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Effects of some plant growth promoting rhizobacteria (PGPR) strains on growth and flowering of chrysanthemum

A. KUMARI, R. K. GOYAL, M. CHOUDHARY AND [1]S. S. SINDHU

Department of Horticulture, College of Agriculture
CCS Haryana Agricultural University, Hisar-125004, Haryana
[1]Department of Microbiology, College of Basic Sciences & Humanities

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ABSTRACT

The present investigation was conducted in the screen-house of the Department of Horticulture, College of Agriculture, CCS Haryana Agricultural University, Hisar during the two successive seasons of 2011-12 and 2012-13 to investigate the potential effect of different strains of Bacillus and Pseudomonas on growth and flowering of chrysanthemum. The obtained results revealed that the inoculation of plants with strains of biofertilizers significantly improved the growth and flowering parameters. The maximum plant spread and fresh weight of plant were recorded in plants inoculated with PS_2 strain of Pseudomonas (CPA152) and BS_3 strain of Bacillus (SB127) in both the years. The dry weight of plant was noticed maximum with PS_3 strain of Pseudomonas (P20) and BS_2 strain of Bacillus (SB155) in first year and PS_2 strain of Pseudomonas (CPA152) and BS_3 strain of Bacillus (SB127) in second year. The maximum number of buds/plant was recorded with inoculation of PS_3 (P20) and PS_2 strains (CPA152) of Pseudomonas, whereas, among Bacillus strains, BS_3 (SB127) was recorded best in both the years. The minimum number of days to first flowering as well as longest flowering duration was recorded with application of PS_2 strain of Pseudomonas (CPA152) in both the years, and among Bacillus strains, BS_3 (SB127) and BS_2 strain (SB155) were found best in the year 2011-12 and 2012-13, respectively. The maximum flower size was noticed with PS_3 strain of Pseudomonas (P20) in first year whereas, in second year, the response of Pseudomonas strains was found non-significant. Among Bacillus strains, the plants inoculated with BS_3 (SB127) recorded maximum flower size. Flower stalk length was significantly influenced by different strains of Pseudomonas and Bacillus. The longest flower stalk was recorded in plants inoculated with PS_3 (P20) and PS_2 (CPA152) strains of Pseudomonas in the year 2011-12 and 2012-13, respectively. The plants inoculated with BS_3 strain of Bacillus (SB127) recorded maximum stalk length in the years. Maximum number of flowers/plant, fresh and dry weight of flower and flower yield/plant were recorded in plants inoculated with PS_2 strains of Pseudomonas (CPA152) and BS_3 strains of Bacillus (SB127). The number of suckers plant^{-1} was noticed maximum with PS_3 strains of Pseudomonas (P20) and BS_3 strains of Bacillus (SB127) in both the years.

***Keywords*: *Bacillus*, chrysanthemum, PGPR, *Pseudomonas*, rhizosphere bacteria**

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) also known as "Queen of the East" belongs to the family Asteraceae. It is one of the most widely cultivated garden flowers and ranks probably next to the rose in popularity (Prasad *et al*., 2012). It is preferred practically due to vast range of shapes and size of flowers, brilliance of colour tones, long lasting floret life, diversity of height and growth habit of the plant, especially hardy nature, relative ease to grow all the year round and versatility of use. The quality of chrysanthemum flowers is greatly influenced by the quantity of nutrients and sources of nutrients. At present, these nutrients are supplied through chemical fertilizers. The use of chemical fertilizers has resulted not only in the deterioration of soil health but also has led to some major environmental problems, such as soil and water pollution and other health related problems, besides increasing the input cost for crop production especially on the marginal farmers. So, there is an urgent need to recycle available organics and manipulate rhizospheric microflora in a more efficient way and improve and expand their usage. Many bacterial species, mostly associated with plant rhizosphere, have been tested and found to be beneficial for plant growth, yield, and crop quality. They have been called "plant growth promoting rhizobacteria (PGPR)". Plant growth promoting rhizobacteria (PGPR) are a group of bacteria that actively colonize plant roots and increase plant growth and yield (Wu *et al*., 2005). A large array of bacteria including species of *Pseudomonas*, *Azospirillum*, *Azotobacter*, *Klebsiella*, *Enterobacter*, *Alcaligenes*, *Arthrobacter*, *Burkholderia*, *Bacillus* and *Serratia* have reported as PGPR to enhance plant growth (Kloepper *et al*., 1989; Glick, 1995). Inoculation of crop plants

