Shrub rose Rosa damascena flowering productivity responding to the soil PGPR bacteria and foliar amino acids

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Abstract

The experiment was conducted for two 2023-2024 consecutive growing seasons, to evaluate the effect of soil drenching with the PGPR Bacillus subtilis, Pseudomonas fluorescens, or Azotobacter chroococcum, and spraying with commercial amino acids at 0, 1.5, 3, or 4.5 g L-1 on plant height and flowering indicators in three varieties of Rosa damascena (red, pink and white). The effect of the treatments on leaf area, number of lateral branches, number of flowers, flower diameter, oil percent in flowers (%) and oil pH. The results showed that the highest leaf area and number of branches were recorded in the red rose. The PGPR A. chroococcum and P. fluorescens bacteria recorded higher value of leaf area and number of lateral branches compared to lower values in the B. subtilis treatment. All amino acid treatments led to higher values in most parameters compared to the control. In general, the number of flowers and petals were the highest in pink and red cultivars, and the highest values of the two indicators were recorded with biofertilization with B. subtilis and P. fluorescens. It was also noted that the number of flowers increased with increasing the concentration of amino acid to 4.5 mg L-1, but not the number of petals. The interaction of pink or red variety and P. fluorescens or Bacillus subtilis led to significantly higher increase in most parameters than other interaction treatments.

Keywords: Biofertilizer, plant hormones, ornamentals, rose water

Introduction

Rose (Rosa sp.) is one of the most popular cut horticultural species in the world [1]. It is one of the most well-known ornamental plants, the rose bush or (Rosa) and one of the oldest flowers in the world since 4000 BC [2]. It is considered one of the main cut flowers and in its use as ornamental plants, in addition to containing many active ingredients, rose flowers contain an essential oil known as rose oil [3]. The flowers are characterized by their aromatic scent, and the beauty of their multiple colors. The cut flowers are single, walnut or semi-walnut, their growth is tree-like, erect or climbing, and some are short. Their flowers live for a long period after harvest [5, 4]. The quality of the flower, especially the shape and structure of the petal during flower opening, the shape of the rose petals and the shape of the flower that determine the economic and aesthetic value of each variety [8, 7,6]. Temperature is the decisive factor in rose cultivation and flower production as well as the factor (light and illumination) affects the growth rate in most rose varieties [9]. The most important sources and plant nutrients that can be introduced to the plant through the soil are fertilizers which contain basic elements that work to ensure the flowering of plants, increase the biomass of the plant and improve productivity in terms of quantity and quality [10]. The use of microorganisms and their biological activity in the soil is one of the most important agricultural techniques as a safe alternative in providing essential nutrients to plants compared to chemical fertilizers with harmful residues to plants and the environment [11]. The use of biological fertilizers is a major strategy for plant production because it protects plants and enhances plant resistance to environmental and biological stresses, increases yield while reducing production costs and ensuring the reduction of harmful residues [12]. The use of biological fertilizers is taken into consideration - one of the scientific methods that are safe for the environment, and is rich in nutrients such as calcium, potassium, magnesium, phosphorus, manganese, zinc, iron, cobalt and copper [13]. Studies have also focused on amino acids in plant nutrition, especially the amino acid lysine, which has shown an important role in the plant life cycle, as it regulates the morphologies of leaves and roots as the only known polar transport hormone [14, 15]. Therefore, this experiment was conducted with the aim of studying the effect of adding bacterial biofertilizers (three types of PGPR) and determining the most efficient type in improving flowering indicators in shrub rose plant varieties in the presence of vegetative spraying with different levels of commercial amino acids and determining the best concentration of amino acids and their reflection on plant height and flowering components of shrub rose.

