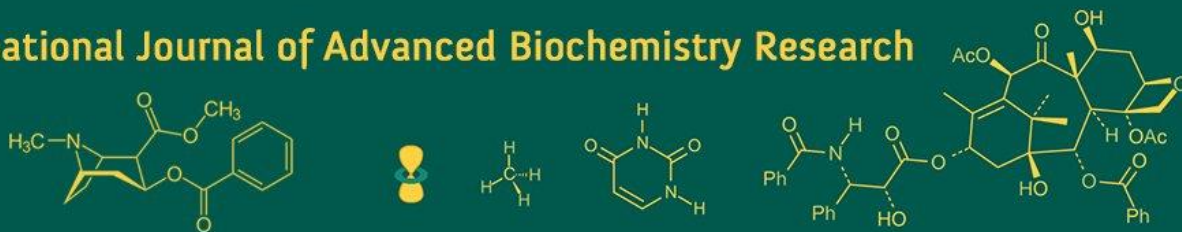


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Effect of organic manures and biofertilizers on herbage and essential oil yield of holy basil (*Ocimum tenuiflorum* L.)

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Abstract

An experiment entitled "Effect of organic manures and biofertilizers on herbage and essential oil yield of holy basil (*Ocimum tenuiflorum* L.)" was conducted over two year from 2023-24 to 2024-25 at Nursery No. 4, College of Horticulture, Dapoli. Sixteen treatment combinations were arranged in factorial randomized block design with three replications. The pooled result of this experiment revealed that the application of vermicompost at 5 t/ha significantly recorded the highest yield parameters viz., fresh herbage yield (268.72 g/plant and 144.79 g/plant at first and second harvest, respectively) (7466.44 kg/hectare and 4021.41 kg/hectare at first and second harvest, respectively) and essential oil yield (1.469 g/plant and 0.791 g/plant at first and second harvest) (40.81 kg/hectare and 21.97 kg/hectare at first and second harvest), The biofertilizer treatment comprising *Azospirillum* at 6 kg/ha showed highest fresh herbage yield (202.47 g/plant and 109.16 g/plant at first and second harvest) and (5624.43 kg/hectare and 3031.25 kg/hectare at first and second harvest) and essential oil yield (0.976 g/plant and 0.529 g/plant at first and second harvest, respectively) and (27.10 kg/hectare and 14.69 kg/hectare at first and second harvest, respectively). Notably, the interaction effect of treatment combination M3B2 (Vermicompost at 5 t/ha and *Azospirillum* at 6 kg/ha) recorded the highest fresh herbage yield (280.58 g/plant and 151.10 g/plant at first and second harvest, respectively) (7796.30 kg/hectare and 4196.76 kg/hectare at first and second harvest, respectively) and essential oil yield (1.686 g/plant and 0.907 g/plant at first and second harvest, respectively) and (46.81 kg/hectare and 25.19 kg/hectare at first and second harvest, respectively).

Keywords: Holy basil, FYM, Vermicompost, Biogas slurry, *Azospirillum*, *Azotobacter*, PSB and VAM

Introduction

Revered as the "Queen of Herbs," holy basil scientifically known as *Ocimum tenuiflorum* L. It is a diploid ($2n=32$) perennial shrub belonging to the Lamiaceae family. Beyond its profound spiritual and religious status, the plant is a cornerstone of traditional Eastern medicinal systems, including Ayurveda and Unani. Its therapeutic utility has been documented for centuries, most notably in the "Charaka Samhita". The species exhibits remarkable ecological adaptability, with a broad distribution spanning from the Andaman and Nicobar Islands to the high-altitude reaches of the Himalayas (up to 1800 m). Within the Indian subcontinent, commercial cultivation primarily focuses on two distinct morphotypes: Sri Tulsi: The more prevalent green-leaved variety and Krishna Tulsi: Distinguished by its purple foliage, this variety is highly prized in the pharmaceutical market for its greater concentration of bioactive compounds. Holy Basil serves as a versatile medicinal agent. Traditionally, it has been employed to address a diverse range of health concerns, including renal dysfunction, respiratory distress, digestive issues and parasitic infections. Modern scientific inquiry corroborates these traditional practices, identifying the plant's essential oils as potent sources of antioxidant, antimicrobial (antibacterial/antifungal) and insecticidal agents (Baranauskiene et al., 2003)^[1].

The pharmaceutical industry's increasing preference for chemical-free raw materials has created a clear imperative to scale up organic production. Historically, the reliance on indiscriminate synthetic fertilization has led to soil nutrient imbalances and degradation, ultimately undermining crop productivity and medicinal quality. To ensure the long-term viability of holy basil cultivation, there is a strategic shift toward the use of organic amendments and biofertilizers, such as *Azotobacter*, *Azospirillum*, PSB and VAM. By enhancing the soil's physicochemical and biological properties, these inputs not only serve as a nutrient source but also optimize the efficiency of the soil-plant system, ensuring a sustainable, high-quality yield that meets rigorous industry standards.

