.932–936.

Zulueta-Rodriguez, R., Cordoba-Matson, M.V., Hernandez-Montiel, L.G., Murillo-Amador, B., Rueda-Puente, E. and Lara, L. (2014) 'Effect of pseudomonas putida on growth and anthocyanin pigment in two poinsettia (Euphorbia pulcherrima) cultivars', *The Scientific World Journal*, Article ID 810192, p.6, DOI: 10.1155/2014/810192.