Materials and methods

The experiment was carried out in the winter season of 2023 and repeated for the following winter season of 2024 at the Agricultural Research Station of the University of Kufa in Najaf Governorate. The soil and wooden canopy were prepared with 50% lighting. The seedlings were brought from a certified cooperative local nursery for commercial seedlings in Baghdad. Where the one-year-old seedlings were planted individually in 15 cm dia. pot containing river sand. Seedlings were transplanted on 12/31/2023 to 29 cm diameter and 30 cm height plastic pots containing sandy soil (mixed sand) and peat moss at a ratio of 1:3 with a total weight of 10 kg and at a rate of one plant/pot. The seedlings were maintained under wooden lathe house conditions. The soil mix medium was also analyzed to determine the components of peat moss (Table 1.(

Table1. Soil mix (growing medium) used in the study determined by its components and contents of some nutritional elements

Constituent	%
N	2.2 – 2.8
P_2O_5	0.1
K_2O	0.1
Na	≥0.01
CL	≥0.8
O.M.	3.2-4.8
PH	0.5-5.9
Moisture	12 – 15
C:N	1:14 - 1:18

Agricultural services were carried out during the experimental period, where all experimental plants were fertilized with 50 g per 20 liters of water with granular NPK compound fertilizer (0-46-18) and fertilization was repeated every 21 days for four times. The plants were irrigated uniformly and whenever

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needed before the planting medium was exposed to drought. The plants were covered during the winter with a thick polyethylene cover to protect the plants from low temperatures in winter, while the plants were covered with a light mesh cover (Saran) to protect the plants from high temperatures in summer.

Preparation of biofertilizers

The biofertilizer was prepared from bacterial isolates (Azotobacter chroococcum, Pseudomonas fluorescens, Bacillus subtilis) which were obtained from the accredited Al-Amin Laboratory in Najaf. The bacterial inoculum was activated and multiplied on the autoclave sterile Nutrient broth liquid medium, where the inoculated media plates were incubated at 28 ±2°C in a shaking incubator for 7 days. Then, the bacterial treatments were added to the rose seedlings as soil injection on 1/25/2024, and the number of bacterial colonies was counted every three weeks (Table2.(

Table 2. Number of bacterial colonies of three bacteria types in two dilutions estimated after 20 days of inoculation DPI on three cultivars of bush roses

Rose type	**No. of days post inoculation DPI**	***Azotobacter chroococcum***		***Pseudomonas fluorescens***		***Bacillus subtilis***	
		N*10^{-5}	**N*10^{-7}**	**N*10^{-5}**	**N*10^{-7}**	**N*10^{-5}**	**N*10^{-7}**
Red	**20**	**23**	**4**	**55**	**12**	**30**	**3**
	40	**35**	**12**	**66**	**20**	**73**	**68**
	60	**29**	**12**	**60**	**7**	**110**	**23**
Pink	**20**	**43**	**6**	**18**	**2**	**15**	**2**
	40	**46**	**23**	**90**	**72**	**80**	**69**
	60	**25**	**15**	**33**	**4**	**33**	**9**
White	**20**	**3**	**0**	**6**	**1**	**14**	**1**
	40	**40**	**13**	**59**	**35**	**90**	**76**
	60	**50**	**20**	**125**	**9**	**95**	**14**

Estimation of bacterial numbers in the inoculum

The Plate count Technique was followed to calculate the total number of bacterial species in dilutions 5-1 to 7-1 by transferring 1 ml of the plates that were incubated at 28±2 °C for three days. Then the numbers of bacterial cells were calculated [16] (Kirchman et al., 1982).

The experimental treatments were three replications distributed in factorial split-split plot design, where the main plot is a three varieties of shrub roses (red, pink, and white). The inoculation with biofertilizers (Bacillus subtilis, Pseudomonas fluorescens, Azotobacter chroococcum) was in the sub-plot, while spraying with amino acids at 0, 1.5, 3, or 4.5) mg L-1 was in the sub-sub plot. Amino acids were sprayed five times, the first

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after 21 days of transplanting and four subsequent sprays with a time interval of 14 days. Spraying was carefully applied in the early morning using a 2-liter hand sprayer. All service operations were carried out from irrigation and weeding to all treatments whenever necessary. The experiment was performed twice for two successive growing seasons .

