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Study on the application of organic manures and biofertilizers on yield performance of lemongrass (*Cymbopogon flexuosus* L.)

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Abstract

An experiment titled “Study on the application of organic manures and biofertilizers on yield performance of Lemongrass (*Cymbopogon flexuosus* L.)” was carried out at Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, (M.S.) during two consecutive years 2023-24 and 2024-25. The experiment comprised of ten treatments arranged in a randomized block design with three replications. Among the various organic manures and biofertilizers treatments, the treatment T₁₀ i.e., Vermicompost (2.5 t/ha) + Farmyard manure (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha), recorded the highest total fresh herb yield (46.64 t/ha), total dry herb yield (22.11 t/ha) and total essential oil yield (321.80 kg/ha). The integrated application of organic manures and biofertilizers significantly enhanced the overall productivity of lemongrass plant.

Keywords: Lemongrass, yield, essential oil, organic manures, biofertilizers

1. Introduction

The genus ‘*Cymbopogon*’ comprises of 180 species of tropical, fast-growing, C₄ perennial aromatic grasses belonging to family Poaceae (Tomar *et al.*, 2025) [17]. Among these, *Cymbopogon flexuosus* (East Indian lemongrass) holds predominant significance due to the high citral content of its essential oil. It is a tufted monocot grass, widely cultivated across India due to its varied agro-climatic conditions that enable the successful cultivation of lemongrass, as rainfed crop in the tropical and subtropical plains and as irrigated crop in the semi-arid regions (Gawali and Meshram, 2019) [7]. India produces around 1000 tonnes of lemongrass annually, out of which 300-400 tonnes are exported to more than 80 nations, strengthening India’s leadership in production and export (Singh *et al.*, 2024) [15]. Lemongrass is widely used across in the cosmetic, pharmaceutical, aromatherapy, agriculture, food and culinary industries. It exhibits antioxidant, anti-inflammatory, antifungal, antimalarial, analgesic properties, anti-bacterial and insecticidal properties (Spriha *et al.*, 2021) [16].

Increasing industrial utilization and expanding export opportunities have created a growing demand for improved yield and quality of lemongrass. The yield and quality of lemongrass are largely dependent on proper nutrient management, as the crop is primarily harvested for its vegetative biomass, which serves as the principal source of essential oil. Continuous and indiscriminate use of chemical fertilizers has led to several adverse effects, including soil degradation, nutrient imbalance, reduced microbial activity and environmental pollution (Trisilawati *et al.*, 2022) [18]. Therefore, enhancing both the quantity and quality of biomass and essential oil production requires the adoption of sustainable and eco-friendly nutrient management practices. Integrated nutrient management through the combined use of organic manures and biofertilizers offers an effective approach to improving soil fertility, nutrient availability, plant growth and overall crop productivity while maintaining long-term soil health and environmental sustainability.

Vermicompost and farmyard manure (FYM) are eco-friendly organic amendments that enhance soil health and promote sustainable crop production. Vermicompost is rich in macro-and micronutrients and also contains growth hormones and humic acids that stimulate

root and plant growth (Adhikary, 2012) ^[1]. FYM improves the physio-chemical properties of soil, including aeration, permeability, water-holding capacity and cation exchange capacity (Bayu *et al.*, 2006) ^[5]. Biofertilizers are regarded as plant growth promoting biological fertilizers. They are inexpensive, renewable and non-toxic nutrient sources that convert unavailable soil nutrients into available forms and fix atmospheric nitrogen biologically (Bandara *et al.*, 2019) ^[3]. Hence, the present investigation entitled “Study on the Application of Organic Manures and Biofertilizers on Yield Performance of Lemongrass (*Cymbopogon flexuosus* L.)” was undertaken to improve nutrient-use efficiency, biomass production and essential oil yield through sustainable nutrient management practices while reducing dependence on synthetic fertilizers and promoting environmentally sustainable agriculture.

