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Effects of Bacteria Inoculation on Yield, Yield Components and Mineral Contents of Tomato

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ABSRACT

In this study, the effects of the bacteria grafting increasing plant growing were studied to determine its effects on yield and some yield components of tomato. Tülin F1 tomato genotype was used as trial material and a total of 10 different applications consisting from 52/1-E43, 21/3F, 17/3N, E43 F, 637 Ca, MFDCa1, 52/1, 21/3+637Ca, 52/1 Zeatin bacteria races and control were used as application. According to the results of the study, yield was changed between 4603,4 kg.da^{-1} and 7409.9 kg.da^{-1}. 21/3F, 52/1, 21/3+637 Ca applications had first sorts. Average fruit weight was obtained from 131.48g to 183.00g and the highest value was taken from 17/3N application. Plant height was changed between 197.5 cm and 212.2cm and, 21/3+637 Ca, 52/1 Zeatin, 17/3N, control had first sorts. Plant internode length was between 8.0 and 8.3 cm and control had the highest value. Root neck diameter changed between 15.9 mm and 19.7 mm and 21/3+637 Ca had the highest value. In common, while the results of study had difference, 21/3F, 21/3+637 Ca and 17/3N bacteria races applications had positive effects on yield and yield components of tomato. 637 Ca, E43F and 21/3+637 Ca applications had positive effects on mineral content of tomato.

1. Introduction

Tomato is the highest grown vegetable species in field and greenhouse conditions around the world and many growth problems come across during that duration. Pesticides and fertilizers are used to solve the growth problems of tomato but unconsciously cause another problem in it. Some applications can be made to untie the problems. One of the application is using micro-organisms in root zone that are affecting on plant development and increasing the root activity (Anaç and Çiçekli 2008; Karaçal and Tüfenkçi 2010).

Many inoculated bacterial species commonly associated with the plant rhizosphere have been tested and determined to be beneficial for plant development, yield and crop quality so far. They have been called plant growth promoting rhizobacteria (PGPR) (Eşitken et al. 2006; Ahn et al. 2007). Many important studies are made on PGPR mechanisms affecting on plant development (Vessy 2003; Lucy et al. 2004; Dursun et al. 2008; Ekinci et al. 2010; Seymen et al. 2010). Although PGPR mechanism affecting on plant growth have not been enough cleared, it is known that PGPR have affect on plant disease resistance, taking plant nutrition and promoting plant development (Lucy et al. 2004)

A group of PGPR increases resistance to biotic and abiotic conditions while the other group of it decreases the harmful effect of phyto-pathogenic microorganism (Bashan and Holguin 1998; Lucy et al. 2004).

Main mechanisms of increasing the resistance to biotic and abiotic stress conditions are affecting on plant development of PGPR. Phosphor content of soil and P compound applied to the soil are fixing in the soil as Ca compound (Yadaw and Dadarwal 1997; Çakmakçı et al. 2008; Karaçal and Tüfenkçi 2010). PGPR is increasing the organic and inorganic P solubility, microbial metabolite effects on plant development and the mineral intake

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by producing organic acid and acid phosphate (Kucey et al. 1989; Kumar and Narula 1999; Puente et al. 2004; Çakmakçı et al. 2005).

Many researchers determined that PGPR can stimulate growth and increase in yield (Gül et al. 2007; Dursun et al. 2008; Seymen et al. 2010), increase leaf and fruit weight (Kıdoğlu et al., 2008), increase in root, stem, plant weight and protein ratio (Çakmakçı et al. 2008; Karthikeyan et al. 2010), increase in shoot ratio, root ratio and plant dry weight (Çakmakçı et al. 2005; Ahn et al. 2007). However, not much is known about their promoting effects on yield, growth and nutrient contents of tomato.

The objective of this study was to determine the effects of different inoculation bacteria on yield, yield components and chemical contents of tomato in greenhouse conditions.

2. Material and Methods

2.1. Bacterial strains, culture conditions, media and treatment

Strains of bacteria, 52/1 and E43, 21/3F, 17/3N, E43 F, 637Ca, MFD Ca1, 52/1, 21/3+637Ca, 52/1 Zeatin, were obtained from Department of Plant Protection at Ataturk University. Bacteria were grown on Nutrient Agar (NA, including 3 g/l beef extract, 5 g/l peptone and 15 g/l agar) for routine use, and maintained in Nutrient Broth (NB, including 3 g/l beef extract and 5 g/l peptone) with 30% glycerol at - 80ºC for long-term storage. For this experiment, the bacterial strains were grown on nutrient agar. A single colony was transferred to 250 ml flasks containing NB, and grown aerobically in flasks on a rotating shaker (95 rpm) for 48 h at 27ºC. The bacterial suspension was then diluted in sterile distilled water to a final concentration of 10^8 CFU ml^{-1}, and the resulting suspensions were used to treat tomato plants and root area. The first bacterial application was made on 12 May, 2010. The plant leaves and root area were sprayed with bacterial suspension (10^8 CFU ml^{-1}) at seven days interval for three times during plant development until getting wet.