Email: anopflori.25@gmail.com

with certain strains of PGPR at an early stage of development improves biomass production through direct effects on root and shoots growth (Saharan and Nehra, 2011). The mechanisms by which PGPR promote plant growth are not fully understood, but it is believed that the plant growth promoting rhizobacteria enhance plant growth and yield either by direct or indirect mechanisms (Glick, 1995). The direct growth promoting mechanisms are as follows: the ability to produce phytohormons like IAA, GA, cytokinins and ethylene (Egamberdiyeva, 2007), asimbiotic N_2 fixation (Salantur *et al*., 2006), antagonism against phytopathogenic microorganisms by production of siderophores (Scher and Baker, 1982), and also solubilisation of mineral phosphates and other nutrients (Cattelan *et al*., 1999). The indirect mechanisms of plant growth promotion by PGPR include the extacellular production of antibiotics, synthesis of antifungal metabolites, production of fungal cell wall lysin enzymes (Ahmad *et al*., 2006; Bharathi *et al*., 2004), depletion of iron from the rhizosphere, competition for sites on roots and induced systemic resistance (Glick *et al*., 1999). In addition to these traits, plant growth promoting bacterial strains must be rhizospheric competent, able to survive and colonize in the rhizospheric soil (Cattelan *et al*., 1999). Thus the aim of this study was to determine the effect of plant growth promoting rhizobacteria on growth and flowering of chrysanthemum.

MATERIALS AND METHODS

The present experiment was carried out in the screen-house of the Department of Horticulture, College of Agriculture, CCS Haryana Agricultural University, Hisar during the year 2011-12 and 2012-13. Hisar is situated at 29° 10′ North latitude and 75° 46′ East longitude with an elevation of 215.2 meters above mean sea level. The tract falls in the semi-arid subtropical region having the characteristic extremes of weather conditions with hot dry winds during summers and severe cold in winters. For experimental purpose, soil was collected from pure sand dune near to Hisar and mixed thoroughly. Each pot was lined with polythene sheet and filled with 5 kg of soil. The experimental soil was sandy in texture having 0.19% organic carbon, 95.00 kg/hectare available nitrogen, 10.00 kg/hectare available phosphorus and 102.00 kg ha^1 available potassium. One month old rooted cuttings of chrysanthemum *cv.* “Dolly Orange” having almost equal size and vigour were transplanted in the centre of pot in the month of September. Soil was firmly pressed around the plant and light watering was done immediately. Three strains of *Bacillus* (BS_0- Control, BS_1- SYB101, BS_2- SB155 and BS_3- SB127), three strains of *Pseudomonas* (PS_0- Control, PS_1- WPS73, PS_2- CPA152 and PS_3-P20) and their combination were applied in three replications having CRD experimental design. In addition to above treatments, nitrogen @ 30 g m^2 or 150 ppm and phosphorus and potash each @ 20 g/m^2 or 100 ppm were also applied. Half dose of nitrogen and full dose of phosphorous and potash were applied as a basal dose just before planting of rooted cuttings, while the remaining half of the nitrogen was applied after 30 days of planting by top dressing method. *Bacillus* and *Pseudomonas* strains were applied to rhizosphere of the plant after 6 days of plantation as per treatments. Data on various growth and flowering parameters *viz*., plant spread (cm), fresh weight of plant (g), dry weight of plant (g), number of buds/plant, days to first flowering, duration of flowering (days), flower stalk length (cm), number of flowers per plant, fresh weight of flower (g) and number of suckers $plant^1$ were recorded and statistically analyzed. Fresh weight of plant was recorded at full bloom stage whereas, for estimation of dry weight of plant, the plant without roots was taken and placed in the hot air oven at 60 ^{0}C until the reduction in weight became constant. The dry matter weight was taken on digital weighing balance and expressed in grams (g).

