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Effect of plant growth promoting Rhizobacteria and growing media on growth parameters of tuberose (*Polianthes tuberosa* L.) cv. Prajwal

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Abstract
A pot experiment was conducted to study the effect of plant growth promoting rhizobacteria and growing media on growth parameters of tuberose (*Polianthes tuberosa* L.) cv. Prajwal at the botanical garden at CCS Haryana Agricultural University, Hisar. The experiment was laid out in a completely randomized design (CRD) with six Rhizobacteria(four strains of *Bacillus viz*., SYB101, RCA3, RCA7, HCA61 and two strains of *Pseudomonas viz*., CP109, and JMM16) and three growing media, *i.e*., sand, sand + FYM (2:1), sand + vermicompost (3:1). Among different rhizobacteria, *Pseudomonas* sp. CP109 and *Bacillus* sp. HCA 61 was found potent in enhancing the vegetative growth of tuberose. Among the growing media, sand followed by sand + FYM (2:1) and, in later stages, sand + vermicompost (3:1) were effective in increasing the vegetative growth of tuberose. *Bacillus* sp. HCA 61 and sand, *Bacillus* sp. HCA 61 and sand + FYM (2:1), and *Pseudomonas* sp. CP 109 and the sand + vermicompost (3:1) combination showed the best results with respect to the growth of tuberose.

Keywords: Bacillus sp., and *Pseudomonas* sp., Sand, FYM, Vermicompost

Introduction
Tuberose (*Polianthes tuberosa*) is very important bulbous crop commonly known as Rajnigandha and belongs to family *Amaryllidaceae*. Commercial cultivation takes place in West Bengal, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Assam, Udaipur, Rajasthan, Uttar Pradesh, Punjab and Haryana in India's tropical and subtropical region. Tuberose is popularly used as loose, cut flower as well as in perfumery industry. Its cut flower used in bouquets, vase decoration and various floral arrangement whereas loose flower used for making *veni, garland*, button-holes or crown and in various industry for essential oil, concrete, absolute. Tuberose is a shallow rooted bulbous plant. Therefore, fertility, moisture, drainage and microbial status in upper soil layer have a great impact on growth, development, flower yield, quality and production of bulbs. In recent era, crop cultivation that warrants high yield and quality requires extensive use of chemical fertilizers, which not only disrupt the balance of nature but also reduce economic efficiency. Regular use of chemical fertilizers, pesticides, and weedicide to increase quality and quantity of crop yield which disrupt the balance of nature by deteriorating soil health, groundwater levels, soil microbes, create imbalance in nutrient uptake and ultimately makes the plant more susceptible to pests and diseases. Emphasis is now placed on the use of organic fertilizer and PGPR as biofertilizer to avoid the problems listed above in relation to modern agriculture. Plant growth-promoting rhizobacteria (PGPR) are naturally occurring heterogeneous plant root colonizing soil bacteria which significantly promotes plant growth. Inoculation of PGPR strains in an early stage plant growth improves biomass production by forming rhizosphere at plant root surface, which direct effects on root and shoots growth. With the improvement in plant growth they help in sustainable agricultural development and protecting the environment (Das *et al*., 2013) [3]. Phosphobacteria mineralizing organic phosphorus compounds e.g. *Pseudomonas*. The genera *Pseudomonas* and *Bacillus* are the early root colonizers belonging to rhizosphere bacteria. Some of rhizobacteria inhibit growth of pathogenic fungi and bacteria through production of hydrolytic enzymes and antibiotics. Growing media provides proper nutrient to plant by improving soil structure physically chemically and biologically. Keeping this in view, the present investigation was undertaken with the objective effect of co-inoculation of effective rhizospheric bacteria and growing media on growth, yield and disease incidence in tuberose.

