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# Influence of spacing, nutrition and growth regulator on yield and quality enhancement in lavender

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**Abstract**
A field investigation was carried out at the Horticulture Research Station, Tamil Nadu Agricultural University, Yercaud, Tamil Nadu to standardize the optimum plant density, inorganic fertilizer recommendation and concentration of growth prompting substance for *Lavandula angustifolia* Mill. The experiment was laid out in a randomized block design with three replications. The treatments consisted of three levels of spacing (40 x 60cm, 45 x 90cm and 60 x 120cm), three graded levels of inorganic fertilizers (100:40:40, 122:400:40 and 150:40:40 kg NPK per hectare) two varying concentration of $GA_3$ (100 and 200 ppm as foliar application). The study revealed that closer spacing of 40x60 cm recorded more plant height (93.28cm) whereas the shortest plant height was observed in the control where $GA_3$ was not sprayed. The earliest flowering (193.43 days), maximum leaf area / plant (9085.62cm$^2$), chlorophyll content (412.63 mg/g), No. of florets/ flower head (22.18), length of flower head (3.75 cm) was observed under the treatment T8. The flower oil yield/plant was maximum in the treatment T14 (29.23mg/plant). The maximum estimated oil yield/ha was registered under the treatment T2 (10.32kg).

**Keywords:** Lavender, Spacing, Nutrition, yield and quality enhancement

## Introduction
Today lavender (*Lavandula angustifolia* Mill.) persists to be cultivated in many countries like Europe, Australia, New Zealand, North and South America. Its extensive existence is understandable due to its beautiful flowers, its fascinating aroma and the extensive uses of lavender oil. It is an evergreen perennial shrub used in traditional system of medicine, cosmetics and to little extent in foodstuff industries (Biswas *et al.*, 2009) [4]. Lavender is cultivated for its fresh flowers from which essential oil is extracted by distillation method. Linalyl acetate and linalool are the key element of lavender oil. Lavender essential oil has sedative, carminative, antiseptic, analgesic and antimicrobial properties because the presence of high terpene content (Biesiada *et al.*, 2008) [3]. Since, lavender plays as a regular ingredient in a large number of personal care products, its share is increasing in the global herbal market (Komnenic *et al.*, 2020) [12]. Owing to greater than before global demand, lavender has been more and more grown in plantations most recently (Touati *et al.*, 2011) [21]. Systematic cultivation methods are required for the flourishing production of lavender, which comprise optimal plant spacing and proper fertilization systems (Klados and Tzortzakis, 2014) [11]. There are very limited or scarce attempts were made to study the effect of plant spacing and fertilization on growth, flower yield and essential oil content of lavender. Lavender does not required extreme nutrients, thus it grows well on all type of soils where the cultivation of most other crops is not profitable.
As in many other crops, research and development of newer varieties and as well as improved management techniques are being constantly pursued to increase the productivity of lavender. Among the various factors affecting productivity of lavender, improper nutritional management practices and plant density during critical crop growth stages can be considered as foremost contributing to low yields. For appropriation of maximized flower and herbage yield, plant density is an important management requirement for the efficient utilization of applied inputs. In recent years, among the various production technologies, improvement of production and quality can be achieved through use of plant growth regulators (Wittwer, 1971) [24]. Among the critical macro nutrients, nitrogen, phosphorous, and potassium have the

supreme impact on lavender growth and oil production. The macro nutrients such as N, P and K have a very encouraging result on the biosynthesis terpene (Hafsi *et al.*, 2014). With this background in consideration, the present study was taken up to standardize the cultivation practices for year round production, with improved nutritional quality and yield enhancement of lavender.

## Materials and Methods

The experiment was conducted at Horticultural Research Station, Yercaud during November 2018 to June 2020 to standardize the package practices for year round production, in lavender (*Lavandula angustifolia* Mill.). The experimental site located in the foot hill of eastern ghats situated at Athiyur village, three kilometre away from Yercaud town on Nagalur Road and 35 km from Salem town. The site is located at latitude of 11.4 to 11.5ºN with the elevation is 1500 m MSL. The annual rainfall is 1600-1800 mm. The mean temperature ranges from 21.0 to 32.2$^0$C during day time and 9.0 to 18.0ºC during night hours. The relative humidity ranges from 58 to 75 per cent. The soil is lateritic with a depth of 0.52 to 1.55 m with the soil pH from 5 to 6. The treatment consist of three levels of planting density (40x60 cm, 45x90cm and 60x120cm), three levels of fertilizer grades (100:40:40 , 125:40:40 and 150:40:40 kg NPK per hectare) and two concentration level of $GA_3$ (100 and 200 ppm) in different combinations (Table 1). The treatment T19 (control) consisted random population of 11,000 nos/ha which applied with 100:40:40 kg NPK per hectare alone. The population under control were not sprayed with $GA_3$