RESULTS AND DISCUSSIONS

Plant spread (cm)

The perusal of data presented in table 1 indicates that plant spread significantly influenced by inoculation of *Pseudomonas* and *Bacillus* strains and their interactions. The maximum plant spread (18.60 and 17.44 cm) was recorded with the application of PS_2, which remained *at par* with PS_3 with the value of 18.32 and 17.40 cm in the year 2011-12 and 2012-13, respectively. Among the *Bacillus* strains, BS_3 treated plants were found best with respect to plant spread (19.17 and 18.00 cm), whereas, it was found minimum (14.77 and 14.18 cm) in control during the year 2011-12 and 2012-13, respectively.

Further, interpretation of data reveals that among interactions, BS_3PS_3 treatment combination was recorded the maximum plant spread (23.60 and 21.60 cm) in both the years, respectively, however, in second year, remained *at par* with BS_3PS_2 (20.97 cm) treatment combination. The minimum plant spread (12.58 and 12.60 cm) was recorded in control during both the years, respectively. The plant growth was more pronounced in response to PGPR application which might be due to multiple direct and indirect mechanisms of actions like increasing nutrient availability, synthesis of phytohormones and suppression of harmful microbes in rhizosphere (Saharan and Nehra, 2011).

Fresh weight of plant

The data pertaining to fresh weight of plant have been shown in table 2. It is evident from the data that fresh weight of plant was significantly influenced by the inoculation of different strains of *Pseudomonas* and *Bacillus*. The maximum fresh weight of plant (98.76 and 102.18 g) was obtained with the application of PS_2 in the year 2011-12 and 2012-13, respectively, which was *at par* with PS_3 (97.27 g) in the year 2011-12. The minimum fresh weight of plant (78.58 and 76.53 g) was recorded in control during both the years, respectively. Further, interpretation of data revealed that the maximum fresh weight of plant (98.70 and 99.57 g) was recorded with the application of BS_3 and minimum (76.78 and 74.00 g) with control during both the years, respectively.

Among the interactions between *Bacillus* and *Pseudomonas* strains, the maximum fresh weight of plant (106.7 g) was found with the application of BS_3PS_3 treatment, which was *at par* with BS_2PS_2 (105.1 g), BS_1PS_3 (103.9 g) and BS_3PS_2 (102.6 g) treatment combinations in the year 2011-12. In the year 2012-13, it was recorded maximum in application of BS_3PS_2 (110.67 g), which was *at par* with BS_2PS_2 (110.09 g) application. The minimum fresh weight of plant (66.53 and 64.03 g) was found in control during both the years, respectively. This might be due to the ability of biofertilizers to produce growth-promoting substances such as IAA and gibberellins like substances *viz*., vitamins, riboflavin, *etc*., which might have helped in increasing plant growth. Sukhda (1999) suggested that improvement in crop growth and quality of produce by producing plant hormones and solubilizing nutritive elements through biological process. The above findings are supported by the views of Prasad *et al.* (2012) in chrysanthemum and Hashemabadi *et al.* (2012) in African marigold.

Table 1: Effect of single and co-inoculation of PGPR on plant spread (cm) in chrysanthemum

Treatments	**2011-12**					**2012-13**				
	Biofertilizer strains					**Biofertilizer strains**				
	PS_0-Control	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**	**PS_0-Control**	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**
BS_0-Control	12.58	14.75	16.72	15.00	**14.77**	12.60	14.08	15.38	14.67	**14.18**
BS_1-SYB101	14.22	15.32	15.62	16.42	**15.39**	14.65	13.22	14.95	15.75	**14.64**
BS_2-SB155	13.70	14.55	19.75	18.25	**16.56**	13.63	14.22	18.47	17.58	**15.98**
BS_3-SB127	16.25	14.53	22.30	23.60	**19.17**	15.58	13.87	20.97	21.60	**18.00**
Mean	**14.19**	**14.79**	**18.60**	**18.32**		**14.12**	**13.85**	**17.44**	**17.40**	

LSD (0.05)	**2011-12**	**2012-13**
Pseudomonas	0.55	0.74
Bacillus	0.55	0.74
Pseudomonas × *Bacillus*	1.10	1.47