Material and methods

A field trial was conducted over two consecutive seasons (2023-24 and 2024-25) at Nursery No. 4, College of Horticulture, DBSKKV, Dapoli. The study employed in FRBD with 16 distinct treatment combinations, replicated three times. The experimental treatments comprised a factorial arrangement of four organic manures and four biofertilizers as follows: Organic Manures (M): absolute control (M₁), FYM at 10 t/ha (M₂), vermicompost at 5 t/ha (M₃) and biogas slurry at 5 t/ha (M₄). Biofertilizers (B): PSB at 6 kg/ha (B₁), *Azospirillum* at 6 kg/ha (B₂), *Azotobacter* at 6 kg/ha (B₃) and VAM at 6 kg/ha (B₄). Standard agronomic practices for the cultivation of holy basil were strictly followed throughout the trial. Yield parameters, specifically fresh herbage yield (g/plant and kg/hectare) and essential oil yield (g/plant and kg/hectare), were measured at two specific harvest intervals: 90 DAT and 150 DAT. All collected data were subjected to statistical analysis using SAS software, with the analysis of variance (ANOVA) performed in accordance with the methodology outlined by Panse and Sukhatme (1965)^[2].

Results and discussion

1 Fresh herbage yield per plant (g)

1.1 Fresh herbage yield per plant at first harvest

Data presented in Table 1 indicated that the organic manures, biofertilizers and their synergistic application significantly influence the fresh herbage yield per plant at first harvest, across two consecutive seasons (2023-24 and 2024-25) along with pooled data.

1.1.1 Effect of organic manures on fresh herbage yield per plant at first harvest of holy basil (M):

Treatment M₃ consistently proved to be the most effective and recorded significantly the highest fresh herbage (262.54 g, 274.89 g and 268.72 g) during the years 2023-24, 2024-25 and pooled analysis, respectively and superior over rest of the treatments. In contrast, treatment M₁ exhibited significant treatment variations and recorded the lowest fresh herbage yields across the same periods, pulling in just 72.17 g, 82.26 g and 77.22 g.

1.1.2 Effect of biofertilizers on fresh herbage yield per plant at first harvest of holy basil (B)

At first harvest, the treatment B₂, resulted in the highest fresh herbage yield (197.06 g, 207.88 g and 202.47 g), demonstrating superiority over all other treatments. Conversely, treatment B₁ exhibited the lowest fresh herbage yield (174.16 g, 185.35 g and 179.76 g) during 2023-24, 2024-25 and in pooled analysis, respectively.

1.1.3 Interaction effect of organic manures and biofertilizers on fresh herbage yield per plant at first harvest of holy basil (M X B)

The highest fresh herbage yield per plant (274.56 g, 286.60 g and 280.58 g) was recorded under M₃B₂ which was significantly higher than all other treatments, while the lowest fresh herbage yield (67.64 g, 77.66 g and 72.66 g) was noticed in M₁B₁ during 2023-24, 2024- 25 and in pooled analysis.

1.2 Fresh herbage yield per plant at second harvest

Table 2 presents a comprehensive dataset illustrating the impact of organic manures, biofertilizers and their combined application on fresh herbage yield per plant at second harvest

over two successive seasons (2023-24 and 2024-25), along with pooled data analysis.

1.2.1 Effect of organic manures on fresh herbage yield per plant at second harvest (M)

At second harvest, treatment M₃ was the most effective treatment, achieving a highest fresh herbage yield (138.74 g, 150.84 g and 144.79 g) which significantly outperformed the remaining treatments during 2023-24, 2024-25 and in pooled analysis. In contrast, treatment M₁ recorded the lowest herbage yield of 35.81 g, 47.61 g and 41.71 g highlighting significant treatment variations. This finding underscores the significant treatment variations observed in the study.

1.2.2 Effect of biofertilizers on fresh herbage yield per plant at second harvest (B)

At second harvest, the treatment B₂ achieved the highest fresh herbage yield (103.13 g, 115.20 g and 109.16 g) this was statistically significant, with a superior outcome compared to all other treatments. In contrast, treatment B₁ resulted in the lowest fresh herbage yield of 90.99 g, 102.59 g and 96.79 g during 2023-24, 2024-25 and in pooled analysis.

1.2.3 Interaction effect of organic manures and biofertilizers on fresh herbage yield per plant at second harvest (M X B)

At second harvest, the highest fresh herbage yield (144.68 g, 157.51 g and 151.10 g) was recorded under M₃B₂ which was significantly superior over other treatments, while the lowest fresh herbage yield (33.71 g, 44.53 g and 39.13 g) was noticed in M₁B₁ during 2023-24, 2024-25 and in pooled analysis.

