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INOCULATION EFFECTS OF *PANTOEA AGGLOMERANS* STRAINS ON GROWTH AND CHEMICAL COMPOSITION OF PLUM

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□ *In this study, five non-pathogenic* Pantoea agglomerans *strains were utilized. The objective of this study was to test for biochemical characteristics of these strains, and to evaluate their inoculation effects on fruit set rate, fruit pomological traits, fruit chemical compositions and some vegetative parameters of plum cultivar 'Stanley'. The results showed that some of the tested strains had beneficial effects on the fruit set rate, fruit pomological traits, fruit chemical composition and/or some vegetative growth parameters of plum in comparison to the control. In conclusion, tested* Pantoea agglomerans *strains (especially RK-85) are the suitable inoculants for plum cultivation in cold areas such as Erzurum, and these strains may be considered as biofertilizer and protector sensitive plants against frost damage by applying in suitable timing and dose.*

Keywords: frost damage, *Pantoea agglomerans*, PGPR, plant growth, plum, stanley

INTRODUCTION

Plum has a wide distribution area and can be grown in different ecological conditions all around of the world. 'Stanley' plum cultivar is included in *Prunus domestica* L. group called the European plums. This cultivar is consumed as dried, fresh, and partially canned.

Plant growth regulators such as inorganic fertilizers (Sezen, 1995; Quaggio et al., 2002; Amiri et al., 2008), natural biostimulators (Boehme et al., 2005), and some phytohormones such as indole-3-acetic acid (IAA) (Westwood, 1993; Jeon et al., 2003; Egamberdiyeva 2005), cytokinins (García de Salamone et al., 2001) and gibberellins (Gutiérrez-Mañero et al., 2001) were carried out increasing fruit yield, quality and plant growth by applying

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in suitable timing and dose (Esitken et al., 2003; Vessey, 2003). Moreover, microbial antagonists used as a biocontrol agent has also shown indirect positive effects on plant growth as a promising alternative to chemicals by means of the production of siderophores, the synthesis of antibiotics, enzymes, antimicrobial compounds and competition with detrimental microorganisms (Nunes et al., 2001; Teixido et al., 2001; Dobbelaere et al., 2002; Bonaterna et al., 2003; Dey et al., 2004; Lucy et al., 2004; Frances et al., 2006).

Some bacterial strains called as plant growth promoting rhizobacteria (PGPR) in the genera *Pseudomonas* and *Bacillus* (Cakmakci et al., 2001) and endophytic bacterial strains in the genera *Pantoea*, *Enterobacter*, *Klebsilla*, *Burkholderia*, *Pneumoniae* and *Stenotrophomonas* have received increasing attention because of their association with important crops and potential to enhance plant growth in recent years (Brandl et al., 1996; Rodriguez and Fraga, 1999; Bloemberg and Lugtenberg, 2001; Esitken et al., 2003; Vessey, 2003; Fuente-Ramirez and Caballero-Mellado, 2005). The PGPR bacteria called as natural fertilizers offer a powerful and environmentally friendly alternative to the use of chemical fertilizers. *Enterobacter agglomerans*, now reclassified as *Pantoea agglomerans* or *Erwinia herbicola*, also induced plant growth (Lindow et al., 1998; Fuente-Ramirez and Caballero-Mellado, 2005; Sergeeva et al., 2007).

In conclusion, there are many studies concerned with the PGPR and endophytic bacteria. However, there are not any studies testing the effect of *P. agglomerans* strains on fruit set, pomological traits, some vegetative parameters, and chemical composition of 'Stanley' cultivar. The objective of this study was to determine the effects of five *P. agglomerans* strains (RK-79, RK-85, RK-86, RK-123, RK-153) on fruit set, fruit quality traits, chemical composition, plant growth and nutrient composition of 'Stanley' cultivar grown economically in eastern Anatolia region of Turkey.