Table 2: Effect of single and co-inoculation of PGPR on fresh weight of plant (g) in chrysanthemum

Treatments	**2011-12**					**2012-13**				
	Biofertilizer strains					**Biofertilizer strains**				
	PS_0-Control	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**	**PS_0-Control**	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**
BS_0-Control	66.53	71.01	87.03	82.55	**76.78**	64.03	68.51	83.68	79.78	**74.00**
BS_1-SYB101	71.05	82.41	100.3	103.9	**89.40**	73.33	80.78	104.28	108.16	**91.64**
BS_2-SB155	86.0	92.18	105.1	96.02	**94.82**	83.83	94.47	110.09	101.29	**97.42**
BS_3-SB127	90.76	94.76	102.6	106.7	**98.70**	84.92	96.37	110.67	106.32	**99.57**
Mean	**78.58**	**85.09**	**98.76**	**97.27**		**76.53**	**85.03**	**102.18**	**98.89**	

LSD (0.05)	**2011-12**	**2012-13**
Pseudomonas	3.18	0.74
Bacillus	3.18	0.74
Pseudomonas × *Bacillus*	6.36	1.47

Dry weight of plant

It is inferred from the data presented in table 3 that dry weight of plant was observed maximum (11.23 g) with PS_3 inoculation, which remained at par with PS_2 (11.00 g) in the year 2011-12, whereas, in the year 2012-13, it was observed maximum with PS_2 (12.36 g). The minimum dry weight of plant (8.62 and 8.73 g) was found in control during both the years, respectively. Dua and Sindhu (2012) reported that *Pseudomonas* isolate WPS3 and WPS90 resulted in 131 and 47% increase in plant dry weight as compared to uninoculated control in wheat. Among the *Bacillus* strains, BS_2 treated plant showed maximum dry weight of plant (10.99 g), which was at par with BS_3 inoculation(10.93 g) in the year 2011-12, whereas, in the year 2012-13, it was noticed maximum (12.31 g) with BS_3 treatment. The minimum dry weight of plant (8.62 and 8.76 g) was recorded in control in both the years, respectively. Habib and Zaghloul (2012) also reported that the increase in root dry weight might be attributed to the activity of free-living bacteria of *Bacillus megatherium* found in the rhizosphere of roots as phosphate dissolving bacteria, which saved the available phosphate in chrysanthemum. The interaction between different strains of *Bacillus* and *Pseudomonas* was found to be non-significant in both the years of experimentation.

Number of buds per plant

The data pertaining to number of buds per plant are furnished in table 3 and revealed that the PS_3 (strain of *Pseudomonas*) treated plants recorded the maximum number of buds per plant (29.92), which was *at par* with PS_2 (29.33) in the year 2011-12, whereas, in the year 2012-13, it was noticed maximum (31.25) with PS_2 application, which was *at par* with PS_3 (30.00). The minimum number of buds per plant (19.92 and 22.25) was recorded in control during both the years, respectively. Further, it is also cleared from the data that the *Bacillus* strains significantly influenced the number of buds per plant. The maximum number of buds per plant (29.67 and 32.42) was observed with BS_3 application and the minimum (22.92 and 22.17) in control during both the years, respectively.

Among the interactions between *Pseudomonas* and *Bacillus* strains, the maximum number of buds per plant (35.67 and 36.00) was recorded with application of BS_3PS_3 in the year 2011-12 and 2012-13, respectively, however, in second year, it was at par with BS_3PS_2 (35.33) and BS_2PS_2 (33.67) treatment combinations. The minimum number of buds per plant (16.67 and 17.33) was observed with control during both the years, respectively. Sufficient N and P continuously maintained vegetative growth of plant, leading to increase in photosynthetic area, resulting in more accumulation of assimilates and their partitioning to the developing flower buds. Current results of our study are in line with the finding of Shivran *et al.* (2103), they reported that seed inoculation of fenugreek with single rhizobacterial bioformulation or combination of bioformulation resulted in higher number of pods per plant as compared to without inoculation.