2. Materials and Methods

The present investigation was conducted during 2023-24 and 2024-25 at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The experiment consisted of ten treatments involving different combinations of vermicompost, farmyard manure (FYM), *Azotobacter* and *Azospirillum*, also included a control with recommended dose of fertilizers (100:45:30 kg NPK/ha). The treatments were laid out in a randomized block design (RBD) with three replications. Healthy rooted slips of Krishna variety of lemongrass were transplanted at 60 × 60 cm spacing. Organic manures and biofertilizers were applied as basal doses according to the treatment schedule, while chemical fertilizers in the control were applied through urea, single super phosphate and muriate of potash. The crop was harvested twice, at 120 DAT (1st harvest) and 210 DAT (2nd harvest *i.e.*, 3 months after 1st harvest). Shade-dried herbage (250 g) was used for essential oil extraction through hydro-distillation using Clevenger’s apparatus. Data on yield parameters were recorded from five randomly selected healthy plants from replication of each treatment and analysed statistically as described by Panse and Sukhatme (1995) ^[10].

3. Results and Discussion

The data related to the yield enhancement in lemongrass, demonstrated significant variations across the different

organic manures and biofertilizers treatments, indicating their pronounced influence on growth and hence productivity of lemongrass in relation to the fresh herb yield (t/ha), dry herb yield (t/ha) and essential oil yield (kg/ha) during both years of the experiment (2023-24 and 2024-25) and then their pooled data was worked out.

3.1 Fresh herb yield (t/ha)

The data concerning the fresh herb yield (t/ha) was recorded twice during 1st harvest (120 DAT) and 2nd harvest (210 DAT *i.e.*, 3 months after 1st harvest). The total fresh herb yield (t/ha) was calculated by combining the yields obtained from both harvests during the research period (2023-25), as indicated in Table 1 and graphically presented in Fig 1. The application of various organic manures and biofertilizers significantly influenced fresh herb yield (t/ha) of lemongrass. Among the treatments, the highest yields (19.12 t/ha and 27.51 t/ha at 1st and 2nd harvest) were reported by treatment T₁₀ *i.e.*, VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha). In contrast, the treatment T₃ *i.e.*, FYM (10 t/ha) recorded the lowest fresh herb yields (11.13 t/ha and 15.88 t/ha at 1st and 2nd harvest, respectively). Overall, the treatment T₁₀ produced the highest cumulative fresh herb yield (46.64 t/ha), while treatment T₃ produced the lowest total yield (27.01 t/ha). Fresh herb yield in lemongrass reflects plant vigour and total biomass production and also demonstrates the effectiveness of treatments applied in the experiment. In the present study, the highest fresh herb yield (t/ha) was recorded in treatment T₁₀, which may be attributed to the synergistic application of organic manures combined with nitrogen-fixing bacteria. Vermicompost and FYM enrich the soil with organic matter and nutrients and improve soil fertility, structure and moisture retention capacity (Sharma *et al.*, 2023) ^[14], while *Azotobacter* and *Azospirillum* enhance nitrogen fixation, nutrient mineralization and the production of growth-promoting substances (Kumar *et al.*, 2019) ^[8]. Their integrated application promotes chlorophyll synthesis and improves photosynthetic efficiency, leading to better vegetative growth and increased fresh herbage yield. Similar results were also reported by Punam *et al.* (2012) ^[11], Anjali (2019) ^[2] and Kumar *et al.* (2021) ^[9] in lemongrass.

Table 1: Study on the application of organic manures and biofertilizers on fresh herb yield (t/ha) of lemongrass-pooled data from 2023-24 to 2024-25.