Studied indicators

At the end of the experiment for each season, data were taken for the studied indicators: plant height (cm), number of leaves (leaf plant-1), number of flowers (flower plant-1): the number of flowers formed was calculated for each plant from the beginning of flowering until the end of the plant, number of flower petals (petal flower-1). The qualitative yield measures also included the percentage of essential oil in the flowers and the specific weight of the resulting oil: The specific weight of the oil was estimated in a volume of 100 microliters of essential oil in a precise volumetric pipette using a sensitive balance (200, Japanese HR) at a temperature of 25°C by dividing the weight of that volume by the weight of the same volume of distilled water [17.[

Statistical analysis

The data were analyzed statistically using the computed statistical analysis program Genstat 12 (VSN, 2009) [56] and ANOVA tables were performed. The averages were also compared using the least significant difference (LSD) at a probability level of 0.05 [18.[

Results and discussion

Regarding plant height, the red cultivar plants were superior for both seasons, recording 43.11 and 48.11 cm, compared to the lowest plant height of the white cultivar of 39.21 and 44.21 cm respectively (Table3). The results showed that B. subtilis inoculum led to a significant increase in plant height to 48.65 and 53.65 cm for both seasons, respectively, with a significant difference from the control plants, which recorded 34.27 and 39.27 cm. It was also observed that soliar spray with amino acids at a concentration of 4.5 mg L-1 recorded the highest average plant height of 48.64 and 53.64 cm, compared to lower concentrations. In general, the highest significant increase was in the treatment of B. subtilis bacteria interaction and spraying with amino acids at 4.5 mg L-1 in the red variety, which recorded the highest values for the two seasons of 64.70 and 69.70 cm, respectively, with a significant difference from most of the interaction treatments, regardless of the concentration or type of bacteria (Table3.(

The process of photosynthesis in plants can be affected by amino acids, as the amino acids Glycine and Glutamine are essential compounds in the construction of chlorophyll. Hance, their availability in sufficient quantities increases the efficiency of the photosynthesis process and the manufacture of nutrients. In addition, the concentration of amino acids inside the cells affects the process of stomata opening movement, as glutamic acid acts as an osmotic factor in guard cells, which encourages the opening of the stomata. Adding amino acids reduces the osmotic potential and thus reduces the water potential, increasing the cell's ability to draw water and dissolved nutrients from the growth medium, and thus the vegetative growth of the plant increases [19]. This is due to amino acids, which are considered a source of proteins, including enzymes important for vital processes. There is evidence that amino acids are the main component of the precursor of polyamines, which are necessary to regulate plant growth and development. This is consistent with findings of by Hadi et al. (2002) [20], or it may be attributed to the fact that amino acids work to regulate osmosis, maintain membranes, and stabilize proteins [21.[

The results indicate that the red rose plants recorded the highest average number of flowers 14.84 and 17.84 flowers plant-1 with a significant difference from the white variety plants with the lowest number of flowers of 12.86 and 15.86 flowers.plant-1 for the two seasons respectively. As for the B. subtilis biofertilizer treatments, it was the highest among the other species with a number of flowers of 20.92 and 23.92 flowers.plant-1 with a significant difference from the untreated plants which gave the lowest number of flowers of 6.87 and 9.87 flowers.plant-1 for the two seasons respectively. It was also observed that the number of flowers increased with increasing amino acid concentration where the concentration of 4.5 mg L-1 recorded the highest number of flowers of rose plants 16.37 and 19.37 flowers plant-1 compared to 11.20 and 14.20 flower plant-1 for the control plants for the two seasons respectively .

Table3. Effect of soil application with three PGPR bacteria and foliar amino acids concentrations on plant height in three varieties of shrub rose

Treatments		**1st season 2023**					**2nd season 2024**				
		Amino acid concentrations (mg L^{-1})					**Amino acid concentrations (mg L^{-1})**				
Rose varieties	**PGPR Bacteria**	**0**	**1.5**	**3**	**4.5**	**Average**	**0**	**1.5**	**3**	**4.5**	**Average**
Red var.	**0**	33.60	35.50	37.60	37.90	36.15	38.60	40.50	42.60	42.90	41.15
	A.chrocum	35.60	37.10	41.90	45.40	40.01	40.60	42.10	46.90	50.40	45.01
	P.florescens	37.10	42.30	48.80	54.60	45.70	42.10	47.30	53.80	59.60	50.70
	B.subtilis	37.20	46.10	54.40	64.70	50.57	42.20	51.10	59.40	69.70	55.57
Pink var.	**0**	32.30	33.50	35.60	35.80	34.30	37.30	38.50	40.60	40.80	39.30
	A.chrocum	33.60	35.10	40.10	43.40	38.05	38.60	40.10	45.10	48.40	43.05
	P.florescens	35.10	40.20	46.50	52.40	43.55	40.10	45.20	51.50	57.40	48.55