Table 3: Effect of single and co-inoculation of PGPR on dry weight of plant (g) in chrysanthemum

Treatments	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
	PS_0-Control	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**	**PS_0-Control**	**PS_1-WPS73**	**PS_2-CPA152**	**PS_3-P20**	**Mean**
BS_0-Control	7.78	7.89	9.88	8.94	**8.62**	7.03	8.19	10.38	9.44	**8.76**
BS_1-SYB101	7.74	9.18	11.28	11.13	**9.83**	8.74	9.63	12.78	10.98	**10.53**
BS_2-SB155	9.91	10.16	11.84	12.06	**10.99**	8.74	9.63	12.78	10.98	**10.53**
BS_3-SB127	9.04	10.89	11.02	12.78	**10.93**	10.41	11.39	13.52	13.92	**12.31**
Mean	**8.62**	**9.53**	**11.00**	**11.23**		**8.73**	**9.71**	**12.36**	**11.33**	

LSD (0.05)	2011-12	2012-13
Pseudomonas	0.74	0.85
Bacillus	0.74	0.85
Pseudomonas × *Bacillus*	NS	NS

Table 4: Effect of single and co-inoculation of PGPR on number of buds per plant in chrysanthemum

Treatments	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	16.67	21.67	28.00	25.33	**22.92**	17.33	21.33	26.67	23.33	**22.17**
BS_1-SYB101	18.33	25.33	26.00	29.00	**24.67**	20.33	24.67	29.33	31.33	**26.42**
BS_2-SB155	20.33	23.67	31.33	29.67	**26.25**	23.67	28.33	33.67	29.33	**28.75**
BS_3-SB127	24.33	26.67	32.00	35.67	**29.67**	27.67	30.67	35.33	36.00	**32.42**
Mean	**19.92**	**24.34**	**29.33**	**29.92**		**22.25**	**26.25**	**31.25**	**30.00**	
LSD (0.05)	**2011-12**					**2012-13**				
Pseudomonas	1.33					1.29				
Bacillus	1.33					1.29				
Pseudomonas x *Bacillus*	2.66					2.59				

Table 5: Effect of single and co-inoculation of PGPR on number of days to first flowering in chrysanthemum

Treatments	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	91.00	89.00	78.33	82.00	**85.08**	92.33	90.67	81.33	85.67	**87.50**
BS_1-SYB101	89.33	86.00	84.67	78.33	**84.58**	90.00	87.00	87.67	78.33	**85.75**
BS_2-SB155	84.33	87.00	79.67	83.67	**83.67**	87.67	85.33	80.00	84.00	**83.11**
BS_3-SB127	84.67	79.00	77.00	78.33	**79.75**	85.67	87.00	75.33	80.67	**82.17**
Mean	**87.33**	**85.25**	**79.92**	**80.58**		**88.92**	**87.50**	**81.08**	**82.17**	
LSD (0.05)	**2011-12**					**2012-13**				
Pseudomonas	2.39					1.79				
Bacillus	2.39					1.79				
Pseudomonas × *Bacillus*	4.78					3.58				

Table 6: Effect of single and co-inoculation of PGPR on duration of flowering in chrysanthemum

Treatments	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	25.33	32.00	36.67	32.00	**31.50**	26.67	30.33	34.33	30.67	**30.50**
BS_1-SYB101	28.33	33.33	41.33	38.00	**35.25**	29.00	31.67	39.33	35.67	**33.92**
BS_2-SB155	29.67	34.33	43.33	40.00	**36.83**	31.00	34.33	45.67	42.00	**38.25**
BS_3-SB127	34.00	30.33	43.33	44.67	**38.08**	30.33	32.33	41.33	39.00	**35.75**
Mean	**29.33**	**32.50**	**41.17**	**38.67**		**29.25**	**32.17**	**40.17**	**36.83**	
LSD (0.05)	**2011-12**					**2012-13**				
Pseudomonas	1.46					1.72				
Bacillus	1.46					1.72				
Pseudomonas × *Bacillus*	2.92					3.44				

Table 7: Effect of single and co-inoculation of PGPR on flower stalk length (cm) in chrysanthemum