Treatments		Fresh herb yield (t/ha)		
		1 st Harvest	2 nd Harvest	Total
T ₁	RDF (100:45:30 NPK kg/ha)-Control	15.60	22.78	38.39
T ₂	Vermicompost (5 t/ha)	11.88	16.79	28.67
T ₃	FYM (10 t/ha)	11.13	15.88	27.01
T ₄	VC (5 t/ha) + <i>Azotobacter</i> (10 kg/ha)	13.92	19.99	33.91
T ₅	FYM (10 t/ha) + <i>Azotobacter</i> (10 kg/ha)	12.75	18.23	30.97
T ₆	VC (5 t/ha) + <i>Azospirillum</i> (10 kg/ha)	14.45	20.71	35.16
T ₇	FYM (10 t/ha) + <i>Azospirillum</i> (10 kg/ha)	13.28	19.41	32.68
T ₈	VC (2.5 t/ha) + FYM (5 t/ha) + <i>Azotobacter</i> (10 kg/ha)	14.94	21.51	36.45
T ₉	VC (2.5 t/ha) + FYM (5 t/ha) + <i>Azospirillum</i> (10 kg/ha)	16.98	24.39	41.37
T ₁₀	VC (2.5 t/ha) + FYM (5 t/ha) + <i>Azotobacter</i> (10 kg/ha) + <i>Azospirillum</i> (10 kg/ha)	19.12	27.51	46.64
Mean		14.41	20.72	35.13
Result		SIG	SIG	SIG
S.Em.±		0.65	0.96	1.45
C.D. at 5%		1.94	2.85	4.30

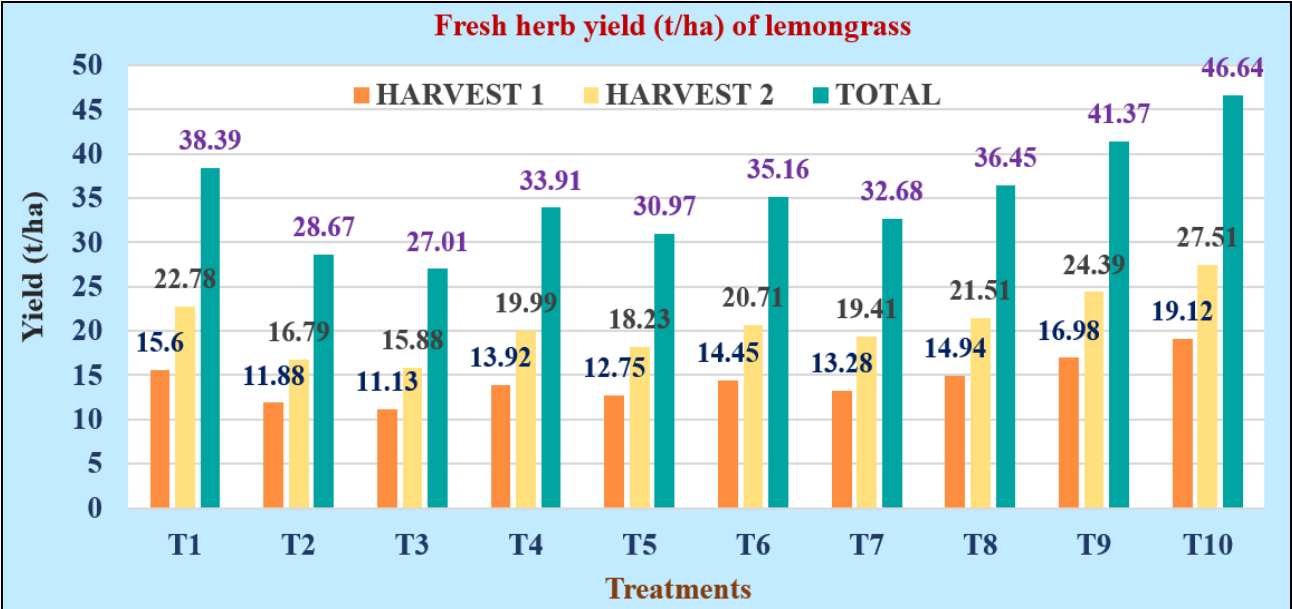


Fig 1: Study on the application of organic manures and biofertilizers on fresh herb yield (t/ha) of lemongrass.