**Table 1:** Details of treatments

| T. No | Treatment |
|---|---|
| T1 | 40x60 cm , 100:40:40 NPK, GA 100 ppm |
| T2 | 40x60 cm , 100:40:40 NPK, GA 200 ppm |
| T3 | 40x60 cm , 125:40:40NPK, GA 100 ppm |
| T4 | 40x60 cm , 125:40:40 NPK, GA 200 ppm |
| T5 | 40x60 cm , 150:40:40NPK, GA 100 ppm |
| T6 | 40x60 cm , 150:40:40 NPK, GA 200 ppm |
| T7 | 45x90cm , 100:40:40 NPK, GA 100 ppm |
| T8 | 45x90cm , 100:40:40 NPK, GA 200 ppm |
| T9 | 45x90 cm , 125:40:40NPK, GA 100 ppm |
| T10 | 45x90 cm , 125:40:40 NPK, GA 200 ppm |
| T11 | 45x90 cm , 150:40:40NPK, GA 100 ppm |
| T12 | 45x90 cm , 150:40:40 NPK, GA 200 ppm |
| T13 | 60x120cm , 100:40:40 NPK, GA 100 ppm |
| T14 | 60x120cm, 100:40:40 NPK, GA 200 ppm |
| T15 | 60x120cm, 125:40:40NPK, GA 100 ppm |
| T16 | 60x120cm, 125:40:40 NPK, GA 200 ppm |
| T17 | 60x120cm, 150:40:40NPK, GA 100 ppm |
| T18 | 60x120cm, 150:40:40 NPK, GA 200 ppm |
| T19 | Control |

The trial was laid out in Randomized Block Design (RBD) with three replications. The observations were recorded on plant morphological, flower yield and quality parameters. Cuttings were raised in the nursery for three months in polyethylene bags and transplanted to the main field by imposing the above treatments. The entire and K along with 20% of N was applied as basal dose. Remaining 80% of N was applied in four splits ie, 30days after planting, 60days after planting, 90days after planting and 120 days after planting. The growth stimulant ($GA_3$) applied as foliar spray on 45$^{th}$, 90$^{th}$, 135$^{th}$ and 180$^{th}$ day after planting of rooted cuttings.

Throughout experimentation, package of practices were carried out as recommended by the Tamil Nadu Agricultural University. The statistical scrutinies of recorded data were done by adopting the standard statistical procedures of Panse and Sukhatme (1985) [16]. The critical difference was worked out for 5 per cent level of significance. Essential oils were measured by the hydrodistillation procedure, using a modified Clevenger apparatus, as suggested by Blank *et al.*, (2007) [7].

## Results and Discussion

### Plant growth and physiological parameters

The plant height ranged from 84.13cm under treatment T9 to 93.28cm in the treatment T6. The plants under control treatment registered 75.24cm as plant height. No. of branches / plant was maximum in the T14 (11.90). This was followed by T8 (11.87), T4 (11.61), T2 (11.53), T15 (11.39), T7 (11.06), T1 (11.06), T6 (10.94), T9 (10.83), T10 (10.83), T13 (10.78) and T3 (10.78) treatments. The mean value for this trait was 10.54

The earliest flowering (193.43 days) was observed under the treatment T8 followed by the treatments viz., T14 (196.43), T7 (197.92), T9 (198.47), T6 (199.48), T3 (203.94), T1 (204.52) , T12 (204.87), T17 (205.48) and T4 (207.06). On an average 211.40 days were taken for the plants to produce flowers under all the treatments.

The maximum leaf area / plant was recorded under the treatment T8 (9085.62cm$^2$). The treatments T11 (9064.58 cm$^2$), T9 (9056.83 cm$^2$), T10 (9024.17 cm$^2$) and T16 (9002.53 cm$^2$) recorded the leaf area of above 9000 cm$^2$ . The plants under control treatment was recorded the value of 8052.78 cm$^2$ for leaf area/plant.

