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Effect of organic manures and biofertilizers on vegetative growth parameters of Lemongrass (*Cymbopogon flexuosus* L.)

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Abstract

The present field experiment entitled “Effect of organic manures and biofertilizers on vegetative growth parameters of Lemongrass (*Cymbopogon flexuosus* L.)” was conducted at College of Horticulture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, (M.S.) during two consecutive years 2023-25. The experiment consisted of ten treatments that were replicated thrice. The results revealed that, significant variations were observed among the different organic manures and biofertilizers treatments in the experiment. The treatment T₁₀ i.e., Vermicompost (2.5 t/ha) + Farmyard manure (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha), consistently recorded the highest plant height (187.19 cm), number of tillers (62.13), number of leaves (201.36), leaf length (153.32 cm) and plant spread (154.41 cm) at 210 days after transplanting (DAT). In contrast, the treatment T₃ i.e., FYM (10 t/ha) recorded the lowest growth throughout the growth period.

Keywords: Lemongrass, growth, organic manures, biofertilizers

1. Introduction

Lemongrass (*Cymbopogon flexuosus* N.) is one of the most economically significant essential oil-bearing aromatic crop belonging to the family Poaceae. It is indigenous to India, Sri Lanka, Myanmar and Thailand (Monika *et al.*, 2024) ^[10]. It is an important multi-purpose crop that provides economical, nutritional and ecological benefits. The crop is highly valued for its essential oil, which contains a high proportion of citral (75–90%), responsible for its characteristic lemon-like aroma (Guenther, 1950) ^[5]. India's diverse agro-climatic condition supports the successful cultivation of lemongrass particularly in the states of Kerala, Maharashtra, Karnataka and Tamil Nadu (Anu *et al.*, 2025) ^[2] and in several other Indian states. The total area under cultivation is about 4000 ha, with an annual yield of 250 ton/ha, accounting for nearly 61% of the area committed to aromatic crop cultivation (Choudhri *et al.*, 2025) ^[3]. In recent years, demand for lemongrass has grown steadily in domestic and international markets due to its medicinal and therapeutic benefits, diverse industrial applications and strong export potential.

Lemongrass is a robust perennial grass characterized by profuse tillering and long narrow leaves, which are the primary site for essential oil biosynthesis (Singh *et al.*, 2024) ^[17]. The crop is primarily harvested for its vegetative biomass, hence quantitative and qualitative improvement of the vegetative growth parameters of lemongrass is highly essential for enhancing crop productivity, improving plant vigour and ensuring efficient nutrient utilization. Plant growth and development are strongly influenced by mineral nutrition. Efficient nutrient management strategies are vital for regulating stress tolerance, nutrient uptake, physiological processes and the production of essential oils and secondary metabolites in medicinal and aromatic plants (Miransari *et al.*, 2025) ^[9], thereby emphasizing the importance of balanced nutrition for sustainable lemongrass cultivation. Improved vegetative growth also contributes to higher photosynthetic activity, greater biomass accumulation and ultimately better yield and quality of the produce.

The intensive use of chemical fertilizers in lemongrass cultivation has raised concerns regarding nutrient leaching, soil degradation, nutrient imbalance and reduced microbial activity, ultimately affecting long-term soil productivity. Therefore, integrating organic and biological nutrient sources offers a more balanced and sustainable approach towards lemongrass cultivation (Ntsomboh-Ntsefong *et al.*, 2025) ^[12]. Organic manures improve soil fertility, structure, moisture retention, microbial activity and overall soil health, resulting in better herb yield and essential oil quality (Verma *et al.*, 2024) ^[18]. Biofertilizers (*Azotobacter* and *Azospirillum*) enhance biological nitrogen fixation, nutrient acquisition and stimulate root and plant growth (Hasan *et al.*, 2025) ^[6]. Their combined application improves nutrient assimilation, encourages production of growth-promoting substances and strengthens plant defence mechanisms, ultimately enhancing crop growth and yield

(Khatib *et al.*, 2026) ^[7].

2. Materials and Methods

The present experiment was undertaken at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) during the year 2023-24 and 2024-25. The experiment was laid out in randomized block design (RBD) with ten treatments that were replicated thrice. The experiment included 30 plots (10 plots per replication), with each plot consisting of 30 plants. Healthy rooted slips of Krishna variety of lemongrass were used in the study and planted at spacing of 60 × 60 cm. Organic manures such as vermicompost and FYM and biofertilizers viz., *Azotobacter* and *Azospirillum* were used in the study and were administered as basal dose according to the treatment details (Table 1).

