Determination of the Effects of Bacterial Fertilizer on Yield and Growth Parameters of Tomato

A. Dursun¹, E. Yildirim¹, M. Turan², M. Ekinci¹, R. Kul¹, and F. Parlakova Karagöz¹*

ABSTRACT

Use of fertilizers is important in agricultural production. In particular, it is more focused on organic fertilizer that increases yield and quality of crops and is not harmful to environment at the same time. In this study, the effect of bacterial biofertilizers on yield and some quality parameters were analyzed in two tomato cultivars (Solanum lycopersicum L., cv. Cevahir F1 and Pala F1) in greenhouse conditions. Three different concentrations (1, 3, and 5 gL⁻¹) and control i.e. uninoculated) and two different bacterial fertilizers including A: Azotobacter spp. (1×10⁹ CFU), and B: mixture of Bacillus subtilis and Bacillus megatarium (1×10⁹ UFC) were evaluated in a completely randomized design with 3 replications. The treatments were applied one week after planting of the seedlings. The solutions were given to the root zone of the plant and repeated 3 times at intervals of 10 days. Average fruit weight, fruit number per plant, fruit weight per plant, plant height, fruit width and length, total soluble solid, pH, ascorbic acid, chlorophyll content, dry matter yield and mineral content were evaluated on tomato. The effects of treatments were found significant on plant growth parameters. Bacterial fertilization increased yield and other parameters in all treatments. Besides, the effects of treatments were significant on mineral content of tomato fruits.

Keywords: Biofertilizer, PGPR, Plant development, Solanum lycopersicum L.

INTRODUCTION

In the production of horticultural crops, the producers and consumers having high education and income levels, especially in the developed countries, have attempted to produce clean products that do not harm the natural balance, do not pollute the environment, and are not toxic to humans and other living things. This production system is called biological, ecological or organic agriculture (Er and Başalma, 2008; Ozyazıcı et al., 2010; Kodaş, 2011).

Organic fertilizer and plant wastes are used in organic farming to improve the physical, biological, and chemical properties of the soil; in this way, the continuity of soil fertility is provided. In this agricultural system, crop rotations, organic wastes, animal fertilizers, green fertilizers and mineral rocks are used for feeding the soil and provide the plant nutrients. In addition, bacterial fertilizers are also used as soil improvers. Bacterial fertilizers refer to containing active strains of microorganisms mainly Plant Growth-Promoting Rhizobacteria (PGPR) in sufficient numbers. They are used to either fix atmospheric nitrogen or solubilize plant nutrients like phosphates, and stimulate plant growth through synthesis of growth-promoting substances (Tilak, 1991; García-Fraile, et al. 2017). Moreover, bacterial fertilizers use in agricultural fields is reasonable due to their
plant nutrients content and high humic acid and low toxic element content.

Plant roots take up essential plant nutrients from the soil (Mills and Jones, 1996; Fageria, 2016), therefore, enhanced plant development depends on good root growth. Promotion of root growth by PGPR is one of the important potential and organic tools for increasing nutrient uptake (Lucy et al., 2004; Biswas et al., 2000; Adesemoye et al., 2009). In previous studies, it was found that PGPR could promote and increase plant growth and yield in mulberry (Sudhakar et al., 2000), apricot (Esitken et al., 2002, 2003), sugar beet and barley (Cakmakci et al., 2001), tomato and pepper (Sahin et al., 2000), bean (Diéz-Méndez et al., 2015) and spinach (Jiménez-Gómez et al., 2018).

Almost all of the vegetables, due to substances they contain, as well as to protect and improve human health, to increase in their effects, are also depend on grown by organic means (Ozer, 2017).

Tomato (Solanum lycopersicum L.) is one of the most produced and economically important vegetables grown worldwide (FAOSTAT, 2017). The aim of this study was to determine the effects of two different certifiable organic bacterial fertilizer on growth and yield of tomato under greenhouse conditions.