2 Fresh herbage yield per hectare (kg)

2.1 Fresh herbage yield per hectare at first harvest

The data on the impact of organic manures, biofertilizers and their combined application on fresh herbage yield per hectare at first harvest including results from two consecutive seasons (2023-24 and 2024-25) and pooled data are presented in Table 3.

2.1.1 Effect of organic manures on fresh herbage yield per hectare at first harvest of holy basil (M)

At first harvest, treatment M₃ emerging as the most effective treatment. This treatment achieved a highest fresh herbage yield per hectare of 7295.14 kg, 7637.73 kg and 7466.44 kg during 2023-24, 2024-25 and in pooled analysis, respectively. In contrast, treatment M₁ recorded the lowest fresh herbage yield per hectare of 2004.63 kg, 2284.72 kg and 2144.68 kg highlighting significant variations among treatments during 2023-24, 2024-25 and in pooled analysis, respectively.

2.1.2 Effect of bio fertilizers on fresh herbage yield per hectare at first harvest of holy basil (B)

The findings of the experimental trial indicated that the treatment B₂ was the most efficacious in enhancing fresh herbage yield per hectare, achieving a highest value (5473.38 kg, 5775.46 kg and 5624.43 kg) during 2023-24, 2024-25 and in pooled analysis, respectively. This value was statistically highest over other treatments. Conversely, treatment B₁ exhibited the lowest fresh herbage yield per hectare (4839.12 kg, 5149.31 kg and 4994.22 kg) during 2023- 24, 2024-25 and in pooled analysis, respectively highlighting the significance of biofertilizer application.

2.1.3 Interaction effect of organic manures and biofertilizers on fresh herbage yield per hectare at first harvest of holy basil (M X B)

The data collected during 2023-24, 2024-25 and pooled analysis indicated that highest fresh herbage yield per hectare (7629.63 kg/ha, 7962.97 kg and 7796.30 kg, respectively) was recorded under M₃B₂ while the lowest fresh herbage yield per hectare (1879.63 kg/ha, 2157.41 kg/ha and 2018.52 kg/ha, respectively) was noticed in M₁B₁.

2.2 Fresh herbage yield per hectare at second harvest

The data on the impact of organic manures, biofertilizers and their combined application on fresh herbage yield per hectare at second harvest including results from two consecutive seasons (2023-24 and 2024-25) and pooled data are presented in Table 4.

2.2.1 Effect of organic manures on fresh herbage yield per hectare at second harvest of holy basil (M)

At second harvest, treatment M₃ emerging as the most effective treatment. This treatment achieved the highest fresh herbage yield per hectare (3854.17 kg, 4188.66 kg and 4021.41 kg) during 2023-24, 2024-25 and in pooled analysis, respectively. In contrast, treatment M₁ recorded the lowest fresh herbage yield per hectare (994.21 kg, 1321.76 kg and 1157.99 kg) highlighting significant variations among treatments during 2023-24, 2024-25 and in pooled analysis, respectively. (Table 4).

2.2.2 Effect of biofertilizers on fresh herbage yield per hectare at second harvest of holy basil (B)

The findings of the first trial (2023-24), second trial (2024-25) and pooled analysis indicated that treatment B₂ was the most efficacious in enhancing fresh herbage yield per hectare at second harvest, achieving a highest value of 2863.43 kg/ha, 3199.07 kg/ha and 3031.25 kg/ha, respectively. This value was statistically highest over other treatments. Conversely, treatment B₁ exhibited the lowest fresh herbage yield per hectare (2527.78 kg, 2848.38 kg and 2688.08 kg) during 2023-24, 2024-25 and in pooled analysis, respectively highlighting the significance of biofertilizer application.

2.2.3 Interaction effect of organic manures and biofertilizers on fresh herbage yield per hectare at second harvest of holy basil (M X B)

At second harvest, collected data indicated that highest fresh herbage yield per hectare (4018.52 kg, 4375.00 kg and 4196.76 kg) was recorded under M₃B₂ during 2023-24, 2024-25 and in pooled analysis, respectively. This treatment was found significantly superior over other treatments, while the lowest fresh herbage yield per hectare (935.19 kg, 1236.11 kg and 1085.65 kg) was noticed in M₁B₁ during 2023-24, 2024-25 and in pooled analysis, respectively.

3 Essential oil yield per plant (g)

3.1 Essential oil yield per plant at first harvest

Table 5 provides a data of the influence of organic manures, biofertilizers and their synergistic application on essential oil yield per plant at first harvest, across two consecutive seasons (2023-24 and 2024-25) along with pooled data.