3.2 Dry herb yield (t/ha)

The dry herb yield (t/ha) was recorded at two successive harvests i.e., 1st at 120 DAT and 2nd at 210 DAT during the experiment. The yields recorded at the harvests (1st and 2nd) were further combined to estimate the cumulative dry herb yield (t/ha) during the period of study (2023-24 and 2024-25). The data pertaining to the same is presented in the Table 2 and depicted in Fig 2. The organic manures and biofertilizers treatments had a

significant effect on dry herb yield (t/ha). The treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha) + Azospirillum (10 kg/ha), consistently produced the highest yields, with 8.95t/ha at 1st harvest and 13.16 t/ha at 2nd harvest, resulting in highest cumulative dry yield (22.11 t/ha). Meanwhile, the lowest yields (5.01 t/ha and 7.36 t/ha at 1st and 2nd harvests, respectively) were exhibited by treatment T₃ i.e., FYM (10 t/ha) and simultaneously, the lowest total dry yield (12.37 t/ha).

Table 2: Study on the application of organic manures and biofertilizers on dry herb yield (t/ha) of lemongrass-pooled data from 2023-24 to 2024-25.

Treatments		Dry herb yield (t/ha)		
		1 st Harvest	2 nd Harvest	Total
T ₁	RDF (100:45:30 NPK kg/ha)-Control	7.23	10.81	18.03
T ₂	Vermicompost (5 t/ha)	5.35	7.80	13.16
T ₃	FYM (10 t/ha)	5.01	7.36	12.37
T ₄	VC (5 t/ha) + Azotobacter (10 kg/ha)	6.38	9.40	15.78
T ₅	FYM (10 t/ha) + Azotobacter (10 kg/ha)	5.79	8.52	14.30
T ₆	VC (5 t/ha) + Azospirillum (10 kg/ha)	6.64	9.77	16.41
T ₇	FYM (10 t/ha) + Azospirillum (10 kg/ha)	6.05	9.10	15.15
T ₈	VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha)	6.88	10.17	17.05
T ₉	VC (2.5 t/ha) + FYM (5 t/ha) + Azospirillum (10 kg/ha)	7.91	11.63	19.54
T ₁₀	VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha) + Azospirillum (10 kg/ha)	8.95	13.16	22.11
Mean		6.62	9.77	16.39
Result		SIG	SIG	SIG
S.Em.±		0.30	0.46	0.68
C.D. at 5%		0.90	1.36	2.03

Dry herb yield is an important parameter for determining the actual quantity of dry matter produced by lemongrass plants and serves as a reliable indicator of biomass production under different treatments. In the present study, the significantly highest dry herb yield (t/ha) was recorded under treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha) + Azospirillum (10 kg/ha). This may be due to the integrated application of organic manures and beneficial microorganisms supplied through biofertilizers. Organic manures improve the physical, chemical and biological properties of soil and enrich it with essential

macro and micronutrients along with organic acids such as humic and fulvic acids (Trisilawati *et al.*, 2022) ^[18]. Biofertilizers like Azotobacter and Azospirillum synthesize growth hormones, enhance nutrient mobilization and aid in mineralization of soil organic matter (Basu *et al.*, 2021) ^[14], thereby improving the rhizosphere environment. This promotes root growth, nutrient uptake, photosynthesis and dry matter accumulation, ultimately resulting in higher dry herb yield. Similar findings were reported by Sangeetha and Stella (2009) ^[12] in vetiver, Punam *et al.* (2012) ^[11] and Anjali (2019) ^[2] in lemongrass.