The chlorophyll content ranged from 326.7 mg/g (T18) to 411.5 mg/g (T12) among the treatments and it was 317.65mg/g in control. The mean value for this character was 371.5665mg/g. Totally 10 treatments recorded more chlorophyll content than the mean chlorophyll value.

The closer spacing of 40x60 cm recorded more plant height (93.28cm) whereas the shortest plant height was observed in the control where $GA_3$ was not sprayed. In the present study, closer spacing significantly increased the plant height, this might be due to the fact that the plants when grown in closer spacing tend to grow vertically for want of more sun light. This result is supported by the findings of Subbireddy and Krishnan, 1991 [19] in *Solanum viarum*, where closer spacing recorded higher plant height than the wider spacing. Similar findings was also observed in *Clocimum* (Umesha *et al.*, 1990) [22], *Ocimum sanctum* (Arularasu, 1995) [1], *Phyllanthus amarus* (Vasumathi, 2001) [23] and Aswagandha (Saraswathy, 2003) [17].

Wider spacing exhibited moderate to lower plant height in the present investigation this might be due to detoxification of free auxins by IAA oxidase, which in turn would have reduced the apical dominance of the shoot. Analysis of data showed that the spacing, nutrients along with growth regulator ($GA_3$) were significantly affected the plant height and number of branches per plant (Table 2). The maximum number of branches per plant (11.90) was recorded in treatment (T14) and the lowest number of branches per plant (6.23) was observed under the control. The higher number of branches per plant might be due more availability of growth factors, better penetration of light, consequently, increasing the number of leaves would have helped for branch production (Nebret Tadesse, 2019) [20].

Ample resources become available for each plant that enhances the lateral vegetative growth of the crop. This result is in line with the result of Tadesse *et al.* (2016) [20] who reported higher branch number per plant in Stevia under wider spacing. Similarly result was also reported by Beemnet *et al*. (2012) [2] on Rose Scented Geranium (*Pelargonium graveolens*), Zewdinesh *et al*. (2011) [25] on Artemisia (*Artemisia annua* L.). More number of branches per plant under wider spacing may be due to less interplant competition for light, soil nutrition, soil moisture and mutual shading of each other than at high plant density.

Wider spacing recorded increase in number of branches with slightly reduction of plant height. This is due to the promotion of lateral buds was stimulated in higher rate at lower concentrations of auxin and optimum levels of cytokinin due to the application of $GA_3$. The treatment T8 (45x90cm , 100:40:40 NPK, GA 200 ppm) recorded the minimum days taken for first flowering (193.43 days), higher leaf area (9085.62 $cm^{2)}$ with high Chlorophyll content (412.63 mg/g). This could be due to the better utilization of water and nutrients for plant growth and development and improved photosynthetic efficiency of individual plants and favourable role of $GA_3$ (Sivakumar *et. al.*, 2008) [18]. The increasing trend observed in leaf canopy cover and leaf area is evidence of good photosynthates assimilation, which resulted in higher vegetative growths (Ibeawuchi *et al*., 2008) [10].

Gibberellic acid has stimulating effects on morphological, physiological and biochemical aspects of plant growth and has additive impacts on overall growth and development of plants. These promoting special effects speed up the conversion of plants towards vegetative to flowering stage.

**Flower stalk and essential oil yield traits**

The maximum number of No. of florets/ flower head was recorded under the treatment T8 (22.18) followed by T10 (22.17), T12 (22.10), T9 (21.45), T11 (21.34) and T2 (21.21). Under control treatment the number of florets produced was 9.35/ flower head.

The length of flower head varied from 3.75 cm (T8) to 2.84 (T14). Under nine treatments the flower leaf length was recorded higher than the average length of 3.23cm. The maximum of flower stalk/ plant/ year was recorded under the treatment T8 (139.56) and in T6 (137.27). The next best treatments recorded more number of flower stalk were T2 (136.35) and T4 (135.26)

The maximum flower stalk weight of 3.78g was registered under the treatment T16 (3.78g) followed by T15 (3.74g), T8 (3.72g), T14 (3.68g), T2 (3.64g), T12 (3.64g) and T7 (3.63g). The flower stalk yield/plant/year was maximum under the treatment T8 (519.16g). The next best treatments for high flower stalk yield were T2 (496.31g) and T6 (495.60g)

The flower oil yield/plant was maximum in the treatment T14 (29.23mg/plant) which was on par with the treatment T16 (29.21). The maximum estimated oil yield/ha was registered under the treatment T2 (10.32kg) followed by T6 (9.91), T1(9.87kg), T5 (9.81), T3 (9.59) and T4 (9.35kg).