Treatments	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	4.45	5.05	5.53	5.32	**5.09**	4.17	5.13	5.50	5.60	**5.10**
BS_1-SYB101	4.92	5.67	5.77	6.05	**5.60**	5.13	5.17	5.53	5.47	**5.33**
BS_2-SB155	5.08	5.37	6.05	6.33	**5.71**	5.37	5.64	6.07	5.73	**5.70**
BS_3-SB127	5.62	5.50	6.13	6.02	**5.82**	5.43	5.93	6.30	6.17	**5.96**
Mean	**5.02**	**5.40**	**5.87**	**5.93**		**5.03**	**5.47**	**5.85**	**5.74**	

LSD (0.05)	2011-12	2012-13
Pseudomonas	0.27	0.24
Bacillus	0.27	0.24
Pseudomonas × *Bacillus*	NS	NS

Days to first flowering

The data pertaining to days to first flowering as influenced by different strains of *Pseudomonas* and *Bacillus* and their interaction are furnished in table 5. The results reveal that the minimum number of days taken to first flowering (79.92 and 81.08 days) was recorded with treatment PS_2, which was *at par* with PS_3 (80.58 and 82.17 days), and it was maximum (87.33 and 88.92 days) in control during the year 2011-12 and 2012-13, respectively. Among the *Bacillus* strains, BS_3 application recorded the minimum number of days taken to first flowering (79.75 and 82.17 days), whereas, in second year, it was *at par* with BS_2 (83.11 days). The maximum number of days taken to first flowering (85.08 and 87.50 days) was found in control during both the years, respectively.

The interactive effect of *Bacillus* and *Pseudomonas* was found to be significant in both the years. The minimum number of days taken to first flowering (77.00 and 75.33 days) was observed with BS_3PS_2 application during the year 2011-12 and 2012-13, respectively, which was *at par* with BS_0PS_2, BS_1PS_3, and BS_3PS_3 (78.33 days), BS_2PS_1 (79.00 days) and BS_2PS_2 (79.67 days) treatment combinations in the year 2011-12, whereas, in the year 2012-13, it was *at par* with BS_1PS_3 (78.33 days). The maximum number of days to first flowering (91.00 and 92.33 days) was observed with control during both the years, respectively. The earliness of flowering may be attributed to the presence of biofertilizers especially inoculation with *Bacillus* and *Pseudomonas* which consequently lead to flower initiation. This may be due to easy uptake of nutrients and simultaneous transport of growth promoting substances like cytokinins to the axil-lary buds resulting in breakage of apical dominance. Ulti-mately, they resulted in better sink for faster mobilization of photosynthates and early transformation of plant parts from vegetative to reproductive phase. Similar findings were published by Moghadam and Shoor (2013) in petunia and Mesharam (2008) in chrysanthemum. The obtained results are in agreement with those reported by Salma *et al*. (2013) and Singh *et al*. (2010) in gladiolus and Jayamma *et al*. (2008) in jasmine.

Duration of flowering (days)

The data regarding the duration of flowering as influenced by different strains of *Bacillus* and *Pseudomonas* and their interaction have been presented in table 6. Among *Pseudomonas* strains, the longest flowering duration (41.17 and 40.17 days) was recorded with PS_2 inoculation and minimum (29.33 and 29.25 days) in control during both the years, respectively. It is also evident from the data that in the year 2011-12, BS_3 treated plants recorded the longest flowering duration (38.08 days), which was *at par* with BS_2 (36.83 days) application, whereas, in the year 2012-13, it was longest (38.25 days) with BS_2 application. The shortest flowering duration (31.50 and 30.50 days) was found with control during both the years, respectively.

With respect to interactions effect of *Bacillus* and *Pseudomonas* strains, the longest flowering duration (44.67 days) was obtained with application of BS_3PS_3, which was *at par* with BS_2PS_2 and BS_3PS_2 (43.33 days) treatment combinations in the year 2011-12, whereas, in the year 2012-13, it was longest with BS_2PS_2 (45.67 days) treatment. The shortest flowering duration (25.33 and 26.67 days) was found with control during both the years, respectively. The longer flowering duration might be attributed to the better overall food and nutrient status under these treatment combinations. Singh (2009) also reported that the vase life of gladiolus spike was superior in the plants inoculated with *Pseudomonas* sp. CPS 20.