3.1.1 Effect of organic manures on essential oil yield per plant at first harvest of holy basil (M)

At first harvest, the treatment M₃ emerged as the most effective treatment among other treatments, achieving a highest essential oil yield (1.445 g, 1.493 g and 1.469 g) during 2023- 24, 2024-25 and in pooled analysis, respectively which was significantly superior over other treatments. Conversely, treatment M₁ recorded the lowest essential oil yield of 0.177 g, 0.231 g and 0.204 g highlighting significant treatment variations during 2023-24, 2024-25 and in pooled analysis, respectively.

3.1.2 Effect of biofertilizers on essential oil yield per plant at first harvest of holy basil (B)

At first harvest, the both experimental trial and pooled data demonstrated that treatment B₂ resulted in the highest essential oil yield of 0.950 g, 1.001 g and 0.976 g respectively, demonstrating superiority over all other treatments. Conversely, treatment B₁ exhibited the lowest essential oil yield of 0.719 g, 0.779 g and 0.749 g during 2023-24, 2024-25 and in pooled analysis, respectively.

3.1.3 Interaction effect of organic manures and biofertilizers on essential oil yield per plant at first harvest of holy basil (M X B)

The data collected during the first trial, second trial and pooled analysis indicated that highest essential oil yield (1.660 g, 1.710 g and 1.686 g, respectively) was recorded under M₃B₂ which was significantly higher than all other treatments while the lowest essential oil yield (0.169 g, 0.217 g and 0.193 g) during 2023-24, 2024-25 and in pooled analysis, respectively was noticed in M₁B₁.

3.2 Essential oil yield per plant at second harvest

Table 6: represents a comprehensive dataset illustrating the impact of organic manures, biofertilizers and their combined application on essential oil yield per plant at second harvest over two successive seasons (2023-24 and 2024-25), along with pooled data analysis.

3.2.1 Effect of organic manures on essential oil yield per plant at second harvest (M)

At second harvest, the treatment M₃ was the most effective treatment, achieving a highest essential oil yield (0.776 g, 0.805 g and 0.791 g) during 2023-24, 2024-25 and in pooled analysis, respectively which significantly outperformed the remaining treatments. In contrast, treatment M₁ recorded the lowest essential oil yield of 0.095 g, 0.124 g and 0.110 g, highlighting significant treatment variations during 2023-24, 2024-25 and in pooled analysis, respectively.

3.2.2 Effect of biofertilizers on essential oil yield per plant at second harvest (B)

The examination of first trial, second trial and pooled data revealed that treatment B₂, which included *Azospirillum* at 6 kg/ha achieved the highest essential oil yield (0.515 g, 0.542 g and 0.529 g, respectively). This was statistically significant, with a superior outcome compared to all other treatments. In contrast, treatment B₁ resulted in the lowest essential oil yield of 0.385 g, 0.413 g and 0.399 g during 2023-24, 2024-25 and in pooled analysis, respectively.

3.2.3 Interaction effect of organic manures and biofertilizers on essential oil yield per plant at second harvest (M X B)

The data collected during 2023-24, 2024-25 and pooled data indicated that highest essential oil yield (0.892 g, 0.922 g and 0.907 g, respectively) was recorded under M₃B₂ which was significantly superior over other treatments while the lowest essential oil yield (0.084 g, 0.112 and 0.099 g) was noticed in M₁B₁ during 2023-24, 2024-25 and in pooled analysis, respectively. (Table 6).

4 Essential oil yield per hectare (kg)

4.1 Essential oil yield per hectare at first harvest

The data on the impact of organic manures, biofertilizers and their combined application on essential oil yield per hectare at first harvest including results from two consecutive seasons (2023-24 and 2024-25) and pooled data are presented in Table 7.

4.1.1 Effect of organic manures on essential oil yield per hectare at first harvest of holy basil (M):

The first trial (2023-24), second trial (2024-25) and pooled data yielded notable results, with treatment M₃ emerging as the most effective treatment. This treatment achieved a highest essential oil yield per hectare of 40.14 kg, 41.48 kg and 40.81 kg, respectively. In contrast, treatment M₁ recorded the lowest essential oil yield per hectare of 4.93 kg, 6.41 kg and 5.67 kg during 2023-24, 2024-25 and pooled data highlighting significant variations among treatments.

4.1.2 Effect of biofertilizers on essential oil yield per hectare at first harvest of holy basil (B)

The findings of the both experimental trials (2023-24 and 2024-25) and pooled data indicated that treatment B₂ was the most efficacious in enhancing essential oil yield per hectare, recorded the highest value of 26.38 kg, 27.81 kg and 27.10 kg, respectively. This value was statistically highest over other treatments. Conversely, treatment B₁ exhibited the lowest essential oil yield per hectare 19.97 kg, 21.63 kg and 20.80 kg during 2023-24, 2024-25 and in pooled analysis, respectively highlighting the significance of biofertilizer application.