Materials and Methods

The study was conducted on "Prajwal" tuberose at Botanical Garden, CCSHAU, Haryana, Hisar (29º10' N latitude and 75º 46' E longitudes). In this investigation uniform sized bulb of tuberose cv. Prajwal was laid out in Completely Randomized Design (CRD) with treatments of six different rhizobacteria (four strains of *Bacillus viz.*, SYB101, RCA3, RCA7, HCA61 and two strains of *Pseudomonas viz.*, CP109, JMM16 and three growing media, *i.e.*, sand, sand+ FYM (2:1), sand+ vermicompost (3:1). With the possible combination of growing media and rhizobacteria. The data were recorded on days taken to sprouting, days taken to complete sprouting, plant height (cm), length of leaves (cm), No. of leaves, days taken to spike emergence, days taken to opening of first floret. For recording the observations in each replication the data were statistically analyzed using OPSTAT 2004.

Result

Application of rhizobacteria and growing media plays an important role in augmenting the yield parameters in different crops. The result of present experiment indicates that bulb inoculation of tuberose plants with rhizobacteria (different strains of *Bacillus* and *Pseudomonas*) and growing media promote growth of tuberose i.e. days taken to sprouting, days taken to complete sprouting, plant height, length of leaf, No. of leaf, Days taken to spike emergence, days taken to opening of first florets.

Days taken to sprouting

The response of rhizobacteria and growing media varied significantly to days taken to sprouting Table1. The minimum days taken (21.75) to sprouting were observed with application of *Pseudomonas* sp. CP 109 and with *Bacillus* sp. HCA 61, it remained at par with *Bacillus* sp. RCA 7 (22.08 days) and with *Bacillus* sp. RCA 3 (22.25 days). The maximum days taken (25.58) to sprouting were recorded with *Pseudomonas* sp. JMM 16 which remained at par with *Bacillus* sp. SYB 101 (25.25 days).

Table 1: Effect of rhizobacteria and growing media on days taken to sprouting of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	23.75	27.75	24.25	25.25
Bacillus sp. RCA 3	23.00	24.25	19.50	22.25
Bacillus sp. RCA 7	20.00	21.25	25.00	22.08
Pseudomonas sp. CP 109	20.75	23.50	21.00	21.75
Bacillus sp. HCA 61	19.50	23.50	22.50	21.75
Pseudomonas sp. JMM 16	28.75	23.00	25.00	25.58
Mean	22.63	23.88	22.88	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	1.00	0.71	1.73	

The days taken to sprouting are significantly influenced by different growing media. The minimum days taken to sprouting (22.63) were noticed with sand which is statistically at par with sand + vermicompost (3:1) with value (22.83 days). The maximum days taken for sprouting were recorded with sand + FYM (2:1).

Among interaction of rhizobacteria and growing media, the minimum days (19.50) taken to sprouting were with the application of *Bacillus* sp. HCA 61 and sand, with application of *Bacillus* sp. RCA 3 and sand + vermicompost (3:1) (19.50 days), which is statistically at par with the application of *Bacillus* sp. RCA 7 and sand (20.00days), *Pseudomonas* sp. CP 109 and sand (20.75 days) and with application of *Pseudomonas* sp. CP109 and sand + vermicompost (3:1) (21.00 days).The maximum days (27.75) taken to sprouting were with application of *Bacillus* sp. SYB 101 is showed in sand + FYM (2:1).

Days taken to complete sprouting

It is inferred from the data presented in Table 2 that the days taken to complete sprouting influenced significantly by different rhizobacteria and growing media and there interaction. The minimum days taken to complete sprouting (24.33 days) was recorded with the application of *Pseudomonas* sp. CP 109, which is statistically at par with *Bacillus* sp. HCA 61 (24.83 days). The maximum days taken to complete sprouting (28.83 days) was recorded with the application of *Pseudomonas* sp. JMM 16, which is at par with *Bacillus* sp. SYB 101 (28.67 days).

