Effect of organic manures and biofertilizers on growth characters of *Lilium* growing under different cultivation Practices

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Abstract. The present experiment was conducted during 2021-22 and 2022-23 at the Agri-tourism Centre, CCS Haryana Agricultural University, Hisar, Haryana, to evaluate the effect of organic manures and biofertilizers on the vegetative growth of Asiatic *Lilium* under different cultivation conditions. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications under polyhouse, shade-net, and open-field conditions. Among all treatments, the combined application of Farm Yard Manure (FYM) @ 5.0 t ha^{-1} + vermicompost (VC) @ 2.5 t ha^{-1} + *Azotobacter* + phosphate-solubilizing bacteria (PSB) (T9) recorded superior performance for vegetative growth parameters during both years of study. The treatment significantly reduced the days taken to bulb sprouting (5.41 and 5.68 days) and increased plant height (102.54 and 105.31 cm), number of leaves per plant (70.86 and 72.91), leaf length (9.25 and 9.70 cm), and leaf width (2.59 and 2.75 cm), respectively, over other treatments. The findings of the study suggest that integrated application of organic manures and biofertilizers under protected cultivation conditions can be an effective and sustainable approach for improving growth and productivity of *Lilium*.

1 Introduction

The genus *Lilium* is herbaceous flowering plants normally growing from bulbs, comprising of about 130 species in the family Liliaceae, all originating from the Northern Hemisphere [1]. The floral industry today has grown to much larger proportions and offers wide scope for growth and profits [2]. The recognition of the potential of commercial floriculture has led in the development of this industry into a viable agri-business choice. The range of lilies in the old world extends across much of Europe, across most of Asia to Japan, south to India and east to Indo-China and the Philippines. In early 1990's Lilies were introduced in the northern part of India for commercial cultivation by commercial growers such as Lake Flowers International in the Uttar Pradesh state of India. *Lilium* is indigenous to north temperate zones of hemispheres, and the area of distribution stretches through India across the Northern India (Uttarakhand, Uttar Pradesh, Himachal Pradesh, Jammu, and Kashmir), Central India (Pune) and Southern India (Ooty and Banglore). *Lilium* longiflorum is a monocotyledon belonging to liliaceae, it grows well demands in tropical region. All *Lilium* species are diploid (2n=2x=24), except some triploid forms of L.tigrinum and L.bulbiferum existing in nature. Due to its size, beauty, and longevity *Lilium* is one of the ten most superior cut flowers in the world [3]. As a cut flower, it is now the fourth most important crop in the Netherlands [4]. In recent years, sustainable nutrient management practices have gained considerable attention in ornamental crop production due to increasing concerns regarding soil degradation, environmental pollution, and excessive dependence on chemical fertilizers. Organic fertilization is an alternative method for *Lilium* production. The organic fertilizers improve soil structure and reduce soil temperature, leading in enhanced root development and increased water and nutrient use efficiency [5]. According to a study conducted by [6], organic manures increase soil quality in terms of a number of indices, such as pH and organic matter content. Physical, chemical, and biological qualities that indicate improved soil health and crop production sustainability [7, 8]. Similarly, biofertilizers including *Azotobacter* and phosphate-solubilizing bacteria (PSB) play an important role in promoting plant growth through atmospheric nitrogen fixation, phosphate solubilization, and production of plant growth-promoting substances.
Although several studies have independently evaluated the effects of organic manures or biofertilizers on ornamental crops, limited information is available regarding their integrated application under different protected and open cultivation environments in *Lilium*. Moreover, comparative assessment of nutrient management strategies under polyhouse, shade-net, and open-field conditions remains insufficiently explored. This study was therefore carried out to evaluate the synergistic effects of organic fertilizers and microbial bioinoculants on the vegetative growth of Asian *Lilium* under various cultivation practices and to identify a

sustainable nutrient management approach to improve growth and commercial production.

2 Materials and Methods

The present investigation entitled "Effect of organic manures and biofertilizers on growth characters of *Lilium* growing under different cultivation practices" was carried out at Agri-tourism Centre, CCS HAU, Hisar (Haryana) in 2021-22 and 2022-23. The investigation was made on growth parameters. The experiment consisted of nine treatments viz., T1 RDF (Control); T2 (Farm Yard Manure (FYM) @ 5.0 t/ha); T3 (Vermicompost (VC) @ 2.5 t/ha); T4 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha) ; T5 (*Azotobacter* + Phosphate Solubilizing Bacteria (PSB) ; T6 (RDF + *Azotobacter* + PSB); T7 (FYM @ 5.0 t/ha + *Azotobacter* + PSB); T8 (VC @ 2.5 t/ha + *Azotobacter* + PSB); T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB). The experiment was conducted in randomized blocks design with three replications per treatment.