Plant density, inorganic fertilizers and growth promoting substance $GA_3$ were significantly affected on flower stalk and oil yield in the current study (Table 3). The treatment (T8) provided with 45x90cm +100:40:40 kg NPK+ GA 200 ppm recorded higher number of florets per inflorescence (22.28), flower head length (3.75 cm), number of flower stalk per plant (139.56), flower stalk weight (3.92g), flower stalk yield per plant (519.16g). This could be due to better accommodation of plants in the spacing of 45x90 cm and better nutrient uptake under 100:40:40 kg NPK with foliar spray of 200 ppm $GA_3$.

The recorded oil yield was high under the treatments from T1 to T6. This is mainly because under the treatments T1 to T6 the plants were planted at closer spacing of 40 x 60cm and they had more population per hectare than under the treatments from T7 to T19. Though the essential oil yield / plant was maximum under the treatments with wider spacing, the oil yield per hectare was low due to reduction in the total population per hectare.

Thus earliness coupled with increase in number of flowers ultimately elevated the flower yield and ultimately oil content in the $GA_3$ sprayed plants than in the plants under control. Similar results were also reported by EL-Naggar *et al* (2009) [6] that $GA_3$ foliar implementation had stimulating effects on flower induction of *Dianthus caryophyllus* L. and hence led to the increased inflorescence biomass and essential oil production.

Essential oil production and accumulation of volatile oil bearing plants positively responds to these molecules especially their synthetic ones at external applications. Among the plant growth regulators, there is strong evidence that $GA_3$ had constant effects on plants growth and development and consequently their active principles content and yield.

Application of $GA_3$ and concomitant increase in assimilation potential led to the suitable interactions of primary and secondary metabolism in favor of essential oil production (Marshner, 1995 and Hassanpouraghdam *et al.,* 2008) [7, 13]. The $GA_3$ application on lavender plants increased the light efficiency and assimilation potential of plants leading to intensified secondary metabolites production and increased volatile oil biosynthesis. Same trend of increase in the essential oil content of lavender with application of $GA_3$ was reported by Hassanpouraghdam, 2011.

Adequate plant spacing coupled with plant population per unit area and optimum nutrient supply gives a good yield. The present results suggest that over spacing of plant does not necessarily result in corresponding increase in yield because excessive spacing does not impact on flowering and essential oil yield enhancement but it may leads to underutilization of the land and other inputs hence it leads to lower the productivity (Madissa *et al*., 2015) [14].

**Table 2:** Influence of spacing, nutrition and $GA_3$ on growth and physiological parameters of lavender

| Treatments | Plant height (cm) | No. of branches | Days to first flowering | Leaf area ($cm^2$) | Chlorophyll content (mg/g) |
|---|---|---|---|---|---|
| T1 | 87.36 | 11.06 | 204.52 | 8542.24 | 379.53 |
| T2 | 92.15 | 11.53 | 207.37 | 8848.22 | 397.42 |
| T3 | 90.67 | 10.78 | 203.94 | 8167.83 | 364.65 |
| T4 | 91.53 | 11.61 | 207.02 | 8426.54 | 366.71 |
| T5 | 90.03 | 9.32 | 230.73 | 8771.59 | 387.36 |
| T6 | 93.28 | 10.94 | 199.46 | 8987.54 | 385.24 |
| T7 | 88.87 | 11.06 | 197.90 | 8956.27 | 402.58 |
| T8 | 93.14 | 11.87 | 193.48 | 9085.62 | 412.63 |
| T9 | 84.13 | 10.83 | 198.44 | 9056.83 | 375.45 |
| 10 | 85.33 | 10.83 | 208.69 | 9024.17 | 387.72 |
| T11 | 86.66 | 10.28 | 210.33 | 9064.58 | 407.64 |
| T12 | 87.28 | 10.28 | 204.84 | 8992.13 | 411.57 |
| T13 | 86.34 | 10.78 | 213.12 | 8853.26 | 364.80 |
| T14 | 91.63 | 11.90 | 196.47 | 8924.61 | 352.43 |
| T15 | 89.48 | 11.39 | 214.21 | 8752.22 | 337.75 |
| T16 | 88.19 | 10.44 | 239.76 | 9002.53 | 361.68 |
| T17 | 86.75 | 9.39 | 205.45 | 8348.22 | 329.83 |
| T18 | 85.63 | 9.83 | 212.42 | 8541.23 | 326.75 |
| T19 (Control) | 75.24 | 6.23 | 268.53 | 8052.78 | 317.65 |
| Mean | 87.88 | 10.54 | 211.40 | 8757.81 | 371.56 |
| CD (5%) | 2.92 | 1.30 | 18.94 | 107.83 | 34.31 |