Table 2: Effect of rhizobacteria and growing media on days taken to complete sprouting of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	27.00	31.00	28.00	28.67
Bacillus sp. RCA 3	26.50	27.25	22.50	25.42
Bacillus sp. RCA 7	23.25	25.25	29.00	25.83
Pseudomonas sp. CP 109	23.50	25.50	24.00	24.33
Bacillus sp. HCA 61	22.00	26.50	26.00	24.83
Pseudomonas sp. JMM 16	32.25	26.50	27.75	28.83
Mean	25.75	27.00	26.21	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.89	0.63	1.55	

The minimum days (25.75) taken to complete sprouting was observed with application of sand, which is statistically at par with sand + vermicompost (3:1) (26.21 days). The maximum days (27.00) taken to complete sprouting were observed with

application of sand + FYM (2:1).

The minimum days taken to complete sprouting (22.00 days) was obtained with the application of *Bacillus* sp. HCA 61 in combination of sand, which was found statistically at par with *Bacillus* sp. RCA 3 in combination with sand + vermicompost (3:1) (22.50 days), *Bacillus* sp. RCA 7 and sand (23.25 days) and *Pseudomonas* sp. CP109 and sand (23.50 days). The maximum days taken to complete sprouting (32.25 days) were observed with application of *Pseudomonas* sp. JMM 16 in combination with sand.

Plant height (cm) at full bloom

The data pertaining to plant height furnished in Table 3 reveals that different rhizobacteria, growing media and there interaction had significant effect on plant height. The tallest plant (70.99 cm) was recorded with the application of *Bacillus* sp. HCA 61, which is at par with *Pseudomonas* sp. CP 109 (70.92 cm). The shortest plant (60.01 cm) was recorded in *Pseudomonas* sp. JMM 16.

The response of growing media was found to be significant and the tallest plant (69.77 cm) in the application of sand, while shortest plant (63.17cm) in sand + FYM (2:1).

Among interaction an effect on tallest plant (77.90 cm) was recorded with *Bacillus* sp. HCA 61 and sand, which is statistically at par with *Bacillus* sp. HCA 61and sand + FYM (2:1) (76.63 cm). The shortest plant (55.58 cm) was recorded with *Bacillus* sp. SYB 101 and sand + vermicompost (3:1).

Table 3: Effect of rhizobacteria and growing media on plant height (cm) at full bloom of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	71.00	58.00	55.58	61.53
Bacillus sp. RCA 3	69.49	59.59	66.85	65.31
Bacillus sp. RCA 7	68.25	67.60	62.54	66.13
Pseudomonas sp. CP 109	69.38	68.43	74.88	70.92
Bacillus sp. HCA 61	77.90	76.63	58.44	70.99
Pseudomonas sp. JMM 16	62.63	48.75	68.64	60.01
Mean	69.77	63.17	64.49	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.86	0.61	1.48	

Length of leaf (cm) at full bloom

The length of leaf as influenced by different rhizobacteria and growing media and their interactions are in Table 4. The maximum length of leaves (33.93 cm) was obtained with application of *Pseudomonas* sp. CP 109, which was at par with *Bacillus* sp. RCA 7 (33.71 cm). The minimum length of leaf (29.61 cm) was obtained with application of *Pseudomonas* sp. JMM 16.

The significantly maximum length of leaf (32.87 cm) was recorded with application of sand and minimum length of leaves (31.38 cm) was obtained with application sand + FYM (2:1), which is at par, with sand + vermicompost (3:1) (31.83 cm).

Among interaction between rhizobacteria and growing media, the maximum length of leaf (39.30 cm) was recorded with the application of *Bacillus* sp.HCA 61 in combination of sand + FYM (2:1), whereas, the minimum length of leaf (20.67 cm) was found in *Pseudomonas* sp. JMM 16 and sand + FYM (2:1).

