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## Morphological response of patchouli (*Pogostemon Cablin Benth*) to integrated nutrient management: Implications of NPK and biofertilizers on multi-harvest growth traits

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### ABSTRACT

Patchouli (*Pogostemon cablin* Benth.) is a perennial aromatic herb belonging to the family Lamiaceae whose oil is highly valued in perfumery industry, yet its response to integrated nutrient management in the Konkan region has been studied very little. The current study focused on “Morphological response of patchouli (*Pogostemon cablin* Benth.) to integrated nutrient management: implications of NPK and biofertilizers on multi-harvest growth traits” was conducted at the Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Dapoli, under the auspices of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, (M.S.). during the two consecutive years 2023-24 and 2024-25, utilizing a Randomized Block Design (RBD) with nine treatments and three replications. The investigation involved the treatments comprised 75% and 100% of the recommended dose of fertilizer, applied alone or in combination with phosphate-solubilizing bacteria (PSB), *Azotobacter*, potassium-solubilizing bacteria (KSB), or all three biofertilizers together. Findings revealed that, Treatments shows the significant variations for all characters at both harvests. The treatment T<sub>9</sub> i.e., 100% RDF + PSB + *Azotobacter* + KSB, consistently recorded the maximum plant height (68.16 cm and 60.45 cm), plant girth at collar (9.38 mm and 13.47 mm), number of primary branches (22.70 and 14.76) and number of secondary branches (31.33 and 20.37) over two years of period at the two harvests, respectively (pooled means). In contrast, the treatment T<sub>1</sub> i.e., 100 % RDF (control) was performed poorest throughout the growth period.

**Keywords:** Patchouli, Biofertilizers, *Azotobacter*, PSB, KSB, Plant height, Girth, Branching

### 1. Introduction

Patchouli (*Pogostemon cablin* Benth.), a perennial aromatic herb of the family Lamiaceae, is cultivated for its essential oil, which is obtained by steam distillation of shade-dried herbage. The oil is a classical fixative in perfumery; it imparts a woody base note and prolongs the persistence of other fragrance components [Angadi and Vasanthakumar, 1995 <sup>[1]</sup>]. Demand for patchouli oil from the perfumery, cosmetic and flavour industries continue to rise, whereas domestic production in India meets only a small proportion of the requirement and most of the oil is imported [Jadhav *et al.*, 2002 <sup>[2]</sup>]. Expansion of domestic production depends on improved agronomy, in which the development of vigorous and well-branched plants is a primary requirement, because the essential oil is synthesized and stored in the leaves, which are borne on the branches [Bhaskar and Vasantha, 2000 <sup>[3]</sup>].

Nutrient management is among the most readily modifiable agronomic factors. Nitrogen (N), phosphorus (P) and potassium (K) are the principal drivers of vegetative growth; however, high and repeated application of chemical fertilizers is costly, and a large proportion of the applied nutrients is not recovered by the crop, with losses estimated at 60–90% [Adesemoye and Kloepper, 2009 <sup>[4]</sup>]. Biofertilizers constitute a low-cost and environmentally benign alternative. *Azotobacter* fixes atmospheric nitrogen and releases plant growth-promoting substances, phosphate-solubilizing bacteria (PSB) convert fixed phosphorus into plant-available forms, and potassium-solubilizing bacteria (KSB) release potassium from insoluble soil minerals [Etesami *et al.*, 2017 <sup>[5]</sup>]. Used together with a reduced dose of chemical fertilizer, these inoculants may sustain crop growth while lowering input costs.

Patchouli has been introduced into the Konkan region and information on the response of its plant architecture to combinations of inorganic fertilizer and biofertilizers is limited. The present investigation was therefore undertaken to assess the effects of nine NPK–biofertilizer treatments on plant height, plant girth at collar and the numbers of primary and secondary branches at the first (120 days after transplanting, DAT) and second (210 DAT) harvests over two seasons.