Flower stalk length

The data depicted in table 7 show that the flower stalk length was significantly longest with PS_3 application (5.93 cm), which was *at par* with PS_2 (5.87 cm) in first year, whereas, in next year, it was recorded longest with PS_2 (5.85 cm), which was *at par* with PS_3 (5.74 cm). The smallest flower stalk (5.02 and 5.03 cm) was found with control during both the years, respectively. Among *Bacillus* strains, the longest flower stalk (5.82 and 5.96 cm) was recorded with application of BS_3 in both the years, which was *at par* with BS_2 (5.71 cm) and BS_1 (5.60 cm) inoculation in the year 2011-12. It might be due to the growth promoted by nitrogen and better mobilization and solubilization of phosphate and better uptake of N and P as well as micronutrients like Zn, which is precursor of auxin, which improved flower stalk length. Further, interaction effect of *Pseudomonas* and *Bacillus* strains on flower stalk length was found to be non-significant in both the years.

Number of flowers per plant

The data pertaining to number of flowers per plant have been presented in table 8. It is apparent from the data that the maximum number of flowers per plant (26.92 and 28.58) was recorded with application of PS_2, which was *at par* with PS_3 (26.50 and 27.92), whereas, it was minimum (17.58 and 19.50) in control during the year 2011-12 and 2012-13, respectively. Among the *Bacillus* strains, the maximum number of flowers per plant (26.50 and 29.08) was recorded in application of BS_3 and minimum in control (18.75 and 19.00) during both the years, respectively.

Further, interpretation of results reveals that the maximum number of flowers per plant (31.33 and 34.33) was recorded with treatment BS_3PS_3, which was *at par* with BS_2PS_2 (29.67 and 32.00), and the minimum number of flowers per plant (11.67 and 14.00) was found with control in the year 2011-12 and 2012-13, respectively. *Pseudomonas* strains have potential for greater solubilization of insoluble P and some other factors such as release of some growth promoting substances, control of plant pathogens and proliferation of beneficial organisms in the rhizosphere. This result is in line with that found by Pandey *et al.* (2013) and Singh (2009) in gladiolus and Karishma *et al*. (2013) in gerbera and Barman *et al*. (2003) in tuberose.

Fresh weight of flower

The data on fresh weight of flower are presented in table 9, which reveal that the maximum fresh weight of flower (2.08 and 1.97 g) was recorded with PS_2 inoculation in the year 2011-12 and 2012-13, respectively, but in the year 2012-13, it was *at par* with PS_3 (1.94 g). The minimum fresh weight of flower (1.71 and 1.70 g) was recorded with control during both the years, respectively. The response of *Bacillus* was also found to be significant in both the years and the maximum fresh weight of flower (2.02 and 2.05 g) was observed with BS_3 application, which was *at par* with inoculation of BS_2 (2.00 and 1.99 g), while the minimum fresh weight of flower (1.69 and 1.62 g) was recorded with control during both the years, respectively.

The interaction effect of biofertilizers strains was found to be non-significant in first year, whereas, it was significant in second year. In the year 2012-13, the maximum fresh weight of flower (2.13 g) was recorded with inoculation of BS_3PS_2, which was *at par* with BS_2PS_2 (2.10 g), BS_1PS_3 (2.07 g), BS_3PS_1 (2.03 g) and BS_2PS_3 (2.00 g) treatment combinations. The minimum fresh weight of flower (1.51 and 1.45 g) was obtained with control in both the years, respectively. Sufficient nitrogen and phosphorus continuously maintain vegetative growth leading to increase in photosynthetic area, resulting in more accumulation of assimilates and partitioning to the developing plant parts.

Number of suckers per plant

The data on number of suckers per plant as influenced by different strains of *Pseudomonas* and *Bacillus* and their interactions are presented in table 10. The maximum number of suckers per plant (7.58 and 7.50) was recorded in PS_3 treated plants, whereas, it was minimum (4.92 and 5.25) in control during the year 2011-12 and 2012-13, respectively. Amongst *Bacillus* strains, inoculation of BS_3 recorded the maximum number of suckers (6.92 and 7.17) in both the years, respectively, which was *at par* with BS_2 (6.83) inoculation in the year 2011-12.