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	B.subtilis	35.80	44.00	52.00	62.70	48.62	40.80	49.10	57.10	67.70	53.62
White var.	**0**	30.50	31.60	33.50	33.80	32.35	35.50	36.60	38.50	38.80	37.35
	A.chrocum	31.60	33.00	38.10	41.50	36.05	36.60	38.10	43.10	46.50	41.05
	P.florecens	33.20	38.20	44.50	50.90	41.7	38.20	43.20	49.50	55.90	46.70
	B.subtilis	34.10	42.40	49.90	60.60	46.75	39.10	47.40	54.90	65.60	51.75
L.S.D. (*P*≤0.05)		1.399				0.612	1.399				0.612
AA means		34.14	38.24	43.58	48.64		39.14	43.24	48.58	53.64	
L.S.D. (*P*≤0.05)		0.421				Var. average	0.421				Var. average
Var × AA	**RED**	35.88	40.23	45.68	50.65	43.11	40.88	45.23	50.68	55.65	48.11
	PINK	34.20	38.20	43.55	48.58	41.13	39.20	43.20	48.55	53.58	46.13
	WHITE	32.35	36.3	41.50	46.70	39.21	37.35	41.30	46.50	51.70	44.21
L.S.D. (*P*≤0.05)		0.636				0.083	0.636				0.082
						PGPR Means					PGPR means
PGPR × AA	**0**	32.13	33.53	35.57	35.83	34.27	37.13	38.53	40.57	40.83	39.27
	A.chrocum	33.60	35.07	40.03	43.43	38.03	38.60	40.07	45.03	48.43	43.03
	P.floresens	35.13	40.23	46.60	52.63	43.65	40.13	45.23	51.60	57.63	48.65
	B.subtilis	35.70	44.13	52.10	62.67	48.65	40.70	49.13	57.10	67.67	53.65
L.S.D. (*P*≤0.05)		0.831				0.405	0.831				0.404

It is also noted (Table 4) that there is a significant effect of the interaction of the red cultivar plants and B. subtilis bacteria or amino acid concentration, which led to an increase in the number of flowers compared to the single factor. In general, the interaction of the red cultivar, B. subtilis bacteria and amino acids at a concentration of 4.5 mg L-1

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recorded a significant superiority in the number of flowers per plant, reaching 25.50 and 28.50 flower plant-1 compared to all other interaction treatments, with a large significant difference from the control treatment of the white rose in the absence of other factors.

The findings showed that the highest average number of petals per a flower was recorded in the red variety plants, 23.15 and 21.15 petal flower-1, significantly superior to the white rose plants, with the lowest number of petals, 19.21 and 17.46 petals flower-1 for the two seasons, respectively. The results also showed that there was a significant increase in the number of petals when the plants were treated with B. subtilis bacteria, 23.98 and 22.14 petals flower-1, compared to the control treatment plants, which recorded 19.31 and 17.39 petal flower-1 for the two seasons, respectively. It was also noted that the amino acid concentrations did not differ significantly in their effect on the number of petals, although the spray treatment at a concentration of 4.5 mg L-1 recorded the highest average number of petals, reaching 23.65 and 21.65 petals. flower-1, with a significant difference from the control with the lowest number of petals, 18.35 and 16.68 petals flower-1 for the two seasons, respectively. It is noted (Table 5) that the interaction of the red variety plants and B. subtilis bacteria recorded higher rates of petal number, reaching 25.98 and 23.98 petals flower-1, compared to other interactions between the variety and the types of bacteria under study. In general, the highest averages of petal number were recorded in the interaction treatments between the red variety and the amino acid at a concentration of 4.5 mg L-1 or the interaction of the amino acid at the same concentration in the presence of biofertilizer with B. subtilis bacteria, compared to the rest of the types of interactions between the study factors (Table5.(