MATERIAL AND METHODS

Bacterial Strains

A total of five *P. agglomerans* strains (RK-79, RK-85, RK-86, RK123, and RK-153) were used in this study. They were isolated from aerial part of pome fruits grown in eastern Anatolia region of Turkey, and selected of a total of 324 strains. In our previous study, it was seen that these non-pathogenic strains had strong antagonistic activities against some plant pathogenic bacteria (Kotan, 2002; Kotan et al., 2004; Kotan and Sahin, 2006). These strains were by using MIDI (Microbial Identification System, Inc., Newark, DE, version 5.0) (Paisley, 1995) and BIOLOG system (Biolog Inc, Hayward, Ca, USA) (Praphailong et al., 1997). All of the bacterial strains were tested for hypersensitivity on tobacco plants (*Nicotina tabacum* L. var. 'Samsun') as

described by Klement et al. (1964) and pathogenicity on young Golden Delicious apple shoots as described previously (Kotan et al., 2006). The bacterial cultures were stored at 80°C in%15 glycerol and Luria Broth (LB) to use further studies.

Biochemical Characterization of the Bacterial Strains

Nitrate reduction and arginine dihydrolase were investigated according to the methods described by Fahy and Hayward (1983). Production of yellow fluorescence pigment was tested on King's B medium (KB) and was checked under ultraviolet-visible (UV) light after 1–3 days. Levan production was tested on Nutrient Agar (NA) (Difco) with 50 g l-1 sucrose and was recorded after 1 and 2 days. In addition, all of the bacterial strains were also tested for growth in N-free *Azotobacter* medium (Eskew et al., 1977), posphate solubilization (Nautiyal et al., 2000).

Orchard Experiment

This investigation was carried out at Research and Application Orchard of Department of Horticulture at Agriculture Faculty of Atatürk University in Erzurum province, Turkey with 1850 m altitude in 2006 and 2007. 'Stanley' plum cultivar of 11–12 years old grafted on wild plum (*Prunus spinosa* L.) used as plant materials. This cultivar is suitable to the ecological conditions of the region, and its commercial potential is very high. In this experiment, twelve plum trees were used in completely randomized design. The bacterial cultures were grown on NA for 24–48 h at 27°C and suspended in sterile distilled water (sdH_2O). Final concentration of the bacterial cell suspensions was adjusted to 1×10^9 CFU ml^{-1}. Absorbance of the bacterial suspension was measured by spectrophotometerically at 660 nm and appropriately diluted to 1×10^9 CFU ml^{-1} in sdH_2O. Two liters of these bacterial suspensions were applied to the trees (Esitken et al., 2003). The sdH_2O was used as negative control. The applications were repeated to same trees in both years. The main branches selected randomly from four different directions of each tree were considered as replication.

Fruit Set

The flowers on main branches in swelling/blooming periods from four different directions of applied trees were determined by counting and labeled. Fruit set rates were determined by counting after small fruit drop (I. drop) and after final drop. The values obtained by counting in two periods were calculated by flower number and obtained percent values (II. drop) (Karakurt, 2006).

Fruit Pomological Traits

Ten fruit were randomly harvested from each branch to determine pomological traits of fruit. The mean weight and pip weight of these fruit were obtained by balance with 0.01 g sensitivity; fruit volume by measuring overflowing water; specific gravity of fruit as d = m/V; fruit width, length, fruit stalk length and stalk thickness by digital compass.

Fruit Chemical Analyses

Some chemical analyses were performed on same fruit on which pomological analyses were done. Total soluble solids (TSS) by digital refractometer; titrable acidity by 0.1 N sodium hydroxide (NaOH) (Pirlak et al., 2003) and glucose, fructose, ascorbic acid, malic acid and pH by RQflex plus 10 Reflectometer were determined.

Plant Growth Parameters

Average shoot lengths and shoot thickness were measured and shoot numbers were counted, leaf areas were measured with a CI 202 portable digital area-meter. All measurements were carried out in the last of vegetative growth period (Aslantas et al., 2007).

Data Analysis

The data of this investigation were evaluated using SPSS software program (SPSS, Chicago, IL, USA) and means were separated by Duncan's multiple range tests. Variance analyses were performed after the data with percent (%) values were applied to angle transformation and the data of both years were evaluated separately.