2.2. Greenhouse experiment

The experiment was carried out on Tülin F1tomato cultivar in the Department of Horticulture at Selçuk University under greenhouse condition in Konya, Turkey in 2010. The soil properties of the experimental area was 33.43 % sand, 24,60 % clay, 41,97 % silt, 15 % lime, EC=1,40 dS/cm and 7,3 pH. The soil volume was 1.48 g/cm^3 with loam characteristics. The experiment was based on a completely randomized design with four replicates. Seedlings of the plants were planted as 50x50x100 cm on 16 April in 2010 and each parcel had 14 plants. Drip irrigation method was used and the other cultural treatments were regularly applied on. First harvest was made on 13 July and it made 3 days intervals. The experiment ended in first week of September in the same year. Growth promoting effects of bacterial treatments were evaluated on 10 plants by determining yield (kg da^{-1}), fruit weight (g), plant height (cm), length between nodes (cm) and root neck diameter (mm). The effects of the bacterial treatments on the plant nutrient elements of fruit, leaf and root were also evaluated.

2.3. Sample analysis

In order to determine the mineral contents, samples were oven-dried at 68ºC for 48 h and then grinded. The micro-Kjeldahl procedure was applied for determination of N. After wet digestion of dried and grinded subsamples in a H_2SO_4-Se-salisilic acid mixture. In the diluted digests, P was measured by spectrophotometric method according to the indophenol-blue method. Potassium and calcium were determined by flame photometry, Mg, Mn, Zn and Cu by atomic absorption spectrometry using the method of AOAC, (1990).

2.4. Data analysis

All data were subjected to a one-way analysis of variance (ANOVA) and separated by Duncan's multiple range tests at 0.05 level using JMP statistical programs.

3. Results and Discussion

3.1. Yield (kg da^{-1})

Effects of different PGPR applications were significantly important in terms of yield. 21/3F, 52/1 and 21/3+637Ca applications increased the yield as 23% (7410 kg), 17% (7081 kg) and 19% (7182 kg) when compared to the control, respectively. There were no differences for the other applications in yield aspect (Table I).

3.2. Average fruit weight (g)

Different PGPR applications on average fruit weight were reported significantly important and the biggest fruit (183 g) was determined in 17/3N application. The other applications were not statistically effective on the weight and they were the same the control or less from the control application (Table I).

3.3. Plant height (cm)

Effects of different PGPR applications were significantly important in terms of plant length. It was 212 cm in 17/3N and 21/3+637Ca and 210 cm in 52/1 Zeatin applications which were the same to the control application. The other PGPR application gave less plant length compared. The less plant length (197 cm) was observed in 52/1 application (Table I).

3.4. Length between nodes (cm)

Different PGPR applications on length between nodes were determined significantly important and the highest length between nodes (8,9 cm) was found in the control application when compared to PGPR applications. The short length between nodes was reported as

8.0 and 8.2 cm in 52/1-E43, E43F and 21/3+637Ca applications (Table I).

3.5. Root neck diameter (mm)

Effects of different PGPR applications were statistically imperative in terms of root neck diameter. The best result was obtained from 21/3+637Ca (19.7 mm) application. 52/1 (17.5 mm), 52/1 Zeatin (17.4 mm), 52/1-E43 (17.4 mm) and 17/3N (15.9 mm) application have shown little response. The other PGPR applications were the same group of the control (Table 1).