MATERIALS AND METHODS

Growth Conditions and Plant Materials

This study was conducted under greenhouse conditions at Ataturk University, Turkey, in 2016. Used greenhouse was 12.5 m wide and 20 m long (250 m²). The sidewalls were 70 cm high, with glass cover and natural ventilation from the roof. Two tomato cultivars (Solanum lycopersicum L., cv. Cevahir F1 and Pala F1) were cultivated under natural light conditions. The seedlings of tomato cultivars were purchased from a commercial company in Erzincan, Turkey. Tomato seedlings were planted with 50 cm row spacing and 50 cm on-row plant spacing in the second week of May, in 2016. The experiment ended on 15 October in the same year.

Bacterial Fertilizers

Three different concentrations (1, 3, and 5 gL⁻¹ and control (un-inoculated) and two different and certifiable bacterial fertilizers including A: Azotobacter spp. ((1×10⁹ UFC) and B: mixture of Bacillus subtilis and Bacillus megatarium (1×10⁹ UFC) were used in this study. The bacterial fertilizers were obtained from Professor Dr. Metin Turan (Yeditepe University, Department of Genetics and Bioengineering, Istanbul, Turkey). These bacterial fertilizers contained also 15% organic matter, 6% organic C, 13% humic+fulvic acid and enzyme, acid phosphatase, urease, denitrogenase, protease, (30 U mL⁻¹ from each) besides the PGPR used in the present study.

Application Procedure

The treatments included three different doses of bacterial fertilizers (1, 3, and 5 gL⁻¹) and control (uninoculated). This experiment consisted of a completely randomized design with 3 replications and each replication had 10 plants. The treatments were applied one week after planting of the seedlings. The solutions were given to the root zone of the plants and repeated 3 times at intervals of 10 days.

Data Collection and Statistical Analysis

The measurements taken included average fruit weight (g) (Biçer, 2011), fruit number per plant, fruit weight per plant, plant length (cm), fruit width and length (cm), total soluble solid (“Brix) (using refractometer, with the refractive index accuracy of ±0.0002 and the “Brix range of 0–95%, with temperature correction.) (Bao et al., 2014), pH (using a pH meter, with an accuracy of
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0.001.) (Bao et al., 2014), ascorbic acid (mg 100 g$^{-1}$) (with a Merck reflectometer set (Merck RQflex) (Ozer, 2017), chlorophyll content [A chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan) was used] (Sahin et al. 2018), dry matter yield (%) and mineral yield in tomato fruit. Macro and micro nutrients (N, K, P, Mg, S, Ca, Na, Fe, Mn, Zn, Cu, Pb, B and Cd) contents of fruits were also determined. Plant samples were oven-dried at 68°C for 48 hours and were then ground. The Kjeldahl method and a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Königswinter, Germany) were used to determine total N (Sahin et al. 2018). Potassium (K), Ca and Mg were determined after wet digestion of dried and ground sub-samples in a H$_2$SO$_4$ -Se-Salicylic acid mixture. Phosphorus (P) was determined spectrophotometrically by the vanadomolybdophosphoric-yellow method (Lott et al., 1956). Potassium (K) and Ca were determined by flame photometry, and Mg, Cu, Fe, Mn, Na, Zn, Pb, B and Cd were determined by atomic absorption spectrometry using the methods of AOAC, (1990). Boron was determined, after dry-ashing of plant samples, spectrophotometrically at 550 nm by the curcumin method (Odom, 1992). All data in the present study were processed by SPSS and the means were separated by Duncan’s multiple range tests.

RESULTS AND DISCUSSION

Plant Growth

Significant differences were observed between Pala F1 and Cevahir F1 cultivars in terms of the evaluated parameters, except for plant height, fruit length, and chlorophyll content. Application of B-5 significantly increased fruit number per plant (6.83), fruit weight per plant (2.16 kg), total soluble solid (6.23 (°Brix)), ascorbic acid (173.50 mg 100 g$^{-1}$), chlorophyll content and dry matter yield (5.87 %) when compared to the control plants (Table 1). Similar results have been reported by Jackson et al. (1964) and Tilak, (1991) in tomato. They found that inoculation with Azotobacter quickened the stem and leaf growth of tomato. In addition, De Silva et al. (2000) reported that the leaf area and stem diameter of high bush blueberry was increased by applying PGPR. Pirlik et al. (2007) determined that inoculation of PGPR increased yield and growth in apple.