The results of Table (6) showed that the flower diameters of the red rose, 7.43 and 8.19 cm, did not differ significantly from those recorded for the pink variety flowers. However, a significant difference was noted compared to the flower diameter of the white cultivar, which showed the lowest flower diameters, 6.819 and 7.944 cm for the two seasons, respectively. Meanwhile, flower diameters increased significantly when plants were treated with P. fluorescens bacteria for the first season and B. subtilis bacteria for the second season, reaching 7.350 and 8.275 cm, compared to the control treatment plants, which recorded flower diameters that did not exceed 6.500 and 7.917 cm for the two seasons, respectively (Table6). The same table also showed that spraying with amino acids at a concentration of 4.5 mg L-1 had a greater effect than the lower concentrations, and the highest flower diameter was recorded at 8.158 and 9.325 cm, with a significant difference from the control plants, which recorded the lowest diameter of 5.075 and 5.850 cm for the two seasons, respectively. The highest average flower diameters were recorded in the interaction treatment of white cultivar plants and B. subtilis bacteria, and spraying with amino acids at a concentration of 4.5 mg L-1 for the first season, while the second season recorded the highest average flower diameter in the interaction treatment of the same factors, biofertilizer (B. subtilis) and amino acid concentration (4.5 mg L-1) in the red cultivar.

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Table4. Effect of soil application with three PGPR bacteria and foliar amino acids concentrations on number of flowers (flower plant-1) in three varieties of shrub rose

Treatments		1st season 2023					2nd season 2024				
		Amino acid concentrations (mg L^{-1})					Amino acid concentrations (mg L^{-1})				
Rose varieties	**PGPR Bacteria**	**0**	**1.5**	**3**	**4.5**	**Average**	**0**	**1.5**	**3**	**4.5**	**Average**
Red var.	**0**	5.50	7.40	8.40	10.40	7.92	8.50	10.40	11.40	13.4	10.93
	A.chrocum	9.10	11.40	13.20	14.40	12.03	12.10	14.40	16.20	17.4	15.03
	P.florescens	13.30	16.30	18.40	20.50	17.12	16.30	19.30	21.40	23.5	20.12
	B.subtilis	18.6	21.6	23.5	25.5	22.3	21.60	24.60	26.50	28.5	25.31
Pink var.	**0**	4.50	6.40	7.30	9.30	6.88	7.50	9.40	10.30	12.3	9.87
	A.chrocum	8.70	10.50	12.40	13.50	11.28	11.70	13.50	15.40	16.5	14.27
	P.florescens	13.4	15.5	17.4	19.50	16.45	16.40	18.50	20.40	22.5	19.45
	B.subtilis	18.5	20.4	21.7	23.20	20.95	21.50	23.40	24.70	26.2	23.95
White var.	**0**	3.70	5.40	6.40	7.70	5.81	6.70	8.40	9.40	10.7	8.81
	A.chrocum	7.60	9.50	11.50	12.40	10.25	10.60	12.50	14.50	15.4	13.25
	P.florecens	13.9	14.60	16.50	18.40	15.85	16.90	17.60	19.50	21.4	18.85
	B.subtilis	17.6	19.50	19.40	21.60	19.53	20.60	22.50	22.40	24.6	22.53
L.S.D. (*P*≤0.05)		1.149				0.608	1.149				0.608
AA means		11.2	13.2	14.7	16.4	11.2	13.2	14.7	16.4	11.2	

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L.S.D. (*P*≤0.05)		0.326				Var. average	0.326				Var. average
Var × AA	**RED**	11.6	14.2	15.9	17.7	14.84	14.63	17.18	18.88	20.70	17.84
	PINK	11.3	13.2	14.7	16.4	13.89	14.28	16.20	17.70	19.38	16.89
	WHITE	10.7	12.3	13.5	15.03	12.86	13.70	15.25	16.45	18.03	15.86
L.S.D. (*P*≤0.05)		0.572				0.312	0.572				0.312
						PGPR means					PGPR means
PGPR × AA	**0**	4.57	6.40	7.37	9.13	6.87	7.57	9.40	10.37	12.13	9.87
	A.chrocum	8.47	10.47	12.37	13.43	11.18	11.47	13.47	15.37	16.43	14.18
	P.floresens	13.5	15.5	17.4	19.5	16.48	16.53	18.47	20.43	22.47	19.48
	B.subtilis	18.2	20.5	21.5	23.4	20.92	21.23	23.50	24.53	26.43	23.92
L.S.D. (*P*≤0.05)		0.665				0.356	0.665				0.356