Table 4: Effect of rhizobacteria and growing media on length of leaf (cm) at full bloom of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	35.56	33.32	24.31	31.06
Bacillus sp. RCA 3	28.94	32.55	32.31	31.27
Bacillus sp. RCA 7	37.65	28.93	34.54	33.71
Pseudomonas sp. CP 109	34.19	33.49	34.13	33.93
Bacillus sp. HCA 61	28.06	39.30	30.40	32.59
Pseudomonas sp. JMM 16	32.84	20.67	35.31	29.61
Mean	32.87	31.38	31.83	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.89	0.63	1.55	

Number of leaf per clump at full bloom

The data pertaining to the influence of different rhizobacteria, growing media and their interaction on the number of leaf per clump have been presented in Table 5. It is inferred from the data that the number of leaf per clump was significantly influenced by different rhizobacteria. The maximum number of leaf per clump (31.42) was found with *Bacillus* sp. HCA 61, which is at par with *Bacillus* sp. SYB 101(30.92) and the minimum number of leaf per clump (21.25) was recorded in *Bacillus* sp. RCA 3, which is at par with *Bacillus* sp. RCA 7 (22.00).

Interpretation of data from table 5 further reveals that the number of leaf per clump was recorded significantly maximum (28.54) with application of sand + FYM (2:1), whereas, it was recorded minimum (23.13) in sand.

Table 5: Effect of rhizobacteria and growing media on number of leaf per clump at full bloom of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	17.75	33.50	41.50	30.92
Bacillus sp. RCA 3	26.25	12.25	25.25	21.25
Bacillus sp. RCA 7	22.25	24.75	19.00	22.00
Pseudomonas sp. CP 109	23.00	34.00	12.50	23.17
Bacillus sp. HCA 61	20.00	42.75	31.50	31.42
Pseudomonas sp. JMM 16	29.50	24.00	18.50	24.00
Mean	23.13	28.54	24.71	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.87	0.62	1.51	

The interaction between rhizobacteria and growing media was found to be significant. The maximum number of leaf per clump (42.75) was recorded with *Bacillus* sp. HCA 61 and sand + FYM (2:1), whereas, the minimum number of leaf per clump (12.25) was recorded in *Bacillus* sp. RCA 3 and sand + FYM (2:1).

Days taken to spike emergence

The data presented in Table 6 shows that the number days taken to spike emergence was significantly influenced by rhizobacteria growing media and there interaction. The minimum days taken to spike emergence (93.22 days) was observed with *Bacillus* sp. HCA61 and the maximum days taken to spike emergence (97.39 days) was recorded with *Pseudomonas* sp. JMM 16, which was at par with *Bacillus* sp. RCA7 (96.60 days).

The minimum number days taken to spike emergence (93.11 days) was recorded with application of sand and maximum number days taken to spike emergence (97.77 days) was obtained with application sand + FYM (2:1).

Among interaction effect the minimum number days taken to spike emergence (85.92 days) was recorded with *Bacillus* sp. HCA 61 and sand, whereas, the maximum number days taken to spike emergence (102.46) was recorded in *Bacillus* sp. SYB 101 and sand + FYM (2:1).

Table 6: Effect of rhizobacteria and growing media on days taken to spike emergence of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	93.00	102.46	91.05	95.50
Bacillus sp. RCA 3	97.25	93.89	91.38	94.17
Bacillus sp. RCA 7	94.38	99.25	96.17	96.60
Pseudomonas sp. CP 109	92.50	95.10	94.75	94.12
Bacillus sp. HCA 61	85.92	99.25	94.50	93.22
Pseudomonas sp. JMM 16	95.63	96.67	99.88	97.39
Mean	93.11	97.77	94.62	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.88	0.62	1.52	

Days taken to opening of first floret

It is inferred from the data presented in Table 7 that the days taken to opening of first floret influenced significantly by different rhizobacteria. The minimum days taken to opening of first floret (108.78 days) was recorded with the application of *Pseudomonas* sp. CP 109, which was statistically at par with *Bacillus* sp. HCA 61 (109.07 days) and at par with *Bacillus* sp. RCA3 (109.42 days). The maximum days taken to opening of first floret (112.63 days) was recorded with the application of *Pseudomonas* sp. JMM 16.