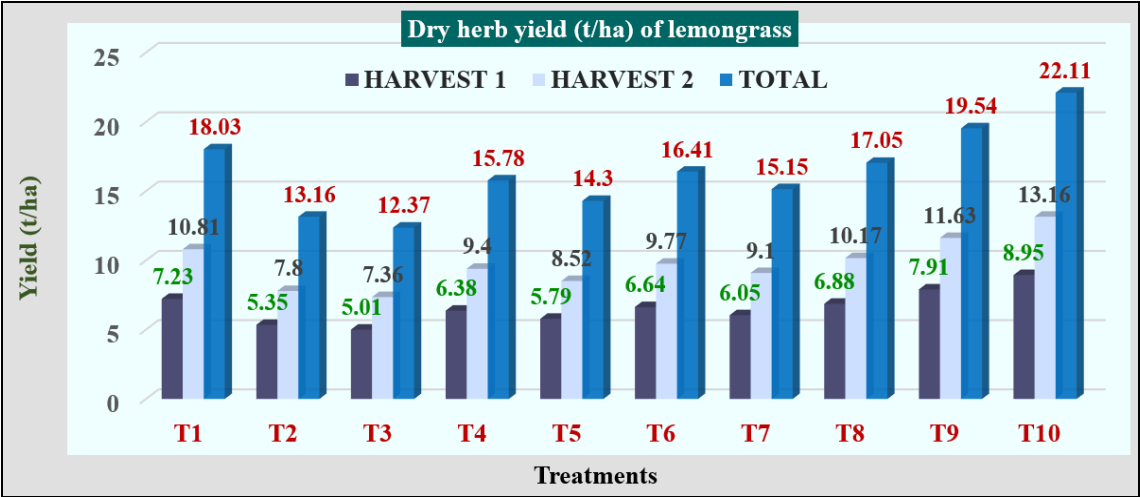


Fig 2: Study on the application of organic manures and biofertilizers on dry herb yield (t/ha) of lemongrass.

3.3 Essential oil yield (kg/ha)

The essential oil yield (kg/ha) was determined following the two consecutive harvests viz., 1st harvest (120 DAT) and 2nd harvest (210 DAT) through hydro-distillation of lemongrass herbage. The total essential oil (kg/ha) was estimated by combining the essential oil yields from both harvests (1st and 2nd) during the study period 2023-24 and 2024-25, as presented in Table 3 and illustrated in Fig 3.

Essential oil yield (kg/ha) varied significantly with the application of organic manures and biofertilizers, indicating their positive impact on lemongrass oil production. Treatment T₁₀ reported the highest yields i.e., 127.93 kg/ha and 193.87 kg/ha at 1st and 2nd harvests, thus resulting in the maximum total oil yield (321.80 kg/ha). In contrast, treatment T₃ recorded the lowest yields at the 1st (65.08 kg/ha) and 2nd harvests (99.08 kg/ha), with the lowest total oil yield (164.16 kg/ha).

Table 2: Study on the application of organic manures and biofertilizers on essential oil yield (kg/ha) of lemongrass-pooled data from 2023-24 to 2024-25.

Treatments		Essential oil (kg/ha)		
		1 st Harvest	2 nd Harvest	Total
T ₁	RDF (100:45:30 NPK kg/ha)-Control	101.15	155.95	257.10
T ₂	Vermicompost (5 t/ha)	70.90	106.75	177.65
T ₃	FYM (10 t/ha)	65.08	99.08	164.16
T ₄	VC (5 t/ha) + Azotobacter (10 kg/ha)	86.82	132.35	219.17
T ₅	FYM (10 t/ha) + Azotobacter (10 kg/ha)	77.73	118.07	195.80
T ₆	VC (5 t/ha) + Azospirillum (10 kg/ha)	91.55	139.23	230.78
T ₇	FYM (10 t/ha) + Azospirillum (10 kg/ha)	81.84	127.22	209.06
T ₈	VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha)	95.45	145.53	240.98
T ₉	VC (2.5 t/ha) + FYM (5 t/ha) + Azospirillum (10 kg/ha)	111.44	169.36	280.80
T ₁₀	VC (2.5 t/ha) + FYM (5 t/ha) + Azotobacter (10 kg/ha) + Azospirillum (10 kg/ha)	127.93	193.87	321.80
Mean		90.99	138.74	229.73
Result		SIG	SIG	SIG
S.Em.±		4.11	6.35	9.52
C.D. at 5%		12.22	18.87	28.29