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## 2. Materials and Methods

**Experimental site and climate:** The field experiment was conducted during 2023–24 and 2024–25 at the Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra, India. The site lies on the west coast of Maharashtra at an elevation of approximately 240 m above mean sea level and about 8 km from the Arabian Sea. The climate is tropical, characterized by warm, humid summers, a heavy monsoon from June to October (mean annual rainfall 4000 mm) and mild winters. Mean minimum and maximum temperatures are approximately 18.5 and 30.8 °C, respectively, and mean relative humidity is about 78%. The soil was red lateritic, well drained and of uniform depth.

**Experimental design and treatments:** Rooted cuttings of the clonal variety 'CIM-Samarth' [Kalra *et al.*, 2006 [6]] were transplanted at a spacing of 60 cm × 60 cm and the experiment was laid out a fresh in each season. The experiment was conducted in a randomized block design with nine treatments (Table 1) and three replications, giving 27 plots of 3.6 m × 3.0 m, each with 30 plants.

**Nutrient and crop management:** The recommended dose of fertilizer (RDF) comprised vermicompost at 5 t ha<sup>-1</sup> and 150:50:50 kg N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O ha<sup>-1</sup>, supplied through urea, single super phosphate and muriate of potash, respectively. Vermicompost was applied before planting. The entire quantity of phosphorus and potassium and one-fourth of the nitrogen were applied as a basal dose, and the remaining nitrogen was top-dressed in three equal splits. *Azotobacter* (*Azotobacter chroococcum*), PSB (*Bacillus megaterium*) and KSB (*Bacillus mucilaginosus*) were applied in solid form at 10 kg ha<sup>-1</sup>, 15 days after the application of chemical fertilizers. Irrigation, hand weeding and need-based plant protection measures were uniform across all plots. The crop was harvested twice, at 120 and 210 DAT.

**Observations:** Five plants were randomly tagged in each plot, and their mean was used for analysis. Plant height was measured from ground level to the tip of the main stem or the longest shoot. Plant girth at collar was measured with a digital vernier calliper. Primary branches (arising from the main stem) and secondary branches (arising from primary branches) were counted at harvest, *i.e.* at 120 and 210 DAT.

### Statistical analysis

Data of each year and the pooled data were subjected to analysis of variance appropriate to a randomized block design [Panse and Sukhatme, 1995 [7]] using SAS software and treatment means were compared at the 5% level of significance using the critical difference (CD).

## 3. Results

The data related to the effect of different levels of NPK and biofertilizers on the vegetative growth parameters of patchouli was recorded at 120 DAT (1<sup>st</sup> harvest) and 210 DAT (2<sup>nd</sup> 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 patchouli plants for various morphological characters like plant height, plant girth at collar, number of primary branches and number of secondary branches.

### 3.1. Plant height (cm)

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

**At 120 DAT:** In the year 2023-24 the highest plant height (66.49 cm) was observed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (60.57 cm). The lowest plant height (46.67 cm) was observed in treatment T<sub>1</sub> *i.e.*, 100 % RDF. During second year

(2024-2025), the highest plant height (69.83 cm) was noticed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (66.94 cm). The lowest plant height (51.00 cm) was recorded in treatment T<sub>1</sub> *i.e.* 100 % RDF. In pooled data, it was observed that the highest plant height (68.16 cm) was recorded in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (63.76 cm). The lowest plant height (48.83 cm) was observed in treatment T<sub>1</sub> *i.e.*, 100 % RDF.

**At 210 DAT:** In the year 2023-24 the highest plant height (58.85 cm) was observed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (53.49 cm). The lowest plant height was observed in treatment T<sub>1</sub> *i.e.*, 100 % RDF (41.78 cm). During second year (2024-25), The highest plant height (62.04 cm) was perceived in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (56.13 cm). The lowest plant height (44.97 cm) was recorded in treatment T<sub>1</sub> *i.e.* 100 % RDF. In pooled data, it was observed that the highest plant height (60.45 cm) was recorded in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (54.81 cm). The lowest plant height (43.38 cm) was observed in treatment T<sub>1</sub> *i.e.*, 100 % RDF.

### 3.2. Plant girth at collar (mm)

Girth of plant is one of the key factor in plant growth which increased from planting time to 210 DAT at an interval of 30 days. The data pertaining to the girth of plant at collar recorded in patchouli was significant at 120 DAT and 210 DAT as a result of application of NPK levels and biofertilizers over the course of experiment (2023-24 and 2024-25) as given in Table 3.