Table 7: Effect of rhizobacteria and growing media on days taken to opening of first floret of tuberose

Rhizobacteria (R)	Growing media (GM)			Mean
	Sand	Sand + FYM (2:1)	Sand + Vermicompost (3:1)	
Bacillus sp. SYB 101	108.33	118.58	104.72	110.54
Bacillus sp. RCA 3	112.88	110.00	105.38	109.42
Bacillus sp. RCA 7	108.88	112.56	111.53	110.99
Pseudomonas sp. CP 109	105.63	109.73	111.00	108.78
Bacillus sp. HCA 61	101.67	116.25	109.29	109.07
Pseudomonas sp. JMM 16	111.58	109.67	116.63	112.63
Mean	108.16	112.80	109.76	
C.D. at 5%	Rhizobacteria	Growing Media	Rhizobacteria x Growing Media	
	0.82	0.58	1.42	

It is also cleared from data that growing media application significantly influenced days taken to opening of first floret. The minimum days taken to opening of first floret (108.16 days) was observed with application of sand. The maximum days taken to opening of first floret (112.80 days) were observed with application of sand + FYM (2:1).

An interaction between rhizobacteria and growing media was found to be significant. The minimum days taken to opening of first floret (101.67 days) was obtained with the application of *Bacillus* sp. HCA 61 in combination of sand. The days

taken to opening of first floret (118.58 days) were observed with application of *Bacillus* sp. SYB 101 in combination with sand + FYM (2:1)

Discussion

Reduction in sprouting period, shortening of complete sprouting, reduction in spike emergence period, reduction in opening of first floret, and increase in plant height, number of leaf per clump, length of leaf per clump with rhizobacteria may be due to easy uptake of nutrients and simultaneous transport of growth promoting substances like cytokinin, auxin, gibberellins to primary roots, which might have stimulated early sprouting. Yadav *et al.* (2005) and Srivastava *et al.* (2014) [12] also obtained similar results in tuberose. Rhizobacteria (*Bacillus* sp. and *Pseudomonas* sp.) reduces ethylene production by synthesizing 1-aminocyclopropane-1-carboxylate (ACC) deaminase enzyme and this enzyme modulates the level of ethylene by hydrolyzing ACC in ammonia and α-ketobutyrate which increases plant growth (Khandelwal and Sindhu 2013) [5].

Number of days taken to sprouting, shortening of complete sprouting, reduction in spike emergence period and reduction in opening of first floret in tuberose also significantly reduced with the growing media. This might be due to nutrients and various growth hormones from growing media took less time to soluble in sand which, resulted in early sprouting of bulbs. Asrey *et al.* (2002) [1] in gladiolus, Chaudhary (2007) [2] in tuberose also obtained similar results.

The interaction of rhizobacteria and growing media was found significant in decreasing the number of days taken for initiation of sprouting, complete sprouting, spike emergence, opening of first floret and increase in plant height, length of leaf and number of leaves with rhizobacteria might be because rhizobacteria promotes root development and nutrients uptake thus affecting the cell division and cell enlargement and ultimately better vegetative growth. Results are in agreement with Srivastava and Govil (2005) [11] in gladiolus, Kumar *et al.* (2012) [6] in tuberose and Kumari *et al.* (2016) [8] in chrysanthemum.

Plant rhizobacteria makes availability of nutrients in sand first, which was closely followed by sand + vermicompost (3:1) that is why there is increase in plant height length of leaf and number of leaf in sand, which is closely followed by sand + vermicompost (3:1). Similar findings were recorded by Preetham *et al.* (2017) [9], Karim *et al.* (2017) [4] and Kumar (2015) [7] in tuberose.

Conclusion

Among different rhizobacteria *Pseudomonas* sp. CP109 and *Bacillus* sp. HCA 61 was found potent in enhancing growth of tuberose. Among growing media sand effective initially in increasing growth of tuberose followed by sand + FYM (2:1) and in later stages sand + vermicompost (3:1) were effective. *Bacillus* sp. HCA 61 and sand, *Bacillus* sp. HCA 61 and sand + FYM (2:1) and *Pseudomonas* sp. CP 109 and sand + vermicompost (3:1) combination showed best results with respect to growth of tuberose.

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