2.1 Experimental methodology

2.1.1 Days taken to bulb sprouting

All the experimental bulbs were observed daily critically for recording the data on bulb sprouting. The data on the days taken to bulb sprouting were recorded from the date of bulb planting to the average date on which the first sign of bulb sprout was visible with the naked eye on the soil surface. These differences were recorded for all experimental bulbs for each treatment and averaged for each replicate.

2.1.2 Plant height (cm) at harvest

For recording plant height, five healthy and representative plants were randomly selected from each treatment at the spike harvesting stage. The height of each plant was measured from the ground level to the tip of the plant using a measuring scale, and the mean plant height was expressed in centimeters (cm).

2.1.3 Number of leaves per plant at harvest

For this study, five healthy plants were selected at the harvesting stage of the spike in each treatment. First, the total number of leaves of the five plants in full bloom stage was counted. Then, the average leaf size per plant was calculated.

2.1.4 Leaf length (cm) at harvest

For this study, five healthy plants were selected at the time of harvesting of the spike for each treatment. First, the length of three leaves (i.e. the fourth leaf from the base of the stem, middle leaf and upper leaf) from the base of the stem to the tip of the leaf of each plant was measured with a meter rod at full flowering and then calculated for each treatment in cm.

2.1.5 Leaf width (cm) at harvest

For this study, five healthy plants were selected at the time of flower harvesting for each treatment group. The width of three leaves (i.e. the fourth leaf from the base, middle and upper margin) from margin to margin at the middle of each plant was measured with the foot scale at the full bloom stage and averaged for each treatment and expressed in cm.

3 Results and Discussions

The overall results of the study are shown in Table 1-5. The minimum days to bulb sprouting (5.12 and 5.37 days), followed by shadenet (5.85 and 6.11 days), while the maximum days for bulb sprouting (6.30 and 6.61 days) were taken when grown under open field conditions. Among the different treatments, the minimum days to bulb sprouting (5.41 or 5.68 days) was observed in T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB treatment) under polyhouse, followed by T8 (5.50 and 5.77 days) while maximum (6.34 or 6.65 days) to bulb sprouting were observed in T1 RDF (Control) under open conditions. The interaction between the bio inoculants and growing conditions was found to be significantly affecting the bulb sprouting. Minimum days to bulb sprouting (4.37 and 4.59 days) was observed in polyhouse (T9C1), while Maximum days to bulb sprouting (6.58 and 6.65) was recorded in (T1C3) in open conditions. Similar results were also reported by [9] in chrysanthemum and [10] in rose. Recent studies also indicated that integrated application of organic manures and biofertilizers under protected conditions significantly improves bulb growth, nutrient uptake, and early establishment in *Lilium* crops [11].

The maximum plant height (109.13 and 112.01 cm) was recorded when produced under polyhouse, followed by shadenet (101.95 and 105.40 cm) conditions. In contrast, the minimum plant height (76.30 and 79.04 cm) was recorded under open field conditions. Among the various treatments, maximum plant height (102.54 and 105.31cm) was observed in treatment T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB), and it was followed by T8 (100.25 and 102.57 cm), whereas minimum height (87.81 and 89.83 cm) was observed in treatment T1 (RDF, control) under open field conditions. The interaction between growing conditions and bio inoculants was also found to be significantly affecting the plant height. Maximum plant height (115.30 and 117.61 cm) was observed in polyhouse (T9C1), while minimum plant height (63.95 and 65.55 cm) was recorded in (T1C3) in open conditions. This might be due to a change in leaf morphology, wherein plants grown in shadenet developed large thin leaves with lesser stomata to compensate for the loss in light intensity by increasing the surface area for the process of photosynthesis [12]. This finding is in line with the study of [13] in lily.