RESULTS

Identification and Biochemical Test Results of the Bacterial Strains

The identification, utilization of carbon sources and some biochemical test results of bacterial strains used in this study were given in Table 1. According to MIS and BIOLOG results, all strains were identified as *P. agglomerans*. We determined that the all strains have a high degree (from 57.89% to 78.94%) of utilization of carbon sources by using BIOLOG system. All strains were capable of nitrogen fixation. Four strains (RK-79, RK-85, RK-86, and RK-153) were also able to solubilize phosphate. Fluorescence pigment on KB, nitrate reduction activity, arginine dihydrolase and levan production results of all strains were negative.

TABLE 1 MIS and BIOLOG results of the bacterial strains used in this study, their similarity indexes, host and location information, percentage utilization of carbon sources and some biochemical characteristics

Strain	MIS and BIOLOG result	MIS/BIOLOG similarity index (%)	Host	Location	UCS (%)	GN	PS	NR	AD	LP	FP
RK-79	*P. agglomerans*	0.762/0.55	Apple	Oltu/Erzurum	63.15	+	+	−	−	−	−
RK-85	*P. agglomerans*	0.857/0.71	Apple	Bardız/Erzurum	57.89	+	+	−	−	−	−
RK-86	*P. agglomerans*	0.698/0.56	Apple	Bardız/Erzurum	58.21	w+	+	−	−	−	−
RK-123	*P. agglomerans*	0.489/0.45	Apple	Bardız/Erzurum	78.94	+	−	−	−	−	−
RK-153	*P. agglomerans*	0.418/0.68	Pear	Yusufeli/Artvin	58.94	+	+	−	−	−	−

UCS (%): Percentage utilized carbon source; GN: Growth in N-free *Azotobacter* medium; PS: Phosphate solubilization; NR: Nitrate reduction activity; AD: Arginine dihydrolase; LP: Levan production; FP: Fluorescence pigment on KB.

Effect of the Bacterial Strains Tested on Fruit Set Rates

The effect of the *P. agglomerans* strains on fruit set rate of plum Stanley cultivar was showed in Table 2. According to these results, there were significant differences among applications in terms of fruit set in both years. The fruit set rate is statistically no significant at I. period in both years ($P < 0.05$), but all bacterial applications increased fruit set rate compared to control. There are statistically significant differences among the applications at II. period in 2006 ($P < 0.01$) and 2007 ($P < 0.05$) years. All bacterial applications increased the fruit set rate at II. period in 2007. Three strains (RK-153, RK-85 and RK-79) also increased the fruit set rate at II. period in 2006. The highest fruit set rate was obtained from *P. agglomerans* strain RK-85 (27.75%)

TABLE 2 The effect of *P. agglomerans* strains tested on fruit set rate of 'Stanley' cultivar in 2006 and 2007

	Fruit set rates (%)			
	2006		2007	
Treatment	I. Period	II. Period	I. Period	II. Period
RK-153	28.54	20.99^{ab}	67.12	45.95^{a}
RK-123	35.69	12.59^{cd}	66.53	29.04^{a}
RK-86	22.68	$15.57b^{cd}$	56.43	34.87^{a}
RK-85	36.51	27.75^{a}	55.81	29.36^{a}
RK-79	30.99	16.27^{bc}	71.86	43.46^{a}
Control	22.11	9.77^{d}	52.87	10.09^{b}
Average	29.42^{ns}	17.16**	61.77^{ns}	32.13*

Data in columns with different letters are statistically different according to Duncan's multiple range tests at $P < 0.05$ and $P < 0.01$; * and **: means followed within each column are significant different according to $P < 0.05$ and $P < 0.01$, respectively; ns: means followed within each column are not significant different according to both $P < 0.05$ and $P < 0.01$.

at II. period in 2006 and *P. agglomerans* strain RK-153 (45.95%) at II. period in 2007 year compared to control (9.77%).