**At 120 DAT:** In the year 2023-24 the highest plant girth (9.22 mm) was observed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (8.94 mm). The lowest plant girth (7.40 mm) was reported in treatment T<sub>1</sub> *i.e.*, 100 % RDF. During second year (2024-25), The highest plant girth (9.55 mm) was found in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (9.28 mm). The lowest plant girth (7.73 mm) was recorded in treatment T<sub>1</sub> *i.e.* 100 % RDF. In pooled data, it was observed that the highest plant girth (9.38 mm) was recorded in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> *i.e.* 75 % RDF + PSB + *Azotobacter* + KSB (9.11 mm). The lowest plant girth (7.57 mm) was observed in treatment T<sub>1</sub> *i.e.*, 100 % RDF.

**At 210 DAT:** During first year (2023-24) the highest plant girth (13.46 mm) was observed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatments T<sub>8</sub> (13.11 mm) and T<sub>5</sub> (12.51 mm) respectively. The lowest plant girth (10.03 mm) was noted in treatment T<sub>1</sub> *i.e.*, 100 % RDF. During second year (2024-25), The highest plant girth (13.48 mm) was noticed in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatments T<sub>8</sub> (13.15 mm), T<sub>5</sub> (12.56 mm), T<sub>7</sub> (12.54 mm) and T<sub>4</sub> (12.36 mm) respectively. The lowest plant girth (10.17 mm) was recorded in treatment T<sub>1</sub> *i.e.* 100 % RDF. In pooled data, it was observed that the highest plant girth (13.47 mm) was recorded in treatment T<sub>9</sub> *i.e.*, 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatments T<sub>8</sub> (13.13 mm) and T<sub>5</sub> (12.54 mm). The lowest plant girth (10.10 mm) was recorded in treatment T<sub>1</sub> *i.e.*, 100 % RDF.

### 3.3. Number of primary branches

The data pertaining to the number of primary branches recorded at 120 DAT and 210 DAT shows significant effect of application of NPK levels and biofertilizers over the course of experiment (2023-24 and 2024-25) as given in Table 4.

**At 120 DAT:** In the first year (2023-24) of experiment, the maximum number of primary branches (22.00) were observed in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (20.37). The minimum number of primary branches (9.93) were recorded in treatment T<sub>1</sub> i.e., 100 % RDF. In the second year (2024-25), the maximum number of primary branches (23.40) were observed in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (22.00). The minimum number of primary branches (10.50) were observed in treatment T<sub>1</sub> i.e., 100 % RDF. The pooled data revealed that the treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB registered maximum number of primary branches (22.70), which was at par with the treatment T<sub>8</sub> (21.20) while minimum number of primary branches (10.22) were recorded in T<sub>1</sub> (100 % RDF).

**At 210 DAT:** In the year 2023-24, the highest number of primary branches (14.30) were observed in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (13.24) while the lowest number of primary branches (6.46) were noted in treatment T<sub>1</sub> i.e., 100 % RDF. During second year (2024-25), the highest number of primary branches (15.21) were recorded in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (14.30). The lowest number of primary branches (6.83) were recorded in treatment T<sub>1</sub> i.e. 100 % RDF. In pooled data, it was observed that the highest number of primary branches (14.76) were recorded in T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (13.77). The lowest number of primary branches (6.64) were recorded in treatment T<sub>1</sub> i.e., 100 % RDF.

### 3.4. Number of secondary branches

The data pertaining to the number of secondary branches recorded at 120 DAT and 210 DAT shows significant effect of application of NPK levels and biofertilizers over the course of experiment (2023-24 and 2024-25) as given in Table 5.