The maximum number of leaves (72.12 and 73.92) per plant found under polyhouse condition, followed by shadenet (67.62 and 69.65). In contrast, the minimum numbers of leaves (62.74 and 64.75) per plant were observed when grown under open field conditions. Among the various treatments, maximum number of leaves per plant (70.86 and 72.91) was observed in treatment T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB), and it was followed by T8 (69.11 and 71.11), whereas minimum number of leaves per plant (63.62 and 65.46) was observed in treatment T1 (RDF, control) under open field conditions. The interaction between growing conditions and bio inoculants was also found to be significantly affecting the number of leaves per plant. Maximum number of leaves per plant (75.05 and 76.93) was observed in polyhouse (T9C1), while minimum number of leaves per plant (59.70 and 61.61) was recorded in (T1C3) in open conditions. *Azotobacter* and PSB in combined inoculation mutually benefitted each other by supplying essential nutrients for their proper activity. Hence, they showed effective growth on these vegetative parameters. These findings are in conformity with the findings of [8] and [14] in marigold and [15] in tuberose. Similar results were also reported by recent workers in *Lilium* and other ornamental crops under integrated nutrient management and protected cultivation conditions [16].

The maximum leaf length (cm) (7.96 and 8.36 cm) was recorded in polyhouse condition, followed by shadenet (10.04 and 10.50 cm) conditions. In contrast, the minimum leaf length (7.22 and 7.59 cm) was recorded when grown under open field conditions. Among the various treatments, maximum leaf length (9.25 and 9.70 cm) was observed in treatment T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB), and it was followed by T8 (9.15 and 9.59 cm), whereas minimum leaf length (7.05 and 7.39 cm) was observed in treatment T1 (Control) under open field conditions. The interaction between growing conditions and bio inoculants was also found to be significantly affecting the leaf length. Maximum leaf length (8.65 and 9.08 cm) was observed in polyhouse (T9C1), while minimum leaf length (6.29 and 6.61 cm) was recorded in (T1C3) in open conditions. This might be due to the optimum nutrition provided by the bio inoculants.

The maximum leaf width (2.36 and 2.50 cm) was recorded in polyhouse, followed by shadenet (2.70 and 2.87 cm) conditions. In contrast, the minimum leaf length (1.99 and 2.12 cm) was recorded when grown under open field conditions. Among the various treatments, maximum leaf width (2.59 and 2.75cm) was observed in treatment T9 (FYM @ 5.0 t/ha + VC @ 2.5 t/ha + *Azotobacter* + PSB), and it was followed by T8 (2.50 and 2.66 cm), whereas minimum leaf width (1.94 and 2.06 cm) was observed in treatment T1 (Control) under open field conditions. The interaction between growing conditions and bio inoculants was also found to be significantly influencing the leaf width (cm). Maximum leaf width (cm) (2.57 and 2.72 cm) was observed in polyhouse (T9C1), while minimum leaf width (1.55 and 1.64 cm) was recorded in (T1C3) in open conditions. This might be due to a sufficient supply of nutrients with a favorable growing environment.

Table 1. Effect of growing conditions and bio inoculants on days taken to bulb sprouting

Treatments	Growing conditions							
	C_1: Poly House		C_2: Shade net		C_3: Open		Mean	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	5.98	6.28	6.47	6.76	6.58	6.91	6.34	6.65
T_2	5.81	6.10	6.39	6.68	6.45	6.77	6.22	6.52
T_3	5.20	5.46	5.79	6.05	6.11	6.42	5.70	5.98
T_4	4.88	5.12	5.70	5.96	6.24	6.55	5.61	5.88
T_5	5.34	5.61	5.90	6.17	6.08	6.38	5.77	6.05
T_6	5.07	5.32	5.78	6.04	6.16	6.47	5.67	5.94
T_7	4.80	5.04	5.59	5.84	6.30	6.62	5.56	5.83
T_8	4.62	4.85	5.53	5.78	6.35	6.67	5.50	5.77
T_9	4.37	4.59	5.48	5.73	6.39	6.71	5.41	5.68
Mean	5.12	5.37	5.85	6.11	6.30	6.61		
CD at 5%	Treatments (2021-22) = 0.23, Treatments (2022-23) = 0.28. Growing Conditions (2021-22) =0.14, Growing Conditions (2022-23) = 0.18 TxC (2021-22) = 0.40, TxC (2022-23) = 0.46							

Where, T1 = RDF (Control), T2 = Farm Yard Manure (FYM) @ 5.0 t/ha, T3 =Vermicompost (VC) @ 2.5 t/ha, T4 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha, T5 =*Azotobacter* + Phosphate Solubilising Bacteria (PSB), T6 = RDF + *Azotobacter* +Phosphate Solubilising Bacteria (PSB), T7 = FYM @ 5.0 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T8 = Vermicompost (VC) @ 2.5 t/ha) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T9 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)