Table 1: Details of treatments used in the experiment

Code	Treatments
T ₁	Recommended dose of fertilizer (100:45:30 NPK kg/ha) – Control
T ₂	Vermicompost (5 t/ha)
T ₃	Farm yard manure (10 t/ha)
T ₄	Vermicompost (5 t/ha) + <i>Azotobacter</i> (10 kg/ha)
T ₅	Farm yard manure (10 t/ha) + <i>Azotobacter</i> (10 kg/ha)
T ₆	Vermicompost (5 t/ha) + <i>Azospirillum</i> (10 kg/ha)
T ₇	Farm yard manure (10 t/ha) + <i>Azospirillum</i> (10 kg/ha)
T ₈	Vermicompost (2.5 t/ha) + Farm yard manure (5 t/ha) + <i>Azotobacter</i> (10 kg/ha)
T ₉	Vermicompost (2.5 t/ha) + Farm yard manure (5 t/ha) + <i>Azospirillum</i> (10 kg/ha)
T ₁₀	Vermicompost (2.5 t/ha) + Farm yard manure (5 t/ha) + <i>Azotobacter</i> (10 kg/ha) + <i>Azospirillum</i> (10 kg/ha)

To evaluate the combined and individual effects of organic manures and biofertilizers on the vegetative growth parameters of lemongrass, five healthy plants were selected randomly for observation from replication of each treatment. The data was statistical analysis following the standard procedure of analysis of variance as described by Panse and Sukhatme (1995) ^[13].

3. Results

The data related to the effect of organic manures and biofertilizers on the vegetative growth parameters of lemongrass was recorded at 120 DAT (1st harvest) and 210 DAT (2nd harvest) during both years 2023-24 and 2024-25 and then their pooled data was worked out. Results of the study revealed significant variations among the treated lemongrass plants for various morphological characters like plant height, number of tillers, number of leaves, leaf length and plant spread.

3.1 Plant height (cm)

Plant height is an important growth parameter that determines the vigour and development of the lemongrass plants. The data presented in Table 2 demonstrated significant differences among the treatments at 120 DAT and 210 DAT, indicating the influence of different organic manures and biofertilizers on the plant height of lemongrass during the study period (2023-24 and 2024-25).

The treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) consistently recorded highest plant height at 120 DAT and 210 DAT during both the years (2023-24 and 2024-25). The highest pooled plant height (171.73 and 187.19 cm) was recorded in treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) at 120 DAT and 210 DAT, whereas the lowest mean plant height (111.10 and 126.03 cm) was registered in the treatment T₃ containing FYM (10 t/ha).

Table 2: Effect of organic manures and biofertilizers on plant height (cm) of lemongrass (*Cymbopogon flexuosus* N.)

Treatments	Plant height (cm)					
	2023-24		2024-25		Pooled	
	120 DAT	210 DAT	120 DAT	210 DAT	120 DAT	210 DAT
T ₁	138.71	150.25	155.95	170.75	147.33	160.50
T ₂	110.56	124.76	127.70	144.42	119.13	134.59
T ₃	104.12	118.25	118.09	133.81	111.10	126.03
T ₄	128.52	138.34	145.57	161.04	137.05	149.69
T ₅	118.05	131.20	135.94	153.66	127.00	142.43
T ₆	132.78	142.92	147.56	164.53	140.17	153.73
T ₇	123.18	134.27	140.78	158.92	131.98	146.59
T ₈	135.67	145.62	150.25	165.32	142.96	155.47
T ₉	146.56	158.04	161.67	177.15	154.12	167.60
T ₁₀	162.85	175.96	180.60	198.41	171.73	187.19
Mean	130.10	141.96	146.41	162.80	138.26	152.38
Result	SIG	SIG	SIG	SIG	SIG	SIG
S.Em.±	5.32	5.80	6.20	6.91	5.61	6.17
C.D. at 5%	15.80	17.24	18.41	20.54	16.67	18.34

3.2 Number of tillers

Tillers are the primary growth characteristics that govern the overall structure and productivity of the lemongrass. The data pertaining to the number of tillers produced in lemongrass was significant at 120 DAT and 210 DAT as a result of application of organic manures and biofertilizers over the course of experiment (2023-24 and 2024-25) as given in Table 3. During both years (2023-24 and 2024-25) and in the pooled analysis, the number of tillers were recorded significantly maximum in the treatment T₁₀ consisting of VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) with the highest mean number of tillers 37.11 and 62.13 at 120 DAT and 210 DAT, respectively. Meanwhile, the lowest pooled number of tillers (22.55 and 38.30) were produced by treatment T₃ i.e., FYM (10 t/ha) at the respective stages.

Table 3: Effect of organic manures and biofertilizers on number of tillers of lemongrass (*Cymbopogon flexuosus* N.)