Effect of the Bacterial Strains Tested on Fruit Pomological Traits

The effect of the strains on pomological parameters of 'Stanley' cultivar are given in Table 3. Some of the tested bacterial strains increased pomological parameters compared to control in 2006 and/or 2007 years. It was determined that the bacterial applications had a statistically significant effect ($P < 0.05$) on fruit width, fruit length, fruit weight, fruit volume and pip weight; and statistically significant ($P < 0.01$) on fruit specific gravity; and non-significant on fruit stalk length and thickness in 2006 year. The highest fruit weight and pip weight by strain RK-153 (37.15 mm; 1.85 g, respectively); and fruit length, fruit weight and fruit volume by strain RK-123 (48.03 mm; 36.19 g; 31.00 mL, respectively) were acquired in 2006 year. Bacterial applications had a statistically significant effect ($P < 0.05$) on fruit stalk thickness; a statistically significant effect ($P < 0.01$) on fruit width and fruit volume; and a nonsignificant effect on fruit length, fruit weight, fruit specific gravity, pip weight and fruit stalk length in 2007. The highest fruit width and fruit

TABLE 3 The effect of *P. agglomerans* strains tested on fruit pomological traits of 'Stanley' cultivar in 2006 and 2007

Treatment	FWi (mm)	FLe (mm)	FW (mm)	FV (ml)	FSG (g/ml)	PW (g)	FSL (mm)	FST (mm)
				2006				
RK-153	37.15^{a}	47.20^{a}	34.75^{a}	31.00^{a}	1.12^{bc}	1.85^{a}	20.68	1.83
RK-123	36.98^{a}	48.03^{a}	36.19^{a}	31.00^{a}	1.17^{b}	1.70^{ab}	20.76	1.62
RK-86	35.43^{a}	47.00^{a}	31.83^{a}	29.50^{a}	1.08^{c}	1.54^{bc}	19.87	1.70
RK-85	35.61^{a}	45.36^{a}	31.99^{a}	29.00^{a}	1.10^{bc}	1.60^{abc}	20.32	1.81
RK-79	35.94^{a}	47.97^{a}	33.86^{a}	27.00^{a}	1.26^{a}	1.76^{ab}	20.21	1.89
Control	29.29^{b}	38.91^{b}	20.27^{b}	18.00^{b}	0.91^{d}	1.37^{c}	19.67	1.46
Average	35.07*	45.74*	31.48*	27.58*	1.10**	1.63*	20.25^{ns}	1.72^{ns}
				2007				
RK-153	37.25^{a}	48.32	35.85	31.50^{b}	1.14	2.04	29.29	1.71^{ab}
RK-123	37.77^{a}	46.19	34.03	36.50^{a}	0.93	2.05	27.85	1.64^{abc}
RK-86	35.86^{ab}	47.52	32.18	30.50^{b}	1.06	2.25	29.01	1.78^{a}
RK-85	34.95^{bc}	47.41	31.60	29.50^{b}	1.07	2.11	27.35	1.52^{bc}
RK-79	33.91^{bc}	46.12	27.61	29.50^{b}	0.94	1.91	27.17	1.58^{abc}
Control	33.47^{c}	45.39	26.04	28.32^{c}	0.92	1.91	26.09	1.42^{c}
Average	35.53**	46.82^{ns}	31.22^{ns}	30.97**	1.01^{ns}	2.04^{ns}	27.79^{ns}	1.61*

FWi: Fruit width (mm); FL: fruit length (mm); FWe: fruit weight (mm); FV: fruit volume (ml); FS: fruit specific gravity (g/ml); PW: pip weight (g); FS: fruit stalk length (mm); FS: fruit stalk thickness (mm). Data in columns with different letters are statistically different according to Duncan's multiple range tests at $P < 0.05$ and $P < 0.01$. * and **: means followed within each column are significant different according to $P < 0.05$ and $P < 0.01$, respectively. ns: means followed within each column are not significant different according to both $P < 0.05$ and $P < 0.01$.

volume by strain RK-123 (37.77 mm; 36.50 mL, respectively) and fruit stalk thickness by strain RK-86 (1.78 mm) were acquired in 2007 year.