**At 120 DAT:** In the first year (2023-24) of experiment, the maximum number (30.67) of secondary branches was observed in treatment T<sub>9</sub> containing 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (29.87). The minimum number (9.73) of secondary branches were recorded in treatment T<sub>1</sub> (100 % RDF). In the second year (2024-25), the maximum number of secondary branches (32.00) was observed with application of treatment T<sub>9</sub> comprising 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (31.20). The minimum number of secondary branches (10.40) was observed in treatment T<sub>1</sub> with 100 % RDF. The pooled data revealed that, the treatment T<sub>9</sub> containing 100 % RDF + PSB + *Azotobacter* + KSB registered maximum number of secondary branches (31.33), which was at par with the treatment T<sub>8</sub> (30.53). The minimum number of secondary branches (10.07) was recorded in treatment T<sub>1</sub> (100 % RDF).

**At 210 DAT:** In the year 2023-24 the highest number of secondary branches (19.93) was observed in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (19.41). The lowest number of secondary branches (6.33) were noted in treatment T<sub>1</sub> i.e., 100 % RDF. During second year (2024-25), The highest number of secondary branches (20.80) were recorded in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (20.28). The lowest number of secondary branches (6.76) were recorded in treatment T<sub>1</sub> i.e. 100 % RDF. In pooled data, it was observed that the highest number of secondary branches (20.37) were recorded in treatment T<sub>9</sub> i.e., 100 % RDF + PSB + *Azotobacter* + KSB, which was at par with treatment T<sub>8</sub> i.e. 75 % RDF + PSB + *Azotobacter* + KSB (19.85). The lowest number of secondary branches were recorded in treatment T<sub>1</sub> i.e., 100 % RDF (6.54).

## 4. Discussion

The superior performance of the combined application of chemical fertilizer with all three biofertilizers for every growth character suggests that the components act on different nutritional constraints. Nitrogen supports cell division and elongation, phosphorus supplies the energy required for growth, and potassium regulates enzyme activity and the translocation of photosynthates. *Azotobacter* supplements nitrogen through biological fixation and releases phytohormones such as auxins and gibberellins that promote internodal elongation, while PSB and KSB maintain the availability of phosphorus and potassium in the root zone. Together, these processes probably provided a steadier nutrient supply than chemical fertilizer alone. Similar increases in plant height with biofertilizers have been reported in patchouli [(Manjunath *et al.*, 2002) [8], (Ruke *et al.*, 2023) [9], (Nevase, 2024) [10]] and in other aromatic crops, namely geranium [Altobaishi *et al.*, 2023 [11]], lemongrass [Massey *et al.*, 2021 [12]], basil [Asadian *et al.*, 2017 [13]], mint [Arafa *et al.*, 2017 [14]] and lavender [Aboud *et al.*, 2021 [15]].

The minimum plant height recorded at 210 DAT than at 120 DAT does not indicate a decline in growth. The 210 DAT observations pertained to shoots regenerated after the first harvest, not to the original shoots and these had only about 90 days to develop.

Plant girth at collar continued to increase after the first harvest probably because harvesting removes the upper shoots but leaves the lower stem, which continues to thicken during regrowth. A thicker collar suggests greater storage of assimilates and a greater capacity to support shoots, which is consistent with the branching data. The beneficial effect of *Azotobacter* is probably related to improved nitrogen supply and to growth-promoting substances that stimulate root development and nutrient uptake, whereas PSB improve phosphorus availability. The present results agree with those reported for basil [Paramanik and Chikkaswamy, 2014 [16]].

The reduction in branch numbers from the first to the second harvest can be explained by the removal of most of the leaf canopy at harvest. Regrowth then depends on carbohydrate reserves rather than on current photosynthesis, which limits the number of new branches that can be initiated [Gastal and Lemaire, 2015 [17]]. Within this limitation, the nutritional effect persisted: nitrogen promotes axillary bud growth and the hormones produced by *Azotobacter* can assist in activating these buds, so that well-nourished, inoculated plants produced more branches. The higher branch numbers with combined chemical and biofertilizer application are in line with earlier findings in patchouli [(Manjunatha, R., 2002), (Saha *et al.*, 2014) [18]] and with reports in tulsi [Nighot, 2023 [19]], rosemary [Harb and Eltatawy], basil [Paramanik and Chikkaswamy, 2014 [16]], mint [Arafa *et al.*, 2017 [14]] and lavender [Aboud *et al.*, 2021 [15]].