Table 1

Effects of different PGPR applications on plant and fruit characteristics

Application	Yield (kg da^{-1})	Fruit weight (g/fruit)	Plant length (cm)	Length between nodes (cm)	Root neck diameter (mm)
52/1-E43	6516 ab	142 ab	205.7 ab	8 b	17.4 b
21/3F	7410 a	147 ab	207 ab	8.5 ab	17.7 ab
17/3N	6842 ab	183 a	212 a	8.4 ab	15.9 b
637 Ca	6638 ab	146 ab	204.4 ab	8.4 ab	17.74 ab
MFDCa1	6981 ab	133 ab	203.6 ab	8.5 ab	17.9 ab
E43 F	4603 b	132 b	205.5 ab	8.1 b	17.7 ab
52/1	7081 a	137 ab	197.5 b	8.6 ab	17.5 b
21/3+637Ca	7182 a	143 ab	212.2 a	8.2 b	19.7 a
52/1 Zeatin	5376 ab	143 ab	210.3 a	8.4 ab	17.4 b
Control	6017 ab	151 ab	207.5 a	8.9 a	17.8 ab
LSD %5	2410	46	11.3	0.7	2.0

3.6. Mineral contents

Effects of different PGPR applications on N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B were found to be different in root, leaf and fruit samples (Table 2). Here we are describing the influences on different elements and the readings were compared with the control sample

N: E43F and 17/3N applications gave the highest total N result in root and leaf while 637Ca application was the best in fruit samples. The other applications gave less total N value comparing to the control (Table 2)

P: MFDCa1, 52/1 and 52/1 Zeatin applications gave wicked total P value comparing to the control while the other applications showed important effect on taking P in root and leaf samples. PGPR application negatively affected on P in fruit samples like according to the control (Table II).

K: While 637Ca application gave the best K result in root samples, E43F was in the fruit samples in that of the parameter. K contents of leaves were less in the applications when compared to the control (Table 2).

Ca: PGPR application positively and negatively affected on Ca content in root and fruit samples, respectively. 17/3N, 21/3F, 637Ca and 52/1-E43 applications positively affected the Ca content (Table 2).

Mg: E43F, 637Ca and 21/3F applications gave the best Mg content when comparing to the control (Table 2).

S: While S content in 52/1, 21/3+637Ca E43F, MFDCa1 and 52/1 Zeatin applications was reported high in root samples, it was high in 17/3N, 21/3 F, 52/1-E43 and 21/3+637Ca application in leaf samples All the applications gave best S contents in fruit samples according to the control (Table 2).

Fe: All the application positively affected on Fe contents in root and fruit samples while 52/1-E43, 21/3F and 17/3N application positively affected on Fe content in leaf samples (Table 2).

Mn: Different PGPR applications significantly affected the Mn contents in root samples and the highest Mn value was reported in MDFCa1 application in leaf samples. All the applications except 637Ca and 17/3N application has shown influences on Mn content in fruit samples as per control (Table 2).

Zn: Zn content was generally observed, 52/1 and 21/3+637Ca application gave the best results in all the samples (Table II).

Cu: In terms of Cu contents, all the PGPR applications gave positive effect in root and fruit samples while 52/1-E43 and E43F application gave the best result in leaf samples when comparing to the control (Table 2).

B: All the PGPR applications except E43F application positively affected the B content in root samples while the applications negatively affected the same in leaf and fruit samples (Table 2).

PGPR applications have differently affected the yield, yield components and mineral contents of tomato under greenhouse conditions. Different PGPR application positively affected the yield. Applications 21/3F, 52/1 and 21/3+637Ca increased the yield as 23% (7410 kg),17% (7081 kg) and19% (7182 kg) as compared to the control, respectively. Similar results have been taken from the different bacterial applications in some studies and cultivars (Zhang et al. 2004; Dursun et al. 2008; Kıdoğlu et al. 2008; Ekinci et al. 2010; Seymen et al. 2010). Bacterial applications have 6-10 % increased yield of tomato under greenhouse conditions (Gagne et al. 1993). In the other greenhouse study, *Bacillus subtilis* strain BS13 have increased 21-25% tomato yield (Mena-Violante and Olalde-Portugal 2007).

Table 2

Effects of different PGPR application on total mineral contents of root, leaf and fruit of tomato