Effect of the Bacterial Strains Tested on Fruit Chemical Compositions

The fruit chemical analyses results are given in Table 4. The all bacterial applications had statistically significant effect only at $P < 0.01$ on whole chemical parameters of the plum fruit in both years. Strain RK-85 had the highest total soluble solid content (18.10%; 14.90%, respectively) compared to the control in 2006 and 2007 years. Strain RK-153 and RK-123 applications had the lowest total soluble solid content (15.65%; 15.40%, respectively) compared to the control (16.50%) in 2006; and strain RK-153 applications had the lowest total soluble solid content (11.25%) compared to the control (12.60%) in 2007 year. Strain RK-153 applications had the highest glucose and fructose and titrable acidity (4.55%; 7.01%, 1.61%, respectively) in 2006 and (4.05%; 4.35%, 1.55%, respectively) in 2007 year. Strain RK-85 applications had the highest ascorbic acid, malic acid and pH (1.45%; 0.33%; 4.25, respectively) in 2006 year and (1.08%; 0.36%; 4.25, respectively) in 2007.

TABLE 4 The effect of *P. agglomerans* strains on fruit chemical composition of 'Stanley' cultivar in 2006 and 2007

Treatment	TSS (%)	Glu (%)	Frc (%)	Asc (%)	Mal (%)	Tit (%)	pH
			2006				
RK-153	15.65^{d}	4.55^{a}	7.01^{a}	1.35^{b}	0.25^{d}	1.61^{a}	4.15^{a}
RK-123	15.40^{d}	4.25^{b}	4.45^{d}	0.70^{c}	0.28^{c}	1.23^{b}	3.95^{b}
RK-86	16.40^{c}	4.45^{a}	5.35^{c}	0.45^{d}	0.29^{bc}	1.16^{c}	4.25^{a}
RK-85	18.10^{a}	3.65^{d}	3.85^{e}	1.45^{a}	0.33^{a}	1.23^{b}	4.25^{a}
RK-79	17.30^{b}	4.05^{c}	5.35^{c}	1.38^{ab}	0.23^{e}	1.09^{d}	4.15^{a}
Control	16.50^{c}	2.85^{e}	6.65^{b}	0.76^{c}	0.30^{b}	0.72^{e}	3.85^{b}
Average	16.56*	3.97*	5.44*	1.01*	0.28*	1.17*	4.10*
			2007				
RK-153	11.25^{d}	4.05^{a}	4.35^{a}	0.91^{d}	0.24^{e}	1.55^{a}	3.95^{cd}
RK-123	14.55^{a}	3.65^{b}	4.13^{b}	0.79^{e}	0.34^{b}	1.48^{b}	4.05^{bc}
RK-86	14.75^{a}	3.25^{c}	3.53^{cd}	1.04^{b}	0.36^{a}	1.35^{d}	4.15^{ab}
RK-85	14.90^{a}	3.25^{c}	3.65^{d}	1.08^{a}	0.36^{a}	1.35^{d}	4.25^{a}
RK-79	13.40^{b}	2.85^{d}	3.45^{e}	1.05^{b}	0.32^{c}	1.42^{c}	4.25^{a}
Control	12.60^{c}	2.65^{e}	4.25^{ab}	0.94^{c}	0.28^{d}	1.28^{e}	3.85^{e}
Average	13.58*	3.28*	3.89*	0.96*	0.31*	1.40*	4.08*

TSS (%): total soluble solids; Glu (%): glucose; Frc (%): fructose; Asc (%): ascorbic acid; Mal (%): malic acid; Tit (%): titrable acid. Data in columns with different letters are statistically different according to Duncan's multiple range tests at $P < 0.05$ and $P < 0.01$. *: means followed within each column are significant different according to $P < 0.01$.