As secondary branches arise from primary branches, a greater number of primary branches provides more sites for their formation. However, the consortium did more than increase primary branching, as indicated by the higher ratio of secondary to primary branches in T<sub>9</sub> than in the control. Improved nutrient uptake, higher photosynthetic activity and a larger supply of assimilates to the growing points could account for this additional effect. This result is in accordance with the findings of earlier workers in patchouli [(Saha *et al.*, 2014) [18], (Ruke *et al.*, 2023) [9]] and tulsi [Nighot, 2023 [19]] and in the other aromatic species cited above. Since leaves are the oil-bearing organs, a more branched canopy is a promising basis for higher herbage and essential oil yield.

## 5. Conclusion

Over two seasons at Dapoli, integration of 100% RDF with PSB, *Azotobacter* and KSB (T<sub>9</sub>) produced the tallest and thickest patchouli plants with the maximum numbers of primary and secondary branches at both 120 and 210 DAT. Reduction of the chemical fertilizer to 75% RDF with the full biofertilizer consortium (T<sub>8</sub>) was statistically at par with T<sub>9</sub> for every character studied, indicating that fertilizer use can be reduced by one-fourth without a loss in growth.

*Azotobacter* was the most effective single biofertilizer. Among all treatments, 100% RDF with PSB, *Azotobacter* and KSB proved to be most effective in enhancing plant height, girth of plant at collar, number of primary and secondary branches of patchouli. Therefore, the

combined use of inorganic fertilizers and biofertilizers improved nutrient availability, microbial activity and photosynthetic efficiency, resulting in vigorous plant growth.

**Table 1.** Treatment details

| Code           | Treatment                                 |
|----------------|-------------------------------------------|
| T <sub>1</sub> | 100% RDF (control)                        |
| T <sub>2</sub> | 75% RDF + PSB                             |
| T <sub>3</sub> | 100% RDF + PSB                            |
| T <sub>4</sub> | 75% RDF + <i>Azotobacter</i>              |
| T <sub>5</sub> | 100% RDF + <i>Azotobacter</i>             |
| T <sub>6</sub> | 75% RDF + KSB                             |
| T <sub>7</sub> | 100% RDF + KSB                            |
| T <sub>8</sub> | 75% RDF + PSB + <i>Azotobacter</i> + KSB  |
| T <sub>9</sub> | 100% RDF + PSB + <i>Azotobacter</i> + KSB |

RDF = recommended dose of fertilizer; PSB = phosphate-solubilizing bacteria; KSB = potassium-solubilizing bacteria; DAT = days after transplanting;  $S_{Em}$  = standard error of the mean; CD = critical difference.

**Table 2.** Effect of NPK levels and biofertilizers on plant height (cm) of patchouli

| Treatment                                                  | Plant height (cm) |              |              |              |              |              |
|------------------------------------------------------------|-------------------|--------------|--------------|--------------|--------------|--------------|
|                                                            | 120 DAT           |              |              | 210 DAT      |              |              |
|                                                            | 2023-24           | 2024-25      | Pooled       | 2023-24      | 2024-25      | Pooled       |
| T <sub>1</sub> : 100% RDF (control)                        | 46.67             | 51.00        | 48.83        | 41.78        | 44.97        | 43.38        |
| T <sub>2</sub> : 75% RDF + PSB                             | 48.37             | 51.71        | 50.04        | 42.86        | 46.10        | 44.48        |
| T <sub>3</sub> : 100% RDF + PSB                            | 54.29             | 57.29        | 55.79        | 46.81        | 50.05        | 48.43        |
| T <sub>4</sub> : 75% RDF + <i>Azotobacter</i>              | 54.86             | 62.54        | 58.70        | 48.41        | 51.55        | 49.98        |
| T <sub>5</sub> : 100% RDF + <i>Azotobacter</i>             | 55.37             | 63.19        | 59.28        | 49.45        | 52.56        | 51.01        |
| T <sub>6</sub> : 75% RDF + KSB                             | 52.09             | 54.25        | 53.17        | 45.64        | 48.83        | 47.24        |
| T <sub>7</sub> : 100% RDF + KSB                            | 50.92             | 55.42        | 53.17        | 44.23        | 47.37        | 45.80        |
| T <sub>8</sub> : 75% RDF + PSB + <i>Azotobacter</i> + KSB  | 60.57             | 66.94        | 63.76        | 53.49        | 56.13        | 54.81        |
| T <sub>9</sub> : 100% RDF + PSB + <i>Azotobacter</i> + KSB | 66.49             | 69.83        | 68.16        | 58.85        | 62.04        | 60.45        |
| <b>Mean</b>                                                | <b>54.40</b>      | <b>59.13</b> | <b>56.77</b> | <b>47.95</b> | <b>51.07</b> | <b>49.51</b> |
| $S_{Em} \pm$                                               | 2.00              | 2.02         | 1.48         | 2.52         | 2.27         | 2.38         |
| CD at 5%                                                   | 6.00              | 6.06         | 4.44         | 7.54         | 6.79         | 7.14         |