Among interaction effects of *Bacillus* and *Pseudomonas* strains, the maximum number of suckers (8.00) was recorded with application of BS_2PS_3 and BS_3PS_3, which were *at par* with BS_0PS_3 and BS_3PS_2 (7.67) and BS_1PS_2 (7.33) in the year 2011-12. In the year 2012-13, it was maximum (8.00) with BS_1PS_2 and BS_3PS_3 treatment combinations, which were *at par* with BS_3PS_2 (7.67), BS_2PS_3 (7.67) and BS_0PS_3 (7.33). The minimum number of suckers per plant (3.33 and 4.00) was noticed with control during both the years, respectively. The positive increment in number of suckers per plant by the application of biofertilizers may be due to the increase in availability of micro and macronutrients to the plants resulting in enhancement of hormonal activities within the plant.

Table 8: Effect of single and co-inoculation of PGPR on number of flowers per plant in chrysanthemum

Year	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
Treatments	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	11.67	15.33	26.00	22.00	**18.75**	14.00	16.33	24.33	21.33	**19.00**
BS_1-SYB101	18.00	22.00	24.00	27.00	**22.75**	18.33	21.33	27.33	29.00	**24.00**
BS_2-SB155	18.67	21.67	29.67	25.67	**23.92**	21.67	25.33	32.00	27.00	**26.50**
BS_3-SB127	22.00	24.67	28.00	31.33	**26.50**	24.00	27.33	30.67	34.33	**29.08**
Mean	**17.58**	**20.92**	**26.92**	**26.50**		**19.50**	**22.58**	**28.58**	**27.92**	

LSD (0.05)	2011-12	2012-13
Pseudomonas	1.47	1.53
Bacillus	1.47	1.53
Pseudomonas × *Bacillus*	2.94	3.06

Table 9: Effect of single and co-inoculation of PGPR on fresh weight of flower (g) in chrysanthemum

Year	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
Treatments	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	1.51	1.60	1.83	1.80	**1.69**	1.45	1.67	1.77	1.60	**1.62**
BS_1-SYB101	1.57	1.77	1.97	1.89	**1.80**	1.50	1.80	1.87	2.07	**1.81**
BS_2-SB155	1.74	1.90	2.33	2.01	**2.00**	1.90	1.97	2.10	2.00	**1.99**
BS_3-SB127	2.00	1.94	2.17	1.97	**2.02**	1.97	2.03	2.13	2.07	**2.05**
Mean	**1.71**	**1.80**	**2.08**	**1.92**		**1.70**	**1.87**	**1.97**	**1.94**	

LSD (0.05)	2011-12	2012-13
Pseudomonas	0.10	0.07
Bacillus	0.10	0.07
Pseudomonas × *Bacillus*	NS	0.14

Table 10: Effect of single and co-inoculation of PGPR on number of suckers per plant in chrysanthemum

Year	2011-12					2012-13				
	Biofertilizer strains					Biofertilizer strains				
Treatments	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean	PS_0-Control	PS_1-WPS73	PS_2-CPA152	PS_3-P20	Mean
BS_0-Control	3.33	4.67	5.67	7.67	**5.33**	4.00	4.67	6.00	7.33	**5.50**
BS_1-SYB101	5.33	6.33	7.33	6.67	**6.42**	5.33	6.67	8.00	7.00	**6.75**
BS_2-SB155	5.67	6.67	7.00	8.00	**6.83**	5.67	7.00	6.67	7.67	**6.75**
BS_3-SB127	5.33	6.67	7.67	8.00	**6.92**	6.00	7.00	7.67	8.00	**7.17**
Mean	**4.92**	**6.08**	**6.92**	**7.58**		**5.25**	**6.33**	**7.08**	**7.50**	

LSD (0.05)	2011-12	2012-13
Pseudomonas	0.48	0.40
Bacillus	0.48	0.40
Pseudomonas × *Bacillus*	0.97	0.80

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