4.1.3 Interaction effect of organic manures and biofertilizers on essential oil yield per hectare at first harvest of holy basil (M X B)

The data collected during 2023-24, 2024-25 and pooled analysis indicated that the highest essential oil yield per hectare (46.11 kg, 47.50 kg and 46.81 kg, respectively) was recorded under M₃B₂ while the lowest essential oil yield per hectare (4.70 kg, 6.02 kg and 5.36 kg) was noticed in M₁B₁ during 2023-24, 2024-25 and in pooled analysis, respectively.

4.2 Essential oil yield per hectare at second harvest

The data on the impact of organic manures, biofertilizers and their combined application on essential oil yield per hectare at second harvest including results from two consecutive seasons (2023-24 and 2024-25) and pooled data are presented in Table 8.

4.2.1 Effect of organic manures on essential oil yield per hectare at second harvest of holy basil (M)

At second harvest, the treatment M₃ emerging as the most effective treatment and recorded the highest essential oil yield

per hectare of 21.56 kg, 22.37 kg and 21.97 kg during 2023-24, 2024-25 and in pooled analysis, respectively. In contrast, treatment M₁ exhibited the lowest essential oil yield per hectare of 2.66 kg, 3.44 kg and 3.05 kg during 2023-24, 2024-25 and in pooled analysis, respectively highlighting significant variations among treatments.

4.2.2 Effect of biofertilizers on essential oil yield per hectare at second harvest of holy basil (B)

The findings of the first trial (2023-24), second trial (2024-25) and pooled data indicated that treatment B₂ was the most efficacious in enhancing essential oil yield per hectare, achieving a highest value of 14.32 kg, 15.06 kg 14.69 kg, respectively and found significantly superior over other treatments. Conversely, treatment B₁ exhibited the lowest essential oil yield per hectare 10.71 kg, 11.47 kg and 11.09 kg during 2023-24, 2024-25 and in pooled analysis, respectively.

4.2.3 Interaction effect of organic manures and biofertilizers on essential oil yield per hectare at second harvest of holy basil (M X B)

At second harvest, the data collected during the first trial, second trial and pooled data indicated that the highest essential oil yield per hectare (24.77 kg, 25.61 kg and 25.19 kg, respectively) was recorded under M₃B₂, while the lowest essential oil yield per hectare (2.36 kg, 3.10 kg and 2.74 kg) was noticed in M₁B₁ during 2023-24, 2024-25 and in pooled analysis, respectively. (Table 8).

Discussion

1. Fresh herbage yield

1.1 Effect of organic manures on fresh herbage yield of holy basil (M)

Vermicompost significantly boosts the fresh herbage yield by improving soil structure, aeration and water-holding capacity, creating an ideal environment for vegetative growth. Its rich profile of essential macro and micronutrients, combined with beneficial microorganisms and plant growth-promoting substances like phytohormones and humic acids, enhances soil fertility and enzymatic activity. Furthermore, vermicompost stimulates root development and increases the efficiency of nutrient uptake; notably, it promotes the accumulation of IAA by inhibiting IAA oxidase, which directly drives superior biomass production and sustained crop yield. The results of the present study are consistent with those reported by Kumar (2007)^[3] in lemon tulsi, Prabu and Arumugam (2013)^[4] in Japanese mint, Raina *et al.* (2013)^[5] in *Ocimum sanctum* L., Abaszadeh *et al.* (2016)^[6] in *Lavandula angustifolia*, Cheena *et al.* (2021)^[7] in *Ocimum basilicum* L. and Beleri *et al.* (2024)^[8] in tulsi.

1.2 Effect of biofertilizers on total fresh herbage yield of holy basil (B)

The increase in total fresh herbage yield per plant might be attributed to the enhanced bioavailability and subsequent uptake of essential nutrients by the plants. *Azospirillum* stimulates plant growth by producing various phytohormones and facilitating biological nitrogen fixation; this increased nutrient availability enables the plant to produce a greater number of branches, leaves and inflorescences, ultimately resulting in a higher total fresh herbage yield per plant. These findings align with the results reported by Kandeel *et al.* (2002)^[9] in sweet basil as well as Manjunatha *et al.* (2002)^[10] in patchouli.

1.3 Interaction effect of organic manures and biofertilizers on fresh herbage yield of holy basil (M X B)

This superior performance is driven by the synergistic effect of the two inputs: vermicompost optimizes the rhizosphere's physical and chemical properties, while *Azospirillum* enhances biological nitrogen fixation. The resulting increase in nitrogen availability supports essential protein synthesis, cell division and enlargement, which together maximize key growth parameters like plant height, leaf count and branching, ultimately leading to significant increases in total biomass accumulation. These results are in conformity with the findings of Hemalatha and Suresh (2012)^[11] as well as Sanjutha *et al.* (2008)^[12] in kalmegh.