Treatments	Number of tillers					
	2023-24		2024-25		Pooled	
	120 DAT	210 DAT	120 DAT	210 DAT	120 DAT	210 DAT
T ₁	29.08	48.95	32.16	54.36	30.62	51.66
T ₂	22.40	37.77	25.73	43.64	24.06	40.70
T ₃	20.95	35.24	24.15	41.36	22.55	38.30
T ₄	26.12	43.58	29.38	49.90	27.75	46.74
T ₅	24.15	40.62	27.45	46.01	25.80	43.32
T ₆	27.30	45.50	30.60	51.42	28.95	48.46
T ₇	24.74	42.15	28.32	48.98	26.53	45.56
T ₈	27.68	46.62	31.28	53.51	29.48	50.07
T ₉	31.46	52.08	35.04	59.07	33.25	55.58
T ₁₀	35.28	58.74	38.95	65.52	37.11	62.13
Mean	26.92	45.13	30.31	51.38	28.61	48.25
Result	SIG	SIG	SIG	SIG	SIG	SIG
S.Em.±	1.26	2.17	1.29	2.13	1.20	2.05
C.D. at 5%	3.73	6.43	3.83	6.32	3.56	6.10

3.3 Number of leaves

The number of leaves serves as the key growth indicator that reflects the vegetative development, vigour, photosynthetic capacity and potential biomass production in lemongrass, thus ultimately determining the herbage and essential oil yield. The number of leaves increased progressively and significantly among the treatments involving organic manures and biofertilizers throughout the research period (2023-24 and 2024-25) and in pooled analysis with data presented in Tables 4.

The significantly highest pooled number of leaves were recorded in treatment T₁₀ which was VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha), with values of 232.05 and 356.41 at 120 DAT and 210 DAT, respectively, which was superior to all other treatments. In contrast, the lowest pooled number of leaves (130.67 and 201.36 at 120 DAT and 210 DAT) was observed in treatment T₃ comprising FYM @ 10 t/ha.

Table 4: Effect of organic manures and biofertilizers on number of leaves of lemongrass (*Cymbopogon flexuosus* N.)

Treatments	Number of leaves					
	2023-24		2024-25		Pooled	
	120 DAT	210 DAT	120 DAT	210 DAT	120 DAT	210 DAT
T ₁	176.36	272.64	200.15	318.50	188.25	295.57
T ₂	129.88	198.25	151.23	230.05	140.56	214.15
T ₃	120.56	187.06	140.78	215.65	130.67	201.36
T ₄	155.31	237.55	177.85	275.72	166.58	256.64
T ₅	140.64	216.98	162.41	248.11	151.52	232.54
T ₆	162.51	248.67	185.60	285.30	174.05	266.99
T ₇	146.34	228.10	170.26	268.98	158.30	248.54
T ₈	166.60	256.51	192.18	299.14	179.39	277.83
T ₉	193.24	297.05	220.07	337.85	206.66	317.45
T ₁₀	217.66	332.36	246.45	380.47	232.05	356.41
Mean	160.91	247.52	184.70	285.98	172.80	266.75
Result	SIG	SIG	SIG	SIG	SIG	SIG
S.Em.±	7.58	11.63	8.16	13.54	7.34	11.74
C.D. at 5%	22.52	34.54	24.24	40.22	21.82	34.89

3.4 Leaf length (cm)

Leaf length is a phenotypic trait that is a strong indicator of a plant's canopy structure, stress reactions and adaptability. The administration of organic manure and biofertilizers treatments resulted in progressive increase in leaf length (cm) of lemongrass across the research period (2023-24 and 2024-25). The data related to the leaf length (cm) of lemongrass at 120

DAT and 210 DAT exhibited significant variation among the different treatments, as illustrated in Table 5.

Among the treatments, T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) reported significantly superior pooled leaf length (138.06 and 147.83 cm) at 120 DAT and 210 DAT, respectively. While the shortest pooled leaf length 89.23 cm (120 DAT) and 104.40 cm (210 DAT) was observed in treatment T₃ i.e., FYM (10 t/ha).

Table 5: Effect of organic manures and biofertilizers on leaf length (cm) of lemongrass (*Cymbopogon flexuosus* N.)

Treatments	Leaf length (cm)					
	2023-24		2024-25		Pooled	
	120 DAT	210 DAT	120 DAT	210 DAT	120 DAT	210 DAT
T ₁	111.52	123.05	125.38	134.79	118.45	128.92
T ₂	88.87	102.80	102.67	117.90	95.77	110.35
T ₃	83.71	98.94	94.75	109.85	89.23	104.40
T ₄	103.35	115.33	117.28	130.66	110.32	123.00
T ₅	94.91	107.09	109.32	123.71	102.12	115.40
T ₆	106.75	116.92	118.64	132.87	112.69	124.90
T ₇	99.06	112.62	113.21	129.30	106.14	120.96
T ₈	109.05	120.88	120.80	139.17	114.93	130.03
T ₉	117.86	128.55	130.05	143.02	123.96	135.79
T ₁₀	130.92	139.11	145.20	156.54	138.06	147.83
Mean	104.60	116.30	117.73	133.13	111.16	124.72
Result	SIG	SIG	SIG	SIG	SIG	SIG
S.Em.±	4.27	4.79	5.003	5.64	4.52	5.08
C.D. at 5%	12.704	14.24	14.87	16.77	13.43	15.09