**Table 3.** Effect of NPK levels and biofertilizers on plant girth at collar (mm) of patchouli

| Treatment                                                  | Plant girth at collar (mm) |             |             |              |              |              |
|------------------------------------------------------------|----------------------------|-------------|-------------|--------------|--------------|--------------|
|                                                            | 120 DAT                    |             |             | 210 DAT      |              |              |
|                                                            | 2023-24                    | 2024-25     | Pooled      | 2023-24      | 2024-25      | Pooled       |
| T <sub>1</sub> : 100% RDF (control)                        | 7.40                       | 7.73        | 7.57        | 10.03        | 10.17        | 10.10        |
| T <sub>2</sub> : 75% RDF + PSB                             | 7.53                       | 7.86        | 7.69        | 10.47        | 10.62        | 10.54        |
| T <sub>3</sub> : 100% RDF + PSB                            | 8.35                       | 8.69        | 8.52        | 12.10        | 12.19        | 12.14        |
| T <sub>4</sub> : 75% RDF + <i>Azotobacter</i>              | 8.42                       | 8.75        | 8.58        | 12.22        | 12.36        | 12.29        |
| T <sub>5</sub> : 100% RDF + <i>Azotobacter</i>             | 8.53                       | 8.86        | 8.69        | 12.51        | 12.56        | 12.54        |
| T <sub>6</sub> : 75% RDF + KSB                             | 8.33                       | 8.49        | 8.41        | 11.87        | 11.89        | 11.88        |
| T <sub>7</sub> : 100% RDF + KSB                            | 8.16                       | 8.66        | 8.41        | 12.07        | 12.54        | 12.30        |
| T <sub>8</sub> : 75% RDF + PSB + <i>Azotobacter</i> + KSB  | 8.94                       | 9.28        | 9.11        | 13.11        | 13.15        | 13.13        |
| T <sub>9</sub> : 100% RDF + PSB + <i>Azotobacter</i> + KSB | 9.22                       | 9.55        | 9.38        | 13.46        | 13.48        | 13.47        |
| <b>Mean</b>                                                | <b>8.32</b>                | <b>8.65</b> | <b>8.49</b> | <b>11.98</b> | <b>12.11</b> | <b>12.04</b> |
| $S_{Em} \pm$                                               | 0.21                       | 0.21        | 0.19        | 0.37         | 0.41         | 0.32         |
| CD at 5%                                                   | 0.62                       | 0.62        | 0.58        | 1.11         | 1.22         | 0.96         |

(continued on next page)