2 Essential oil yield of holy basil

2.1 Effect of organic manures on essential oil yield of holy basil (M)

Essential oil biosynthesis is intrinsically linked to photosynthetic activity, as it requires a high expenditure of ATP and NADPH to generate terpenoid precursors like IPP and DMAPP. In this study, the application of vermicompost at 5 t/ha significantly increased essential oil content by boosting the net photosynthetic rate, thereby enhancing both precursor availability and downstream enzymatic activity. This process is further supported by the presence of humic acids, plant growth regulators and beneficial rhizospheric microorganisms in the vermicompost, which promote structural growth such as increased leaf count and inflorescence number that correlates directly with higher volatile oil accumulation across leaves, stems and inflorescences. These results align with the findings of Jayasri and Anuja (2010)^[13] in sweet basil, Raina *et al.* (2013)^[5] in *Ocimum sanctum* L. Abaszadeh *et al.* (2016)^[6] in *Lavandula angustifolia*, Cheena *et al.* (2021)^[7] in *Ocimum basilicum* L. and Beleri *et al.* (2024)^[8] in tulsi.

2.2 Effect of biofertilizers on essential oil yield of holy basil (B)

This improvement stems from a combination of increased vegetative biomass and higher oil concentration in leaf tissues, driven by the biofertilizer's ability to stimulate the endogenous production of growth regulators like IAA, gibberellic acid and kinetin, which upregulate secondary metabolic pathways. Furthermore, *Azospirillum* improves the mobilization and uptake of nitrogen and phosphorus, fuelling profuse vegetative growth by accelerating the conversion of photosynthates into structural proteins and amino acids, ultimately creating a more robust foundation for essential oil accumulation. The present results are in conformity with the findings of Manjunatha *et al.* (2002)^[10] in patchouli (*Pogostemon cablin*) and Aboud *et al.* (2021)^[14] in lavender (*Lavandula officinalis* L.).

2.3 Interaction effect of organic manures and biofertilizers on essential oil yield of holy basil (M X B)

The superior essential oil yield achieved through the integrated application of vermicompost and *Azospirillum* stems from their synergistic ability to optimize the rhizosphere and enhance nutrient bioavailability. By improving soil physical properties, water-holding capacity and nutrient uptake efficiency, this combination supports vigorous vegetative growth including increased leaf area, plant height and branching which is tightly correlated with higher volatile oil accumulation in aromatic species like holy basil. Furthermore, the ample nitrogen supply fuelled by these inputs promotes chlorophyll synthesis and metabolic activity, facilitating the production of essential carbohydrates and amino acids that serve as precursors for phytohormones and secondary metabolites. Ultimately, this integrated approach creates an optimal physiological environment that maximizes both biomass production and the biosynthetic capacity for essential oils. The findings of this research align closely with the results Kumar (2009)^[15] in stevia, Rajamanickam *et al.* (2011)^[16] in mint, Abhilasha Srivastava (2017)^[17] in kalmegh, Yashaswini *et al.* (2020)^[18] in tulsi.

Table 1a: Effect of organic manures and biofertilizers on fresh herbage yield (g/plant) of holy basil at first harvest

Treatment	Fresh herbage yield (g/plant) at first harvest														
	2023-24					2024-25					Pooled				
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean
M ₁	67.64	73.38	73.13	74.55	72.17	77.66	84.49	83.26	83.65	82.26	72.66	78.94	78.20	79.10	77.22
M ₂	207.71	236.56	237.78	222.76	226.20	218.66	246.63	242.31	233.84	235.36	213.19	241.60	240.04	228.30	230.78
M ₃	248.56	274.56	264.41	262.63	262.54	261.10	286.60	276.77	275.08	274.89	254.83	280.58	270.60	268.86	268.72
M ₄	172.75	203.74	191.95	187.34	188.94	183.97	213.82	202.23	197.46	199.37	178.36	208.78	197.09	192.40	194.16
Mean	174.16	197.06	191.81	186.82		185.35	207.88	201.14	197.51		179.76	202.47	196.48	192.16	
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test
M	1.290		3.889		SIG	1.033		3.114		SIG	0.877		2.644		SIG
B	1.290		3.889		SIG	1.033		3.114		SIG	0.877		2.644		SIG
M X B	2.580		7.777		SIG	2.066		6.229		SIG	1.754		5.288		SIG

Table 1b: Effect of organic manures and biofertilizers on fresh herbage yield (g/plant) of holy basil at second harvest