Table 2. Effect of growing conditions and bio inoculants on plant height (cm) at harvest

	Growing conditions							
	C_1: Poly House		**C_2: Shade net**		**C_3: Open**		**Mean**	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	105.00	107.10	94.48	96.84	63.95	65.55	87.81	89.83
T_2	106.32	108.45	97.07	99.50	70.75	72.52	91.38	93.49
T_3	109.12	111.30	103.30	105.88	77.94	79.89	94.09	99.02

T_4	110.51	112.72	105.42	108.06	80.01	82.01	97.95	100.93
T_5	107.53	109.68	97.30	99.73	77.45	79.39	96.79	96.27
T_6	110.20	112.40	104.99	107.61	78.65	80.62	99.40	100.21
T_7	111.94	114.18	105.89	108.54	80.37	82.38	98.64	101.70
T_8	112.40	114.65	107.13	109.81	81.23	83.26	100.25	102.57
T_9	115.30	117.61	109.86	112.61	83.62	85.71	102.54	105.31
Mean	109.13	112.01	101.95	105.40	76.30	79.04		
CD at 5%	Treatments (2021-22) = 0.66, Treatments (2022-23) = 0.74 Growing Conditions (2021-22) =0.40, Growing Conditions (2022-23) = 0.48 TxC (2021-22) = 1.13, TxC (2022-23) = 1.21							

Where, T1 = RDF (Control), T2 = Farm Yard Manure (FYM) @ 5.0 t/ha, T3 =Vermicompost (VC) @ 2.5 t/ha, T4 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha, T5 =*Azotobacter* + Phosphate Solubilising Bacteria (PSB), T6 = RDF + *Azotobacter* +Phosphate Solubilising Bacteria (PSB), T7 = FYM @ 5.0 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T8 = Vermicompost (VC) @ 2.5 t/ha) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T9 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)

Table 3. Effect of growing conditions and bio inoculants on number of leaves per plant

Treatments	Growing conditions							
	C_1: Poly House		C_2: Shade net		**C_3: Open**		**Mean**	
	2021-22	2022-23	2021-22	2022-23	**2021-22**	**2022-23**	**2021-22**	**2022-23**
T_1	68.09	69.79	63.08	64.97	59.70	61.61	63.62	65.46
T_2	70.55	72.31	65.70	67.67	61.63	63.60	65.96	67.86
T_3	72.23	74.04	66.61	68.61	62.37	64.37	67.07	69.01
T_4	72.70	74.52	68.90	70.97	62.90	64.91	68.17	70.13
T_5	71.34	73.12	66.24	68.23	61.90	63.88	66.49	68.41
T_6	72.40	74.21	67.38	69.40	62.70	64.71	67.49	69.44
T_7	73.19	75.02	69.37	71.45	63.42	65.45	68.66	70.64
T_8	73.50	75.34	69.66	71.75	64.18	66.23	69.11	71.11
T_9	75.05	76.93	71.65	73.80	65.89	68.00	70.86	72.91
Mean	72.12	73.92	67.62	69.65	62.74	64.75		
SD at 5%	Treatments (2021-22) = 0.24, Treatments (2022-23) = 0.32 Growing Conditions (2021-22) =0.15, Growing Conditions (2022-23) = 0.21 TxC (2021-22) = 0.42, TxC (2022-23) = 0.54							

Where, T1 = RDF (Control), T2 = Farm Yard Manure (FYM) @ 5.0 t/ha, T3 =Vermicompost (VC) @ 2.5 t/ha, T4 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha, T5 =*Azotobacter* + Phosphate Solubilising Bacteria (PSB), T6 = RDF + *Azotobacter* +Phosphate Solubilising Bacteria (PSB), T7 = FYM @ 5.0 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T8 = Vermicompost (VC) @ 2.5 t/ha) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T9 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)

Table 4. Effect of growing conditions and bio inoculants on leaf length (cm) at harvest