TABLE 5 The effect of *P. agglomerans* strains on some vegetative growth parameters of 'Stanley' cultivar in 2006 and 2007

	Vegetative growth parameter					
	2006			2007		
Treatment	LA (cm^2)	SL (cm)	ST (mm)	LA (cm^2)	SL (cm)	ST (mm)
RK-153	13.68^{ab}	19.50^{b}	3.86^{bc}	11.32^{b}	16.50^{bc}	3.75^{b}
RK-123	14.87^{a}	25.00^{a}	4.42^{ab}	11.46^{ab}	24.50^{ab}	4.30^{ab}
RK-86	12.58^{bc}	18.00^{b}	4.31^{ab}	11.45^{ab}	17.00^{bc}	4.19^{ab}
RK-85	14.33^{ab}	25.00^{a}	4.77^{a}	10.72^{b}	27.50^{a}	4.63^{a}
RK-79	15.28^{a}	21.00^{b}	4.65^{a}	12.33^{a}	19.00^{bc}	4.52^{a}
Control	10.99^{c}	15.50^{b}	3.79^{c}	8.13^{c}	13.00^{c}	3.69^{b}
Average	13.62*	20.67**	4.30*	10.90**	19.58*	4.18*

LA (cm^2): leaf area; SL (cm): shoot length; ST (mm): shoot thickness. Data in columns with different letters are statistically different according to Duncan's multiple range tests at $P < 0.05$ and $P < 0.01$. * and **: means followed within each column are significant different according to $P < 0.05$ and $P < 0.01$, respectively.

Effect of the Bacterial Strains Tested on Some Vegetative Growth Parameters

The results of vegetative growth parameters were given in Table 5. Bacterial applications had statistically significant ($P < 0.05$) effect on leaf area and shoot thickness, statistically significant ($P < 0.01$) effect on shoot length in 2006 and statistically significant ($P < 0.05$) effect on shoot length and shoot thickness, statistically significant effect ($P < 0.01$) on leaf area in 2007. All the bacterial applications increased the measured vegetative growth parameters compared to control in both years. Strain RK-79 applications provided the highest leaf area (15.85 cm^2; 12.33 cm^2, respectively) in 2006 and 2007 years. Strain RK-85 applications provided the highest shoot length (25.00 cm; 27. 50 cm, respectively) and shoot thickness (4.77 mm; 4.63 mm, respectively) compared to control in 2006 and 2007 years.

DISCUSSION

Non-pathogenic bacteria are the most abundant inhabitants of the plant rhizosphere and phyllosphere. They can promote plant growth as well as suppress disease. For these reasons, they are very important for agriculture in order to promote the circulation of plant nutrients and reduce the need for chemical fertilizers. Some researchers reported that the bacterial treatments increased shoot length and shoot thickness in apricot (Esitken et al., 2003); in wheat (Khalid et al., 2004); in apple (Aslantas et al., 2007). Also, it was reported that bacterial treatments increased leaf area in rabbiteye blueberry (De Silva et al., 2000); in mulberry (Sudhakar et al., 2000); in apple (Aslantas et al., 2007). In the present study, our results showed that all strains also

increased fruit set rate and vegetative growth. Furthermore, some strains showed also positive or negative effect on fruit pomological traits and fruit chemical composition. There were partial differences between both years that might be from climatic differences.

Fruit quality may be affected by the bacterial application indirectly because the phytohormones synthesed by bacteria may have effects on fruit set, fruit pomological traits and vegetative growth. It can be pointed out that all tested bacterial strains in this study have the increasing effect to vegetative growth by promoting production of auxins and cytokinin hormones in plant shoots. In addition, the bacterial applications increased vegetative growth such as leaf area, shoot development. These strains may affect on plant growth by means of increase in cell growth by acting such as auxine (IAA) (Lindow et al., 1998; Fuente-Ramirez and Caballero-Mellado 2005; Sergeeva et al., 2007) and cytokinin syntesis (Lichter et al., 1995; Omer et al., 2004). These phtohormones released by *P. agglomerans* may have positively affected fruit quality.