3.5 Plant spread (cm)

Plant spread (cm) is a crucial parameter that represents the plant's establishment, tillering ability and contributes towards enhancing crop growth and productivity. During the experiment (2023-24 and 2024-25), data on the plant spread of lemongrass exhibited significant differences among the different organic manures and biofertilizers treatments, as shown in Tables 6.

The mean plant spread of lemongrass was significantly greater (130.14 cm and 154.41 cm at 120 DAT and 210 DAT) in treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha). Meanwhile, treatment T₃, i.e., FYM (10 t/ha) reported the least pooled spread (84.18 cm and 103.95 cm) at 120 DAT and 210 DAT, respectively.

Table 6: Effect of organic manures and biofertilizers on plant spread (cm) of lemongrass (*Cymbopogon flexuosus* N.)

Treatments	Plant spread (cm)					
	2023-24		2024-25		Pooled	
	120 DAT	210 DAT	120 DAT	210 DAT	120 DAT	210 DAT
T ₁	104.75	123.21	118.50	141.75	111.63	132.48
T ₂	83.42	102.35	97.05	119.82	90.24	111.09
T ₃	78.61	96.85	89.75	111.05	84.18	103.95
T ₄	97.04	113.54	110.68	133.62	103.86	123.58
T ₅	89.15	107.61	103.31	127.50	96.23	117.56
T ₆	100.25	117.20	112.18	136.51	106.22	126.86
T ₇	92.95	110.05	106.97	131.92	99.96	120.99
T ₈	102.45	119.38	114.25	137.25	108.35	128.32
T ₉	110.65	129.55	122.81	147.05	116.73	138.30
T ₁₀	123.05	144.27	137.22	164.55	130.14	154.41
Mean	98.23	116.40	111.27	135.10	104.75	125.75
Result	SIG	SIG	SIG	SIG	SIG	SIG
S.Em.±	4.02	4.83	4.71	5.73	4.25	5.13
C.D. at 5%	11.95	14.35	13.99	17.03	12.64	15.24

4. Discussion

In the present study, the treatment T₁₀ i.e., VC (2.5 t/ha) + FYM

(5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) significantly influenced the vegetative growth of lemongrass plants, highlighting its superiority in promoting growth of lemongrass. Enhanced plant height, tiller number, leaf number, leaf length and plant spread may be attributed to improvements in soil and rhizosphere conditions that favour nutrient availability, microbial activity, water retention, root growth and shoot development as a result of combined application of organic nutrient sources and biofertilizers.

Vermicompost and FYM provide organic matter, beneficial microorganisms and readily available macro- and micronutrients, while also improving soil physical, chemical and biological properties (Verma *et al.*, 2024) ^[18]. These manures support efficient nutrient mineralization and uptake, resulting in vigorous vegetative growth. *Azotobacter* and *Azospirillum* further enhanced plant growth by increasing nutrient availability through biological nitrogen fixation and by producing vitamins and plant growth-promoting substances (Manasi, 2024) ^[8].

The synergistic interaction of biofertilizers with vermicompost and FYM improves nitrogen supply, an essential component of chlorophyll, amino acids, proteins and enzymes, thereby promoting photosynthesis and overall plant development (Mwithiga *et al.*, 2024) ^[11]. Their application also stimulates the production of phytohormones such as auxins, cytokinins and gibberellins, which enhance cell division and cell expansion (Shraddha, 2024) ^[16], leading to improved vegetative growth. Similar findings related to the increase in the vegetative growth parameters due to integrated nutrient management have been reported by Sangeetha and Stella (2009) ^[15] in vetiver, Punam *et al.* (2012) ^[14] and Anjali (2019) ^[1] in lemongrass and Dora *et al.* (2024) ^[4] in citronella.

5. Conclusion

Based on the experimental results, it can be concluded that lemongrass growth and vegetative performance were significantly influenced by the integrated application of organic manures and biofertilizers. Among all treatments, T₁₀ consisting of VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) proved to be most effective in enhancing plant height, tiller production, number of leaves, leaf length and plant spread of lemongrass. The combined use of vermicompost, FYM and beneficial microorganisms improved soil health, nutrient availability, microbial activity and photosynthetic efficiency, resulting in vigorous plant growth. Therefore, integrated nutrient management using organic and biological inputs can be considered a sustainable and eco-friendly approach for improving lemongrass cultivation and productivity.

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