Both bacterial fertilizers were found statistically significant in terms of ascorbic acid and chlorophyll content between cultivars and applications. The higher ascorbic acid and chlorophyll content were found in B-5. Bacterial fertilizers were found as increasing in ascorbic acid (Aiyer et al., 1964; Bangerth, 1976) and chlorophyll content (Zodape et al., 2011) in tomatoes.

Fruit Nutrient Contents

The effects of bacterial fertilizer applications on mineral (N, P, Mg, Ca, Na, K, Cu, Mn, Fe and Zn) contents of tomato were significant at P< 0.05, 0.01 and 0.001 (Table 2). All bacterial fertilizer applications affected the plants by increasing N, P, K, Mn, Zn, Pb, B and Cd contents of the fruits (Table 2).

The highest average K (23767.50 mg kg$^{-1}$) and B (26.01 mg kg$^{-1}$) contents were obtained from A-5 application in both tomato cultivars. B-3 and A-3 applications increased N content of the fruit in Pala F1 cultivar. In addition, Azotobacter spp. (1×10$^8$) (A) treatment increased Pb, B and Cd contents of the fruit in Cevahir F1 cultivar. As the concentration of organic bacterial fertilizer increase N, P, K, Ca and Mn contents of fruits increased in the present study (Table 2).

Kalantari et al. (2010) reported that application of compost and vermicompost increased the concentrations of P, K, Ca, and Mg in the shoot. However, Mg, Pb, and Zn declined with increase in the concentration of organic bacterial fertilizer in present study (Table 2). Yıldırım et al. (2010) reported
Table 1. Effect of different bacterial fertilizers on plant growth, yield and quality of fruit. *

<table>
<thead>
<tr>
<th>Treatments/Cultivars</th>
<th>Fruit number per plant</th>
<th>Fruit weight per plant (kg)</th>
<th>Average weight (kg) per fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pala F1</td>
<td>Cevahir</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td>4.24 c*</td>
<td>19.57 m</td>
<td>11.90 NS</td>
</tr>
<tr>
<td>A-1</td>
<td>5.89 ab</td>
<td>19.72</td>
<td>12.8</td>
</tr>
<tr>
<td>B-1</td>
<td>4.49 bc</td>
<td>20</td>
<td>12.24</td>
</tr>
<tr>
<td>A-3</td>
<td>5.67 abc</td>
<td>19.81</td>
<td>12.74</td>
</tr>
<tr>
<td>B-3</td>
<td>5.50 abc</td>
<td>20.52</td>
<td>13.01</td>
</tr>
<tr>
<td>A-5</td>
<td>5.76 abc</td>
<td>18.05</td>
<td>11.9</td>
</tr>
<tr>
<td>B-5</td>
<td>6.83 a</td>
<td>20.79</td>
<td>13.81</td>
</tr>
<tr>
<td>Mean</td>
<td>5.48 ***</td>
<td>19.78</td>
<td>12.63</td>
</tr>
</tbody>
</table>

**Note:** A: Bacterial fertilizer of Azotobacter spp. (1×10^6); B: Bacterial fertilizer mixture of Bacillus subtilis and Bacillus megatarius (1×10^6); Control: 0; A/B-1: 1 g L^-1; A/B-3: 3 g L^-1; A/B-5: 5 g L^-1. * P< 0.05, ** P< 0.01, *** P< 0.001. Means sharing similar letter are statistically not different.
### Table 2. Effect of different bacterial fertilizers on fruit chemical contents of tomato cultivars.