The cultural treatments such as fertilizers (Sezen, 1995; Quaggio et al., 2002), phytohormones (Westwood, 1993), bacterial treatments (Ngugi et al., 2005; Aslantas et al., 2007) affect fruit set. The phytohormones such as cytokinins and especially IAA released by *P. agglomerans* induced plant growth (Fuente-Ramirez and Caballero-Mellado 2005; Sergeeva et al., 2007). The bacterial applications carried out in full blooming time were thought to do the positive effect on fruit set. A direct effect of auxine on fruitlet abscission may potentially result in a delay of fruitlet abscission and/or an increase in set. This effect is only shown when ethylene synthesis is low or prevented. Although all strain were capable of nitrogen fixation and four strains were also able to solubilize phosphate, these properties are not considered as contributing to growth promotion under the condition used in this study.

One of the most important alternative control methods of plant disease is the use of biological control agents. The biological control offers a powerful and environmentally friendly alternative to the use of synthetic pesticides. Many PGPR stimulate the growth of plants by helping to control pathogenic organism. *P. agglomerans* is considered an epiphyte and is very common on the aerial parts of plants. Besides, some strains of them show biological control feature against many harmful microorganism, insects, and pests (Lucy et al., 2004; Frances et al., 2006). So far, a lot of studies have successfully employed to determine antagonistic bacteria to control plant disease. Furthermore, these studies have been generally focused on *P. agglomerans* (El-Goorani et al., 1992; Poppe et al., 2003; Hsieh et al., 2005). In our previous study, we determined that the strains used in this study significantly have inhibitory activity ranging from 50 mm to 95 mm inhibition zone on Petri plate against *Erwinia amylovora* and/or *Pseudomonas syringae* pv. *syringae*. Furthermore, the *in-vivo* tests results conducted using one year old Golden delicious apples shoots showed *P. agglomerans* RK-79 and RK-84

strains significantly reduced disease severity of *E. amylovora* compared with the positive control (treated pathogen). In addition, *P. agglomerans* RK-79 and RK-86 strains were also found effective antagonist of *P. s.* pv. *syringae* (Kotan, 2002; Kotan et al., 2004; Kotan and Sahin, 2006). This situation may also positively affect plant growth and indirectly fruit quality.

In addition, ice nucleation active bacterial (INA) population which triggers low temperature harm in plants (in general, by highly effecting between the range of −1°C, −5°C) reduced by application of naturally occurring or genetically engineered strains of *P. agglomerans* (Koda et al., 2000), *P. syringae* (Buttner and Amy, 1989). In this study, the used bacterial strains may positively act on plant growth by suppressing INA population on plant materials in the experiment region (altitude 1850 m) where the temperature difference between day and night is high and temperature decreases to 0°C below even in May month when full blooming occurs. Koda et al. (2000) reported that *P. agglomerans* strain IFO12686 produced distinctive proteins that could protect the freeze labile enzyme lactate dehydrogenase against freeze-thaw denaturation. We determined that the all strains have a high degree (from 57.89% to 78.94%) of utilization of carbon sources by using BIOLOG system. For this reason, we think that there is an important correlation between carbon source utilization of tested strains and their effectiveness on fruit set rate and vegetative growth parameters of 'Stanley' cultivar.

In conclusion, our results showed that some of the tested strains have beneficial effects on the fruit set rate, fruit pomological traits, fruit chemical composition and/or some vegetative growth parameters of plum in comparison to the control. Although all strain were capable of nitrogen fixation and four strains were also able to solubilize phosphate, we think that only these properties are not considered as contributing to growth promotion. It is supposed that the plants sprayed with bacteria may be protected from freeze injuries to some extent. The tested *P. agglomerans* strains (especially RK-85) are the suitable inoculants for plum cultivation in cold areas such as Erzurum, and these strains may be considered as biofertilizer and protector sensitive plants against frost damage by applying in suitable timing and dose. Therefore, they may be considered as biofertilizer for fruit, vegetable and ornamental plants production in sustainable and ecological agricultural systems.

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