Table5. Effect of soil application with three PGPR bacteria and foliar amino acids concentrations on number of petals (petal flower-1) in three varieties of shrub rose

Treatments		**1st season 2023**					**2nd season 2024**				
		Amino acid concentrations (mg L^{-1})					**Amino acid concentrations (mg L^{-1})**				
Rose varieties	**PGPR Bacteria**	**0**	**1.5**	**3**	**4.5**	**Average**	**0**	**1.5**	**3**	**4.5**	**Average**
Red var.	**0**	18.2	20.3	22.3	24.1	21.23	16.2	18.3	20.3	22.1	19.23
	A.chrocum	19.1	21.4	23.4	24.5	22.10	17.1	19.4	21.4	22.5	20.10
	P.florescens	20.9	22.7	24.2	25.4	23.30	18.9	20.7	22.2	23.4	21.30
	B.subtilis	23.2	25.9	26.2	28.6	25.98	21.2	23.9	24.2	26.6	23.98
Pink	**0**	16.2	18.3	20.3	22.1	19.23	14.2	16.3	18.3	20.1	17.23

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var.	***A.chrocum***	17.1	19.4	21.4	22.5	20.10	16.1	17.4	19.4	20.5	18.35
	P.florescens	18.9	20.7	22.2	23.4	21.30	16.9	18.7	20.2	21.4	19.30
	B.subtilis	21.2	23.9	24.2	26.6	23.98	19.2	21.9	23.2	24.6	22.23
White var.	**0**	14.2	17.3	18.3	20.1	17.48	13.2	15.3	16.3	18.1	15.73
	A.chrocum	15.1	17.4	19.4	20.5	18.10	15.1	15.4	17.4	18.5	16.60
	P.florecens	16.9	18.7	20.2	21.4	19.30	14.9	16.7	18.2	19.4	17.30
	B.subtilis	19.2	21.9	22.2	24.6	21.98	17.2	19.9	21.2	22.6	20.23
L.S.D. (*P*≤0.05)		2.938				1.162	2.824				1.086
AA means		18.35	20.66	22.03	23.65		16.68	18.66	20.19	21.65	
L.S.D. (*P*≤0.05)		0.902				Var. average	0.871				Var. average
Var × AA	**RED**	20.35	22.58	24.03	25.65	23.15	18.35	20.58	22.03	23.65	21.15
	PINK	18.35	20.58	22.03	23.65	21.15	16.60	18.58	20.28	21.65	19.28
	WHITE	16.35	18.83	20.03	21.65	19.21	15.10	16.83	18.28	19.65	17.46
L.S.D. (*P*≤0.05)		1.356				0.107	1.32				1.32
						PGPR Means					PGPR means
PGPR × AA	**0**	16.2	18.63	20.3	22.1	19.31	14.5	16.6	18.3	20.1	17.39
	A.chrocum	17.1	19.4	21.4	22.5	20.10	16.1	17.4	19.4	20.5	18.35
	P.floresens	18.9	20.7	22.2	23.4	21.30	16.9	18.7	20.2	21.4	19.30
	B.subtilis	21.2	23.9	24.2	26.6	23.98	19.2	21.9	22.9	24.6	22.14
L.S.D. (*P*≤0.05)		1.737				0.772	1.664				0.714

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Table6. Effect of soil application with three PGPR bacteria and foliar amino acids concentrations on flower diameter (cm) in three varieties of shrub rose