Fresh herbage yield (g/plant) at second harvest															
Treatment	2023-24					2024-25					Pooled				
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean
M ₁	33.71	36.99	36.35	36.20	35.81	44.53	49.09	47.85	48.98	47.61	39.13	43.04	42.10	42.59	41.71
M ₂	108.53	124.27	121.74	116.68	117.80	121.05	135.92	133.80	129.18	129.99	114.79	130.10	127.77	122.93	123.90
M ₃	131.66	144.68	139.95	138.67	138.74	142.76	157.51	152.23	150.87	150.84	137.21	151.10	146.09	144.77	144.79
M ₄	90.07	106.57	99.52	97.85	98.50	102.02	118.27	112.72	109.35	110.59	96.04	112.42	106.12	103.61	104.55
Mean	90.99	103.13	99.39	97.35		102.59	115.20	111.65	109.60		96.79	109.16	105.52	103.47	
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test
M	0.377		1.136		SIG	0.419		1.262		SIG	0.327		0.986		SIG
B	0.377		1.136		SIG	0.419		1.262		SIG	0.327		0.986		SIG
M X B	0.754		2.272		SIG	0.838		2.525		SIG	0.654		1.972		SIG

Table 2a: Effect of organic manures and biofertilizers on fresh herbage yield (kg/ha) of holy basil at first harvest

Fresh herbage yield (kg/ha) at first harvest															
Treatment	2023-24					2024-25					Pooled				
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean
M ₁	1879.63	2037.04	2032.41	2069.45	2004.63	2157.41	2347.22	2310.19	2324.07	2284.72	2018.52	2192.14	2171.30	2196.76	2144.68
M ₂	5768.52	6569.45	6606.48	6185.19	6282.41	6074.08	6851.85	6731.48	6495.37	6538.19	5921.30	6710.65	6668.98	6340.28	6410.30
M ₃	6907.41	7629.63	7347.23	7296.30	7295.14	7254.63	7962.97	7689.82	7643.52	7637.73	7081.02	7796.30	7518.52	7469.91	7466.44
M ₄	4800.93	5657.41	5328.71	5203.71	5247.69	5111.12	5939.82	5615.75	5486.12	5538.20	4956.03	5798.62	5472.23	5344.91	5392.94
Mean	4839.12	5473.38	5328.70	5188.66		5149.31	5775.46	5586.81	5487.27		4994.22	5624.43	5457.76	5337.96	
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test
M	35.920		108.276		SIG	28.526		85.987		SIG	24.053		72.503		SIG
B	35.920		108.276		SIG	28.526		85.987		SIG	24.053		72.503		SIG
M X B	71.841		216.551		SIG	57.052		171.975		SIG	48.105		145.006		SIG

Table 2b: Effect of organic manures and biofertilizers on fresh herbage yield (kg/ha) of holy basil at second harvest

Fresh herbage yield (kg/ha) at second harvest													
Treatment	2023-24					2024-25					Pooled		
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃
M ₁	935.19	1027.78	1009.26	1004.63	994.21	1236.11	1361.11	1328.71	1361.11	1321.76	1085.65	1194.45	1168.99
M ₂	3018.52	3449.08	3379.63	3240.75	3271.99	3361.11	3773.15	3717.60	3587.97	3609.95	3189.82	3611.12	3548.61
M ₃	3657.41	4018.52	3888.89	3851.86	3854.17	3962.97	4375.00	4226.85	4189.82	4188.66	3810.19	4196.76	4057.87
M ₄	2500.00	2958.34	2763.89	2717.60	2734.95	2833.34	3287.04	3134.26	3037.04	3072.92	2666.67	3122.69	2949.08
Mean	2527.78	2863.43	2760.42	2703.71		2848.38	3199.07	3101.85	3043.98		2688.08	3031.25	2931.14
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%
M	10.623		32.023		SIG	11.323		34.132		SIG	8.964		27.020
B	10.623		32.023		SIG	11.323		34.132		SIG	8.964		27.020
M X B	21.247		64.045		SIG	22.647		68.264		SIG	17.928		54.041

Table 3a: Effect of organic manures and biofertilizers on essential oil yield (g/plant) of holy basil at first harvest

Essential oil yield (g/plant) at first harvest													
Treatment	2023-24					2024-25					Pooled		
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃
M ₁	0.169	0.170	0.191	0.180	0.177	0.217	0.225	0.250	0.232	0.231	0.193	0.197	0.221
M ₂	0.828	1.159	1.101	0.935	1.006	0.879	1.211	1.148	0.984	1.055	0.854	1.185	1.125
M ₃	1.278	1.660	1.467	1.376	1.445	1.324	1.710	1.514	1.423	1.493	1.301	1.686	1.491
M ₄	0.601	0.811	0.724	0.689	0.706	0.696	0.860	0.776	0.735	0.766	0.649	0.836	0.750
Mean	0.719	0.950	0.871	0.795		0.779	1.001	0.922	0.843		0.749	0.976	0.896
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%
M	0.015		0.044		SIG	0.020		0.061		SIG	0.016		0.048
B	0.015		0.044		SIG	0.020		0.061		SIG	0.016		0.048
MX B	0.029		0.088		SIG	0.041		0.122		SIG	0.032		0.095