Treatments	**Growing conditions**							
	C_1: Poly House		**C_2: Shade net**		**C_3: Open**		**Mean**	
	2021-22	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
T_1	6.91	7.26	7.94	8.31	6.29	6.61	7.05	7.39
T_2	7.63	8.01	8.69	9.09	7.10	7.46	7.81	8.19
T_3	7.80	8.19	9.22	9.64	7.22	7.59	8.08	8.47
T_4	8.13	8.54	11.04	11.55	7.35	7.72	8.84	9.27
T_5	7.70	8.09	8.79	9.19	7.15	7.51	7.88	8.26
T_6	8.01	8.41	10.59	11.08	7.28	7.65	8.63	9.05
T_7	8.27	8.68	11.27	11.79	7.44	7.82	8.99	9.43
T_8	8.55	8.98	11.37	11.89	7.53	7.91	9.15	9.59
T_9	8.65	9.08	11.47	12.00	7.64	8.03	9.25	9.70
Mean	7.96	8.36	10.04	10.50	7.22	7.59		
SD at 5%	Treatments (2021-22) = 0.38, Treatments (2022-23) = 0.45 Growing Conditions (2021-22) =0.24, Growing Conditions (2022-23) = 0.33 TxC (2021-22) = 0.65, TxC (2022-23) = 0.76							

Where, T1 = RDF (Control), T2 = Farm Yard Manure (FYM) @ 5.0 t/ha, T3 =Vermicompost (VC) @ 2.5 t/ha, T4 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha, T5 =*Azotobacter* + Phosphate Solubilising Bacteria (PSB), T6 = RDF + *Azotobacter* +Phosphate Solubilising Bacteria (PSB), T7 = FYM @ 5.0 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T8 = Vermicompost (VC) @ 2.5 t/ha) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T9 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)

Table 5. Effect of growing conditions and bio inoculants on leaf width (cm) at harvest

Treatments		**Growing conditions**							
		C_1: Poly House		**C_2: Shade net**		**C_3: Open**		**Mean**	
		2021-22	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
T_1	9	1.99	2.11	2.29	2.43	1.55	1.64	1.94	2.06
T_2	8	2.28	2.42	2.59	2.75	1.86	1.97	2.24	2.38
T_3	6	2.35	2.49	2.68	2.85	1.96	2.08	2.33	2.47
T_4	4	2.41	2.55	2.78	2.95	2.07	2.20	2.42	2.57
T_5	7	2.31	2.45	2.63	2.79	1.92	2.04	2.29	2.43
T_6	5	2.39	2.53	2.73	2.90	2.04	2.16	2.39	2.53
T_7	3	2.45	2.60	2.82	2.99	2.13	2.26	2.47	2.62
T_8	2	2.48	2.63	2.85	3.03	2.18	2.31	2.50	2.66
T_9	1	2.57	2.72	2.96	3.14	2.24	2.38	2.59	2.75
Mean		2.36	2.50	2.70	2.87	1.99	2.12		
SD at 5%		Treatments (2021-22) = 0.15, Treatments (2022-23) = 0.18 Growing Conditions (2021-22) =0.10, Growing Conditions (2022-23) = 0.14 TxC (2021-22) = NS, TxC (2022-23) = 0.NS							

Where, T1 = RDF (Control), T2 = Farm Yard Manure (FYM) @ 5.0 t/ha, T3 =Vermicompost (VC) @ 2.5 t/ha, T4 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha, T5 =*Azotobacter* + Phosphate Solubilising Bacteria (PSB), T6 = RDF + *Azotobacter* +Phosphate Solubilising Bacteria (PSB), T7 = FYM @ 5.0 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T8 = Vermicompost (VC) @ 2.5 t/ha) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB), T9 = Farm Yard Manure (FYM) @ 5.0 t/ha + Vermicompost (VC) @ 2.5 t/ha + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)

4 Conclusions

From the present study, it can be concluded that among the three growing conditions, Asiatic *Lilium* cultivated under polyhouse conditions performed significantly better with respect to vegetative growth parameters, including days taken to bulb sprouting, plant height at harvest, number of leaves per plant, leaf length, and leaf width during both the years of experimentation, as compared to shade-net and open-field conditions. Among the nutrient and biofertilizer treatments, T9 (FYM @ 5.0 t ha^{-1} + VC @ 2.5 t ha^{-1} + *Azotobacter* + PSB) recorded superior performance for all vegetative characters. The enhanced growth under polyhouse conditions may be attributed to the favorable microclimatic environment coupled with improved nutrient availability and microbial activity under integrated organic nutrient management. Therefore, the combined application of organic manures and microbial biofertilizers under protected cultivation can be recommended as a sustainable and efficient production strategy for commercial cultivation of *Lilium* to achieve improved plant growth, better crop quality, and higher economic returns.

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Data availability statement

All data generated or analyzed during this study are included in this article.

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