Treatments		**1st season 2023**					**2nd season 2024**				
		Amino acid concentrations (mg L^{-1})					**Amino acid concentrations (mg L^{-1})**				
Rose varieties	**PGPR Bacteria**	**0**	**1.5**	**3**	**4.5**	**Average**	**0**	**1.5**	**3**	**4.5**	**Average**
Red var.	**0**	3.80	8.00	7.60	7.80	6.80	4.50	8.60	9.90	9.50	8.13
	A.chrocum	5.80	8.40	8.50	8.90	7.90	5.60	7.80	8.30	8.70	7.61
	P.florescens	6.20	7.70	8.10	8.30	7.58	6.90	7.60	9.40	9.50	8.35
	B.subtilis	6.20	7.60	7.60	8.40	7.45	7.30	7.60	9.60	10.20	8.68
Pink var.	**0**	4.40	6.30	7.00	7.50	6.30	4.70	8.20	9.10	9.90	7.95
	A.chrocum	4.50	7.70	7.40	8.00	6.90	5.50	8.70	8.40	9.10	7.91
	P.florescens	5.20	7.10	7.80	8.40	7.13	6.20	8.10	8.80	9.40	8.13
	B.subtilis	4.50	7.50	7.60	8.20	6.95	7.10	8.50	8.60	9.20	8.35
White var.	**0**	4.40	6.60	7.60	7.10	6.40	4.70	9.20	8.60	8.20	7.68
	A.chrocum	4.60	6.80	7.30	7.70	6.60	5.60	9.10	8.80	9.80	8.31
	P.florecens	5.90	6.60	8.40	8.50	7.35	6.10	8.50	8.40	9.10	8.01
	B.subtilis	5.40	6.60	8.60	9.20	7.45	6.10	8.20	7.50	9.40	7.81
L.S.D. ($P \leq 0.05$)		0.756				0.334	0.876				0.342
AA means		5.08	7.24	7.79	8.16		5.85	8.33	8.78	9.33	
L.S.D. ($P \leq 0.05$)		0.227				Var. average	0.269				Var. average
Var × AA	**RED**	5.50	7.93	7.95	8.35	7.43	6.08	7.91	9.31	9.48	8.19
	PINK	4.65	7.15	7.45	8.03	6.82	5.88	8.38	8.71	9.38	8.08
	WHITE	5.08	6.65	7.98	8.10	6.95	5.61	8.73	8.33	9.13	7.94

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L.S.D. (*P*≤0.05)		0.375				0.169	0.438				0.179
						PGPR means					PGPR means
PGPR × AA	**0**	4.20	6.97	7.40	7.43	6.50	4.63	8.67	9.17	9.21	7.92
	A.chrocum	4.97	7.63	7.73	8.20	7.13	5.57	8.51	8.51	9.17	7.93
	P.floresens	5.77	7.13	8.10	8.40	7.35	6.37	8.07	8.87	9.33	8.16
	B.subtilis	5.37	7.23	7.93	8.60	7.28	6.83	8.11	8.57	9.61	8.28
L.S.D. (*P*≤0.05)		0.438				0.196	0.506				0.199

Findings of this study showed the positive effect of the treatments in increasing plant growth indicators, especially plant height. These results are consistent with previous studies indicating the superiority of vegetative growth indicators, plant height and number of leaves, due to the addition of peat moss and amino acids to the growth medium, which stimulates an increase in vegetative growth characteristics [22,23,24,25]. It was found that spraying with amino acids led to a clear increase in plant growth. Kakoei and Salehi (2013) [26] explained that growing Spathiphyllum in different media containing perlite + sand at a ratio of 3:1 with added amino acids was the best in increasing the number of leaves. It was also shown [46] that mixing bacterial biofertilizer with soil planted with Zinnia elegans led to a positive effect on plant height and number of leaves, consistent with similar results [27] where adding 40% biofertilizer with soil planted with Calendula officinalis L. led to a significant increase in the number of leaves when using a growth medium mixture consisting of (3 mixture: 1 peat moss). A significant increase in vegetative growth characteristics was obtained. Amino acids have an effect on the structure and activity of some enzymes, opening of stomata, removing heavy metal toxins, and have a role in regulating the transport of ions and acting as osmo-regulators [28] [29] [30.[

The most important sources and plant nutrients that can be introduced to the plant through the soil are fertilizers, as they are considered one of the basic elements that work to ensure the prosperity of plants, which can work to increase the biomass of the plant and improve productivity in terms of quantity and quality [10]. The study found an increase in floral growth indicators due to the effect of treating the soil with peat moss and bacterial fertilizers. Organic matter (peat moss) generally maintains the temperature of the soil and increases biological activity in it as a result of the increase in the quantity and diversity of microorganisms due to biofertilizers. Thus, it contributes directly and indirectly to the growth and development of the plant, as it is either a growth stimulant due to an enzymatic or hormonal effect, or it affects the increase in the readiness of the elements originally present in the soil or added to it, leading to increased production and improved quality [31 .[