Table 3b: Effect of organic manures and biofertilizers on essential oil yield (g/plant) of holy basil at second harvest

Treatment	Essential oil yield (g/plant) at second harvest													
	2023-24					2024-25					Pooled			
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄
M ₁	0.084	0.107	0.093	0.098	0.095	0.112	0.133	0.126	0.124	0.124	0.099	0.120	0.110	0.112
M ₂	0.445	0.625	0.593	0.501	0.541	0.474	0.651	0.618	0.534	0.569	0.460	0.638	0.606	0.518
M ₃	0.686	0.892	0.789	0.739	0.776	0.715	0.922	0.816	0.768	0.805	0.701	0.907	0.803	0.754
M ₄	0.324	0.437	0.391	0.367	0.379	0.350	0.463	0.417	0.400	0.407	0.337	0.450	0.404	0.384
Mean	0.385	0.515	0.466	0.426		0.413	0.542	0.494	0.456		0.399	0.529	0.480	0.442
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%	
M	0.009		0.026		SIG	0.010		0.030		SIG	0.008		0.025	
B	0.009		0.026		SIG	0.010		0.030		SIG	0.008		0.025	
M X B	0.017		0.051		SIG	0.020		0.060		SIG	0.017		0.051	

Table 4a: Effect of organic manures and biofertilizers on essential oil yield (kg/ha) of holy basil at first harvest

Treatment	Essential oil yield (kg/ha) at first harvest														
	2023-24					2024-25					Pooled				
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean
M ₁	4.70	4.71	5.31	5.00	4.93	6.02	6.25	6.95	6.44	6.41	5.36	5.48	6.13	5.72	5.67
M ₂	23.00	32.18	30.58	25.98	27.93	24.40	33.61	31.90	27.32	29.31	23.70	32.90	31.25	26.65	28.62
M ₃	35.49	46.11	40.74	38.21	40.14	36.81	47.50	42.09	39.54	41.48	36.15	46.81	41.42	38.88	40.81
M ₄	16.70	22.53	20.10	19.14	19.62	19.31	23.89	21.58	20.42	21.30	18.00	23.22	20.84	19.78	20.46
Mean	19.97	26.38	24.18	22.08		21.63	27.81	25.63	23.43		20.80	27.10	24.91	22.76	
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test
M	0.41		1.23		SIG	0.57		1.71		SIG	0.44		1.33		SIG
B	0.41		1.23		SIG	0.57		1.71		SIG	0.44		1.33		SIG
M X B	0.81		2.46		SIG	1.13		3.41		SIG	0.88		2.65		SIG

Table 4b: Effect of organic manures and biofertilizers on essential oil yield (kg/ha) of holy basil at second harvest

Treatment	Essential oil yield (kg/ha) at second harvest														
	2023-24					2024-25					Pooled				
	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean	B ₁	B ₂	B ₃	B ₄	Mean
M ₁	2.36	2.97	2.59	2.73	2.66	3.10	3.71	3.48	3.47	3.44	2.74	3.34	3.04	3.10	3.05
M ₂	12.41	17.41	16.48	13.89	15.04	13.20	18.06	17.18	14.82	15.81	12.80	17.74	16.83	14.35	15.43
M ₃	19.03	24.77	21.95	20.51	21.56	19.86	25.61	22.69	21.34	22.37	19.45	25.19	22.32	20.93	21.97
M ₄	9.03	12.13	10.84	10.19	10.55	9.73	12.87	11.58	11.12	11.32	9.38	12.50	11.21	10.66	10.94
Mean	10.71	14.32	12.96	11.83		11.47	15.06	13.73	12.69		11.09	14.69	13.35	12.26	
	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test	S.Em ±		CD at 5%		F- test
M	0.24		0.71		SIG	0.28		0.84		SIG	0.23		0.71		SIG
B	0.24		0.71		SIG	0.28		0.84		SIG	0.23		0.71		SIG
M X B	0.47		1.43		SIG	0.55		1.67		SIG	0.47		1.41		SIG

Treatment Details														
M ₁	:	Control			M ₂	:	FYM (10 t/ha)			M ₃	:	Vermicompost (5 t/ha)		
B ₁	:	PSB (6 kg/ha)			B ₂	:	Azospirillum (6 kg/ha)			B ₃	:	Azotobacter (6 kg/ha)		

Conclusion

Based on the two-year experimental results, it could be concluded that the application of vermicompost at 5 t/ha significantly enhanced the herbage and essential oil yield of holy basil. With respect to biofertilizers, treatment B₂ (*Azospirillum* at 6 kg/ha) enhanced the herbage and essential oil yield of holy basil. The combined effect of vermicompost at 5 t/ha + *Azospirillum* at 6 kg/ha (M₃B₂) significantly enhanced the herbage and essential oil yield of holy basil, outperforming other treatment combinations.

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