**Table 3:** Influence of spacing, nutrition and $GA_3$ on flower stalk and oil yield of lavender

| Treat ments | No. of florets/ flower head | Flower head length (cm) | No. of flower stalk / plant/ year | Flower Stalk weight (g) | Flower stalk yield/ plant/year (g) | Flower Oil yield (mg/plant) | Estimated Flower Oil yield (kg/ha) |
|---|---|---|---|---|---|---|---|
| T1 | 17.63 | 3.06 | 132.54 | 3.58 | 474.49 | 23.72 | 9.87 |
| T2 | 21.21 | 3.52 | 136.35 | 3.64 | 496.31 | 24.82 | 10.32 |
| T3 | 18.54 | 3.27 | 130.42 | 3.41 | 461.24 | 23.06 | 9.59 |
| T4 | 18.67 | 3.43 | 135.26 | 3.45 | 449.95 | 22.50 | 9.35 |
| T5 | 19.33 | 3.26 | 134.63 | 3.48 | 441.92 | 23.60 | 9.81 |
| T6 | 19.14 | 3.14 | 137.27 | 3.63 | 495.60 | 23.82 | 9.91 |
| T7 | 19.33 | 2.93 | 136.53 | 3.47 | 446.33 | 27.26 | 6.71 |
| T8 | 22.18 | 3.75 | 139.56 | 3.72 | 519.16 | 28.55 | 7.02 |
| T9 | 21.45 | 3.10 | 131.18 | 3.55 | 465.69 | 25.61 | 6.30 |
| 10 | 22.17 | 3.37 | 123.76 | 3.56 | 437.03 | 24.04 | 5.91 |
| T11 | 21.34 | 3.14 | 127.54 | 3.53 | 450.22 | 24.76 | 6.09 |
| T12 | 22.10 | 3.23 | 124.32 | 3.64 | 452.53 | 24.89 | 6.12 |
| T13 | 19.18 | 3.22 | 132.83 | 3.55 | 428.95 | 25.74 | 3.55 |
| T14 | 14.62 | 2.84 | 129.37 | 3.68 | 487.12 | 29.23 | 4.03 |
| T15 | 17.25 | 2.93 | 129.82 | 3.74 | 485.53 | 25.13 | 4.02 |
| T16 | 15.67 | 3.12 | 128.79 | 3.78 | 486.83 | 29.21 | 4.03 |
| T17 | 16.41 | 3.45 | 133.68 | 3.15 | 421.09 | 25.27 | 3.49 |
| T18 | 17.24 | 3.29 | 128.64 | 2.98 | 383.35 | 23.00 | 3.17 |
| T19 (Control) | 9.35 | 2.23 | 87.34 | 2.54 | 294.36 | 18.53 | 2.04 |
| Mean | 18.57 | 3.17 | 129.46 | 3.48 | 451.46 | 24.88 | 6.39 |
| CD (5%) | 1.47 | 0.37 | 2.36 | 0.15 | 10.83 | 1.45 | 1.87 |