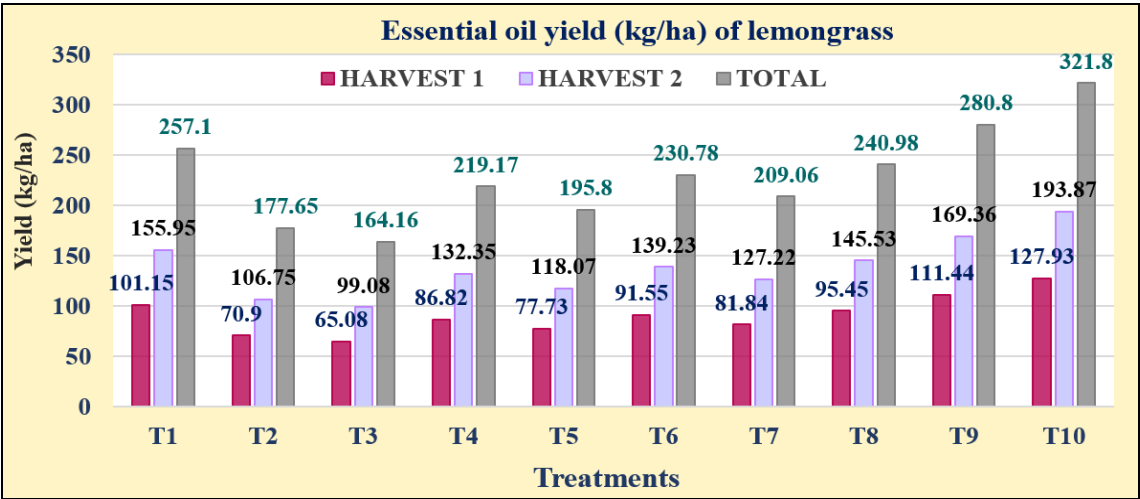


Fig 3: Study on the application of organic manures and biofertilizers on essential oil yield (kg/ha) of lemongrass.

Essential oil is the most economically important product of lemongrass plant. In the present investigation, the highest essential oil yield was recorded in treatment T₁₀ i.e., VC (2.5 t/ha) + FYM (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha). The increased oil yield may be attributed to higher fresh and dry herbage yields under this treatment. The combined application of organic manures and biofertilizers improves soil fertility, nutrient availability and enzymatic activity, while enhancing nitrogen fixation, microbial activity and nutrient mobilization. This synergistic effect promotes better root growth, nutrient uptake and physiological activity, leading to greater biomass accumulation, increased essential oil biosynthesis and accumulation in lemongrass. Similar findings were reported by Sasikala *et al.* (2016) ^[13], El-Sayed *et al.* (2018) ^[6] and Anjali (2019) ^[12] in lemongrass.

4. Conclusion

The study concluded that the integrated application of organic manures and biofertilizers significantly enhanced the yield performance of lemongrass. Among the different treatments, T₁₀ consisting of Vermicompost (2.5 t/ha) + Farmyard manure (5 t/ha) + *Azotobacter* (10 kg/ha) + *Azospirillum* (10 kg/ha) was found to be the most effective in improving fresh and dry herb yield as well as essential oil production. The combined use of vermicompost and FYM improved soil health and nutrient availability, while biofertilizers enhanced nitrogen fixation and plant growth-promoting activities. Thus, the integrated use of organic manures and biofertilizers can be recommended as a sustainable nutrient management strategy for increasing lemongrass productivity and maintaining soil fertility.

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