Application	N (%)			P (%)			K (%)		
	root	leaf	fruit	root	leaf	fruit	root	leaf	fruit
52/1-E43	0.19 f	2.25 cde	0.54 c	0.14 d	0.32 bc	0.39 c	0.15 e	2.59 d	3.1 c
21/3F	0.44 ab	2.88 ab	0.56 c	0.16 bc	0.34 b	0.41 bc	0.27 b	2.82 bc	2.7 d
17/3N	0.30 d	3 a	0.62 ab	0.17 b	0.46 a	0.33 b	0.24 c	3.38 a	2.9 cd
637 Ca	0.41 bc	2.41 c	0.68 a	0.19 a	0.31 cd	0.52 a	0.29 a	2.63 cd	3.09 c
MFDCa1	0.38 c	2.25 cd	0.52 cd	0.13 e	0.29 d	0.35 d	0.18 d	2.65 cd	2.92 cd
E43 F	0.45 a	2.77 b	0.65 ab	0.15 cd	0.35 b	0.52 a	0.17 d	2.86 b	4.14 a
52/1	0.23 e	2.05 e	0.48 de	0.09 f	0.25 e	0.34 d	0.15 e	2.26 e	2.33 e
21/3+637Ca	0.24 e	1.73 f	0.44 e	0.10 f	0.35 b	0.35 d	0.13 e	2.25 e	2.25 e
52/1 Zeatin	0.42 ab	2.19 de	0.66 b	0.14 d	0.29 d	0.44 b	0.25 c	2.16 e	2.83 d
Control	0.43 ab	2.25 cde	0.66 b	0.14 d	0.31 cd	0.50 a	0.25 c	2.12 e	3.42 b
LSD %5	0.03	0.19	0.056	0.010	0.026	0.031	0.019	0.21	0.255
	Ca (%)			Mg (%)			B (ppm)		
	root	leaf	fruit	root	leaf	fruit	root	leaf	fruit
52/1-E43	0.17 cde	3.39 b	0.30 ef	0.13 f	0.77 cde	0.18 c	13.53 cd	46.74 c	4.48 f
21/3F	0.19 bc	3.38 b	0.31 e	0.31 ab	0.93 ab	0.18 c	16.13 a	38.95 d	4.64 ef
17/3N	0.20 b	3.83 a	0.38 cd	0.21 d	1.03 a	0.21 ab	15.20 ab	55.94 b	7.83 b
637 Ca	0.23 a	3.71 a	0.32 e	0.29 bc	0.83 c	0.22 a	15.21 a	30.39 e	5.21 de
MFDCa1	0.17 de	3 c	0.41 c	0.27 c	0.77 cd	0.17 cd	12.14 de	41.22 d	5.53 d
E43 F	0.19 b	3.21 bc	0.27 fg	0.32 a	0.95 b	0.21 ab	10.60 f	37.36 d	7.09 c
52/1	0.10 g	3.15 bc	0.38 d	0.16 e	0.70 e	0.16 de	13.77 bc	25.04 f	3.15 g
21/3+637Ca	0.12 f	2.62 d	0.26 g	0.17 e	0.59 f	0.14 e	13.15 cd	39.11 d	4.48 f
52/1 Zeatin	0.18 bcd	3.07 c	0.46 b	0.30 ab	0.75 de	0.20 b	11.44 ef	31.03 e	9 a
Control	0.16 e	2.95 c	0.51 a	0.30 ab	0.77 cde	0.22 ab	11.52 ef	68.82 a	8.83 a
LSD %5	0.016	0.289	0.033	0.024	0.068	0.018	1.431	3.982	0.609
	S (%)			Fe (ppm)			Mn (ppm)		
	root	leaf	fruit	root	leaf	fruit	root	leaf	fruit
52/1-E43	0.07 e	0.38 c	0.26 ab	1503 b	105.2 a	22.5 g	70.08 b	60.47 f	29.62 abc
21/3F	0.11 d	0.44 b	0.25 ab	1490 b	109 a	46 e	65.06 c	70.76 e	27.99 bcd
17/3N	0.10 d	0.47 a	0.24 bc	1477 b	91.2 b	59.2 d	64.48 c	77.75 d	26.32 d
637 Ca	0.11 d	0.20 e	0.24 bc	1770 a	30 f	102.5 a	78.10 a	85.25 bc	22.51 e
MFDCa1	0.23 bc	0.21 e	0.23 cd	1308 c	30.7 f	55 d	18.98 g	92.13 a	32.20 a
E43 F	0.25 b	0.30 d	0.24 bc	1819 a	56.7 d	78 c	37.78 de	84.01 cd	30.04 abc
52/1	0.28 a	0.20 e	0.24 bc	583 f	40.5 e	26.2 g	37.07 e	91.45 ab	30.22 abc
21/3+637Ca	0.29 a	0.36 c	0.26 a	511 f	26.2 f	84 b	42.30 d	85.6 abc	30.54 ab
52/1 Zeatin	0.23 bc	0.31 d	0.23 cd	920 d	60.7 d	39 f	39.51 de	83.61 cd	29.19 bc
Control	0.23 bc	0.30 d	0.22 d	714 e	70.5 c	33.2 f	28.65 f	91.56 ab	27.46 cd
LSD %5	0.015	0.025	0.018	129.5	7.69	5.75	4.90	6.848	2.86
	Zn (ppm)			Cu (ppm)					
	root	leaf	fruit	root	leaf	fruit			
52/1-E43	39.29 g	90.08 cde	80.54 b	50.25 b	24.48 a	13.77 cde			
21/3F	51.21 ef	91.03 cde	78.32 bc	48.26 b	18.40 c	14.8 bc			
17/3N	47.71 f	87.02 ef	78.34 bc	35.3 e	16.46 d	13.35 de			
637 Ca	54.42 e	100.95 a	73.25 cd	42.57 d	15.86 d	11.18 f			
MFDCa1	69.38 cd	81.90 f	64.57 e	36.6 e	11.48 e	16.92 a			
E43 F	73.56 bc	90.39 cde	70.94 d	54.82 a	21.38 b	14.06 cde			
52/1	87.18 a	99.72 ab	84.09 b	47.13 bc	16.29 d	15.55 b			
21/3+637Ca	86.03 a	94.08 bcd	93.71 a	57.89 a	12.14 e	15.8 ab			
52/1 Zeatin	64.51 d	97.19 abc	79.61 b	43.5 cd	16.37 d	14.63 cde			
Control	78.25 b	90.08 de	79.03 b	35.94 e	18.39 c	13.11 e			
LSD %5	4.900	6.828	5.787	3.964	1.787	1.293			