**Table 4.** Effect of NPK levels and biofertilizers on number of primary branches of patchouli

| Treatment                                                  | Number of primary branches |         |        |         |         |        |
|------------------------------------------------------------|----------------------------|---------|--------|---------|---------|--------|
|                                                            | 120 DAT                    |         |        | 210 DAT |         |        |
|                                                            | 2023-24                    | 2024-25 | Pooled | 2023-24 | 2024-25 | Pooled |
| T <sub>1</sub> : 100% RDF (control)                        | 9.93                       | 10.50   | 10.22  | 6.46    | 6.83    | 6.64   |
| T <sub>2</sub> : 75% RDF + PSB                             | 14.73                      | 16.20   | 15.47  | 9.58    | 10.53   | 10.05  |
| T <sub>3</sub> : 100% RDF + PSB                            | 15.40                      | 16.40   | 15.90  | 10.01   | 10.66   | 10.34  |
| T <sub>4</sub> : 75% RDF + <i>Azotobacter</i>              | 15.80                      | 16.20   | 16.00  | 10.27   | 10.53   | 10.40  |
| T <sub>5</sub> : 100% RDF + <i>Azotobacter</i>             | 16.17                      | 16.80   | 16.48  | 10.51   | 10.92   | 10.71  |
| T <sub>6</sub> : 75% RDF + KSB                             | 14.53                      | 15.17   | 14.85  | 9.45    | 9.86    | 9.65   |
| T <sub>7</sub> : 100% RDF + KSB                            | 14.40                      | 15.70   | 15.05  | 9.36    | 10.21   | 9.78   |
| T <sub>8</sub> : 75% RDF + PSB + <i>Azotobacter</i> + KSB  | 20.37                      | 22.00   | 21.20  | 13.24   | 14.30   | 13.77  |
| T <sub>9</sub> : 100% RDF + PSB + <i>Azotobacter</i> + KSB | 22.00                      | 23.40   | 22.70  | 14.30   | 15.21   | 14.76  |
| Mean                                                       | 15.93                      | 16.93   | 16.43  | 10.35   | 11.00   | 10.68  |
| S <sub>Em</sub> ±                                          | 0.54                       | 0.63    | 0.50   | 0.35    | 0.41    | 0.33   |
| CD at 5%                                                   | 1.63                       | 1.89    | 1.50   | 1.06    | 1.23    | 1.01   |

**Table 5.** Effect of NPK levels and biofertilizers on number of secondary branches of patchouli

| Treatment                                                  | Number of secondary branches |         |        |         |         |        |
|------------------------------------------------------------|------------------------------|---------|--------|---------|---------|--------|
|                                                            | 120 DAT                      |         |        | 210 DAT |         |        |
|                                                            | 2023-24                      | 2024-25 | Pooled | 2023-24 | 2024-25 | Pooled |
| T <sub>1</sub> : 100% RDF (control)                        | 9.73                         | 10.40   | 10.07  | 6.33    | 6.76    | 6.54   |
| T <sub>2</sub> : 75% RDF + PSB                             | 9.83                         | 10.50   | 10.17  | 6.39    | 6.83    | 6.61   |
| T <sub>3</sub> : 100% RDF + PSB                            | 12.73                        | 13.40   | 13.07  | 8.28    | 8.71    | 8.49   |
| T <sub>4</sub> : 75% RDF + <i>Azotobacter</i>              | 15.93                        | 16.60   | 16.27  | 10.36   | 10.79   | 10.57  |
| T <sub>5</sub> : 100% RDF + <i>Azotobacter</i>             | 19.73                        | 20.40   | 20.07  | 12.83   | 13.26   | 13.04  |
| T <sub>6</sub> : 75% RDF + KSB                             | 10.93                        | 12.40   | 11.67  | 7.11    | 8.06    | 7.58   |
| T <sub>7</sub> : 100% RDF + KSB                            | 11.73                        | 11.60   | 11.67  | 7.63    | 7.54    | 7.58   |
| T <sub>8</sub> : 75% RDF + PSB + <i>Azotobacter</i> + KSB  | 29.87                        | 31.20   | 30.53  | 19.41   | 20.28   | 19.85  |
| T <sub>9</sub> : 100% RDF + PSB + <i>Azotobacter</i> + KSB | 30.67                        | 32.00   | 31.33  | 19.93   | 20.80   | 20.37  |
| Mean                                                       | 16.80                        | 17.61   | 17.20  | 10.92   | 11.45   | 11.18  |
| S <sub>Em</sub> ±                                          | 0.64                         | 0.58    | 0.61   | 0.42    | 0.38    | 0.39   |
| CD at 5%                                                   | 1.92                         | 1.73    | 1.81   | 1.25    | 1.13    | 1.18   |

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