<table>
<thead>
<tr>
<th>Treatments / Cultivars</th>
<th>N (%)</th>
<th>P (mg kg⁻¹)</th>
<th>K (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pala F1</td>
<td>3.35***</td>
<td>3800.33***</td>
<td>19646.67***</td>
</tr>
<tr>
<td>Cevahir F1</td>
<td>3.55***</td>
<td>3822.17***</td>
<td>20975.00***</td>
</tr>
<tr>
<td>Control</td>
<td>2.36 b***</td>
<td>3444.00 c**</td>
<td>22303.33 C**</td>
</tr>
<tr>
<td>A-1</td>
<td>3.53</td>
<td>32.44 AB</td>
<td>21258.24 AB</td>
</tr>
<tr>
<td>B-1</td>
<td>3.46</td>
<td>3.16 B</td>
<td>21889.17 ABC</td>
</tr>
<tr>
<td>A-3</td>
<td>3.7</td>
<td>3.42 AB</td>
<td>23548.33 A</td>
</tr>
<tr>
<td>B-3</td>
<td>3.84</td>
<td>4.014.67 a</td>
<td>23532.67 AB</td>
</tr>
<tr>
<td>A-5</td>
<td>3.8</td>
<td>3.45 AB</td>
<td>23986.67 A</td>
</tr>
<tr>
<td>B-5</td>
<td>3.64</td>
<td>3.36 AB</td>
<td>23767.50 A</td>
</tr>
<tr>
<td>Mean</td>
<td>3.62</td>
<td>3726.24 ***</td>
<td>2582.14</td>
</tr>
</tbody>
</table>

### Additional Information

A: Bacterial fertilizer of Azotobacter spp.  
B: Bacterial fertilizer mixture of Bacillus subtilis and Bacillus megatarium (1×10⁸); Control: 0; A/B-1: 1 g L⁻¹; A/B-3: 3 g L⁻¹; A/B-5: 5 g L⁻¹. * P < 0.05, ** P < 0.01, *** P < 0.001. Means sharing similar letter are statistically not different.
that the yield, growth, and nutrition of broccoli plant under organic growing conditions significantly increased (Turan et al., 2004).

Also, Pirilak et al. (2007) found that inoculation of PGPR increased N, K, and Mn contents in apple. It is commonly known that increased N content in the plant results in higher uptake of nutrients elements such as K, Ca, Mg and P from the soil (Marschner, 1995).

The data presented in this study are in agreement with previous studies in that the amount of P, K, Ca, and Mg was significantly increased, probably, by N₂-fixing activity of the bacterial population.

CONCLUSIONS

In conclusion, bacterial fertilizers containing strains of microorganisms mainly plant growth-promoting rhizobacteria in sufficient numbers can be environmentally safe means of converting into an acceptable source of organic matter. Bacterial biofertilizers are excellent material for use in intensive vegetable production, as it improves yield and nutrition of the tomato. The results of our experiment may lead to increase in organic and high quality tomato production grown in the greenhouse conditions.

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بعین اثر کود باکتریایی بر عملکرد و پارامترهای رشد گوجه فرنگی

ادرسون، ا. ایلدیرین، م. تری، م. اکین، ر. کول، و. ف. باراکاکوا کاراگوز

چکیده

در تولید محصولات کشاورزی، مصرف کود از اهمیت بروزدار است. تاکید این امر به ویژه بر کود آلی است که میزان عملکرد و کیفیت محصول در افزایش داده و در عین حال به محیط زیست صدهم نمی‌زند. در این پژوهش، اثر مصرف کود باکتریایی روی عملکرد و برخی پارامترهای کیفیت محصول Cevahir F1 و Pala F1 (Solanum lycopersicum L) در شرایط گلخانه بررسی شد. به این منظور، سطح غلظت (0.1 و 5 میلی گرم در لیتر) از دو کود متفاوت شامل کود A: Azotobacter spp. (1x10^9 UFC) و کود B: مخلوطی از Bacillus megatatarium (1x10^9 UFC) و Bacillus subtilis در یک طرح آماری کاملاً تصادفی در سه تکرار ارزیابی شد. تیمار یک کود مصرف شد. محلول های آزمایش سه بار با فواصل 10 روزه به ریشه‌های افزوده شد. اندازه‌گیری ها شامل میانگین وزن موهای نهایی، وزن موهای نهایی، تعداد میوه در هر بیه، تعداد میوه در هر بیه، طول و عرض میوه، کل مواد مایع، pH محلول، استیم اسکرابیک، محیط کلروفیل، عملکرد ماده خشک و عنصر معدنی بود. نتایج حاکی از معنادار بودن اثر تیمارها روی پارامترهای رشد گیاهی بود. درهمه تیمارها، کودهای باکتریایی منجر به افزایش عملکرد و دیگر پارامترهای رشد میوه بود. افزون بر آن، اثرات تیمارها روی میوه محیط معدنی در میوه‌های گوجه فرنگی معنادار بود.