Al-Shaikhli (2010) [32] confirmed that peat moss medium with sandy soil is the best growing medium in terms of floral growth characteristics, number of flowers and number

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of petals. It was also noted that the growing medium to which biofertilizers are added is an important factor for the success of various propagation processes, which is positively reflected in the development and growth of seedlings. Biofertilizers (microbial inoculants) are a group of highly active microbial species that work to encourage the vital role in the soil and improve plant growth as they represent the natural environment for these organisms to live in. Since the root zone is rich in nutrients due to the accumulation of a variety of plant secretions such as organic acids, amino acids and sugars, which provides a rich source of energy and nutrients for bacteria [33 .[

Amino acids contribute to improving nutritional balance, which helps stimulate buds, regulate flowering rate, and regulate the transfer of solutes and mineral elements and their accumulation in flowers [34]. Amino acids play an important role in vital signaling when stimulating cell growth and increasing plant resistance to stress. They are an important source of carbon and energy supply and protecting the cell from ammonia poisoning [35]. Plant resistance to severe environmental conditions increases when treated with amino acids, as these compounds increase the effectiveness of oxidation and reduction enzymes (peroxidase and catalase), which play a defensive role in resisting unfavorable conditions in many plants [36, 37]. Youssef (2014) [38] mentioned that adding some amino acids to the cone flower plant (Echinacea purpurea) led to obtaining the largest number of flower heads with an increase in the fresh and dry weight of flower heads for each plant. It can be said that stimulating plant growth when treated with amino acids may be due to the vital role of these acids in stimulating cell division and elongation [39]. Adding biofertilizer to the soil of the zinnia plant led to a significant increase in the number of flowers, flower diameter, and flower stalk length and reduced the number of days required for flower buds to open [40]. Scientific research has shown that biofertilizers have a clear effect on the floral growth characteristics of plants [41]. It was reported that the increase in the number of stems and plant height attributed to the high nitrogen content in amino acids, as nitrogen increase cell proteins and stimulates the plant to produce auxins, which encourages cell division and thus increases the number of stems and increases the height of the plant [42.[

Free amino acids are an essential nitrogen source in the construction of enzymes and the preparation of energy that encourages vegetative and root growth [43]. Amino acids directly or indirectly affect the stimulation of physiological activities carried out by plants [44]. As for their role in building plant hormones, amino acids are the initiator of hormone formation. For example, methionine is the initiator of ethylene formation, and tryptophan is the initiator of auxin formation [45]. It was found [35, 46, 47] that the opening and closing of stomata can be controlled by increasing the plant's ability to photosynthesize by spraying with amino acids arginine and proline, which has a positive effect in increasing the number of leaves and flowers and improving their growth [48]. Amino acids are involved in the construction of other organic compounds such as amines, vitamins, alkaloids, enzymes and terpenoids [49]. Plants need amino acids basically for growth and increasing the yield in quantity and quality. The addition of amino acids through the leaves depends on the plant's need and the stage of plant growth. They are absorbed through the stomata in the leaves and the absorption process is affected by the temperature of the environment surrounding the plant [50 .[

Conclusion

Findings of this study showed that the rose varieties differed among each other in their flowering and flower quality indicators and in their responses to biofertilization and amino acids foliar spray. The highest growth and rose qualitative indicators were recorded in the red variety, followed by the pink one then the white rose. It was also found that the three PGPR bacteria had similar positive effect on number of leaves, but the P. fluorescens resulted in highest plant height. However, plant height was negatively affected by higher foliar amino acids concentrations. The best flowering measurements were obtained in the interaction treatment of the pink or red rose sprayed with 3 or 4.5 mg L-1 amino acids in the presence of B. subtilis. The flowering indicators were at highest values in pink and red variety fertilized with B. subtilis or P. fluorescens. Increasing amino acid concentration increased number of rose flowers, but not the number of petals per a flower.

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