In different PGPR applications, the biggest fruit (183 g) was determined in 17/3N application and the highest plant length was 212 cm in 17/3N and 21/3+637Ca and 210 cm in 52/1 Zeatin applications which were the same as control application. The maximum length between nodes (8,9 cm) was found in the control application and the minimum length between nodes was reported as 8.0 and 8.2 cm in 52/1-E43, E43F and 21/3+637Ca applications. The best root neck diameter was obtained from 21/3+637Ca (19.7 mm) application. PGPR application have a positive effect on plant length, root length, stem thickness, wet plant weight and dry plant weight of tomato (Wei et al. 2009). Similarly, PGPR applications have positively affected the fruit number, plant length, fruit weight, pH and fruit hardness of cucumber (Seymen et al. 2010).

Analysis of mineral contents of root, leaf and fruit samples of tomato, E43F and 637Ca application gave the highest total N result and all PGPR applications affected the intake of P content. In terms of K, 637Ca and E43F applications gave the best result. 17/3N, 21/3F, 637Ca and 52/1-E43 applications positively affected the Ca content and E43F, 637Ca and 21/3F applications gave the best Mg content. S content was high in all the applications. 52/1-E43, 21/3F and 17/3N application positively affected the Fe content and all the applications except 637Ca and 17/3N application importantly affected the Mn content. 52/1 and 21/3+637Ca application gave the best Zn content and 52/1-E43 and E43F application gave the best Cu content, and in terms of B contents, all the PGPR applications except E43F application have positive effect on B content. PGPR increased in organic and inorganic soluble phosphor with microbial metabolites causing plant development and producing organic acid and acid phosphate increases the intake of mineral contents (Kucey et al. 1989; Kumar and Narula 1999; Puente et al. 2004; Çakmakçı et al. 2005). Çakmakçı et al. (2005) reported that *Bacillus* M-13 and *Bacillus* RC07 are soluble P and NO3-N is fixing N2. *Bacillus* OSU-142, *Paenibacillus* RC05 and *Rhodobacter* RC04 have increased the P and N uptake. Additionally, *Bacillus* RC07 and *Bacillus* M-13 had arranged in soil pH and affected by soluble calcium phosphate. Karlıdağ et al. (2007) reported that OSU-142 bacterial application increased the N contents of apple leaf and M3 bacterial application increased the P content. The applications increased Ca, Fe and Zn content in leaf. PGPR application have increased intake of N, P and K as well as the other mineral elements from the plant (Dobbelaere et al. 2003). Khan (2005) reported that PGPR like *Pseudomonas* and *Acinetobacter* have increased Fe, Zn, Mg, Ca, K, and P contents in plant.

In the present study, effects of different PGPR application on yield, plant characteristics and mineral contents of tomato grown under greenhouse conditions were investigated and the outcomes were in accordance with the previous findings. 21/3F, 52/1 and 21/3+637Ca application gave the best results in terms of the yield. Therefore, the mentioned bacteria could be suggested for the greenhouse tomato growers. The 637 Ca, E43F and 21/3+637 Ca applications had also positive effects on mineral content of tomato.

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