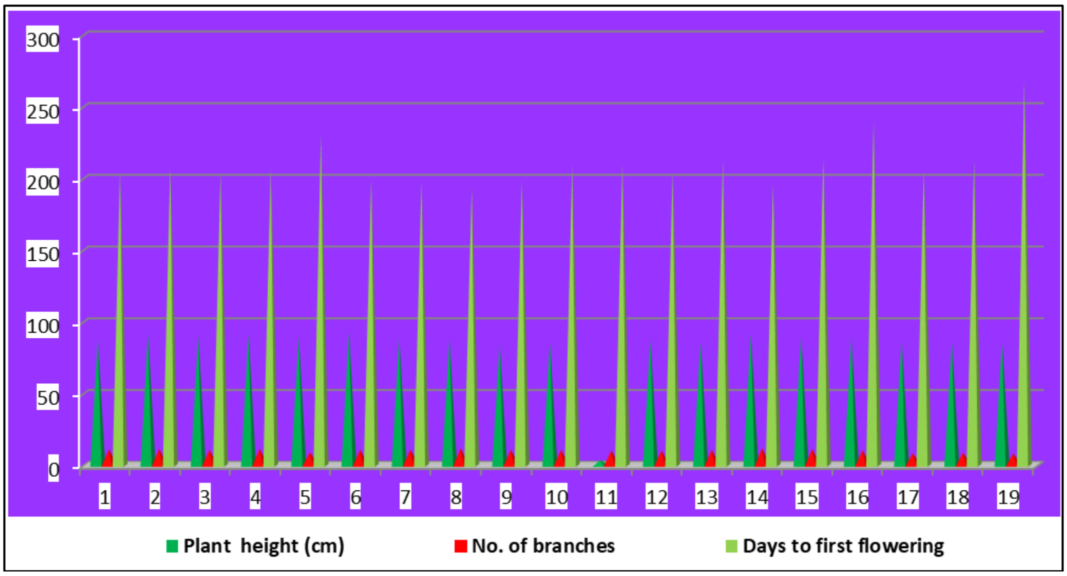


**Fig 1:** Influence of spacing, nutrition and $GA_3$ on vegetative characters of lavender

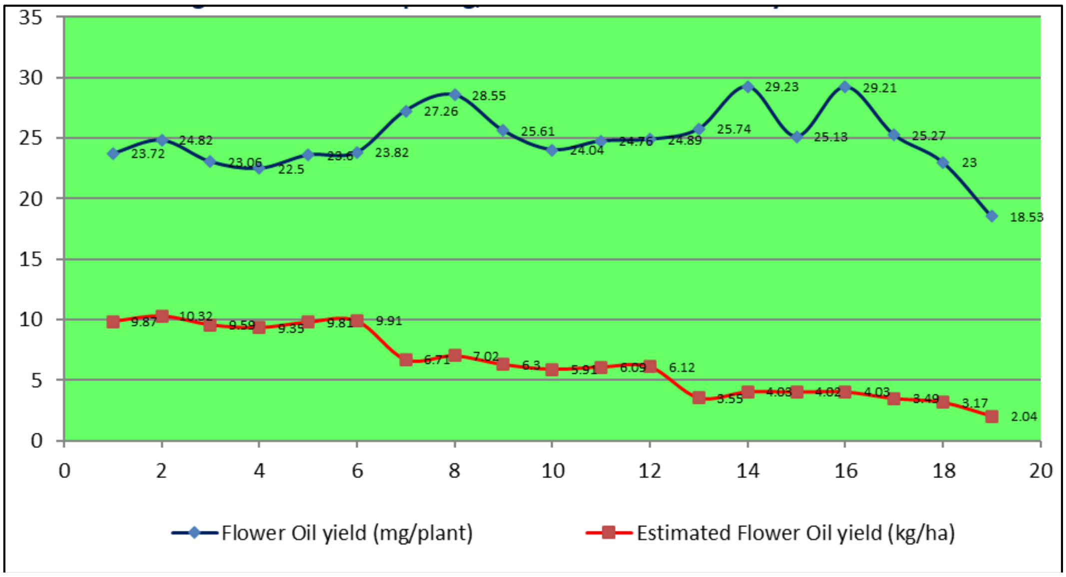


**Fig 2:** Influence of spacing, nutrition and GA3 on oil yield of lavender

## Conclusion

The results of the current field trial exposed that lavender has confidently responded to plant population, inorganic fertilization and $GA_3$ application as foliar spray. Among the different spacing and fertilizers combinations, the treatment with 45x90cm spacing, 100:40:40 kg per ha NPK along with $GA_3$ 200 ppm resulted better vegetative and flower yield and recorded moderate oil yield as well. Though at moderate spacing enhancement of vegetative and floral characters were registered, closure spacing of 40x60 cm + 100:40:40 kg per ha NPK along with $GA_3$ 200 ppm recorded the maximum oil yield /ha.

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