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Assessment of Organic and Inorganic Fertilizers for Growth, Yield and Essential Oil Quality of Industrially Important Plant Patchouli (Pogostemon cablin) (Blanco) Benth.

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Assessment of Organic and Inorganic Fertilizers for Growth, Yield and Essential Oil Quality of Industrially Important Plant Patchouli (*Pogostemon cablin*) (Blanco) Benth.

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Abstract: The present study was conducted to evaluate the right proportion of organic and inorganic fertilizers for growth, oil yield and nutrient uptake pattern of patchouli. The results indicated that significantly higher oil yield was recorded in 75 % VC+25 % NPK (256 %) followed by100 % NPK (249 %) as compared to control. An increase of 6 % in essential oil content was achieved in treatment with 75 % VC+25 % NPK and 25 % VC+75 % NPK but the effect was non-significant. Also, the quality of essential oil, which is basically measured by patchouli alcohol, was not affected by any treatments. Enhancement in vermicompost doses significantly improved the bulk density (0.61- 13.94 %), total organic carbon (3.3-34.4 %) and soil microbial biomass (3-149 %). Availability of N, P and K was significantly higher in 75 % VC+25 % NPK (20 %, 103 % and 64 %, respectively) over control. Maximum nutrient (N, P and K) uptake was found in treatment with 100 % NPK (78 %, 67 % and 54 %, respectively) followed by 75 % VC+25 % NPK (76 %, 63 % and 51 %, respectively). The present study clearly indicated that 75 % chemical fertilizer could be saved by integrating 75 % vermicompost with 25 % chemical fertilizer resulted similar oil yield and improved soil health.

Key words Patchouli, essential oil, sustainable agriculture, vermicompost.

Introduction

Medicinal and aromatic plants are economically of paramount importance. This is because of the continuous and increased demand for their products from local and foreign markets [1,2]. Chemical fertilizers together with available quantity of organic manure/compost are now commonly used to sustain soil fertility and attain the desired level of yield of high-value essential oil-bearing crop [3]. Integrated supply of nutrient to plants through planned combinations of organic and inorganic sources is becoming an increasingly important aspect of environmentally sound agriculture especially in aromatic crops [3]. The unique advantage with organic manure (farm yard manure (FYM), compost and green manuring) is that besides supplying major as well as trace elements, it improves the physical and biological properties of the soil [4]. On the other hand, besides their difficult availability, higher cost and being manufactured from non-renewable energy sources; inorganic fertilizers are potent agents for

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polluting the environment and contaminating ground water. The basic problem with organic manure is that the nutrients supplied through them are not sufficient to sustain the productivity of high yielding food and other crops. The best proposition, therefore, is to manage the crop with a judicious combination of organic and inorganic source of plant nutrients, putting less emphasis on expensive synthetic inorganic fertilizer [5]. Vermicomposts, or earthworm-processed organic wastes are finely divided peat-like materials with high porosity, aeration, drainage, and water-holding capacity [6] containing substances that stimulate and regulate plant growth [7]. As an organic fertilizer, vermicompost from wastes of medicinal and aromatic crops has been shown to improve soil nutrient status, overall health and yields of medicinal and aromatic plants [3, 8-14].

Patchouli [(*Pogostemon cablin*) (Blanco) Benth.], an industrially important essential oil bearing crop belonging to family *Lamiaceae*, is a native of Philippines [15]. Patchouli is grown widely in India in states like Karnataka, Maharashtra, Goa, Gujarat, Assam and Kerala [16]. Distillation of shade dried herb yields yellow colored essential oil which is used in high value perfumes, cosmetics, toiletries, breath fresheners, flavouring baked foods, meat, sausages, etc.[17]. Patchouli oil ranks high among essential oils [18]. The patchouli oil is in great demand in perfumery industry, as the oil blends well with other essential oils, like vetiver, sandalwood, geranium, lavender, clove [19]. There is hardly any preparation of oriental nature where patchouli oil is not used. It is used mainly because of fixative property as it gives tenacity to other perfumes [20]. The oil is reputed to possess several properties such as antidepressant, antiseptic, antirheumatic, aphrodisiac, astringent, fungicidal, insecticidal, etc.[21]. There is no synthetic replacement for the oil of patchouli, which further enhances its value [22]. Reports available on world production of patchouli oil indicate that Indonesia, the largest producer, has a production exceeding 1500 t of oil (91.7 % of the total) [23]. Production of patchouli oil in India is limited (20 t annum^{-1}) and presently, India is annually importing over 200 t oil from Indonesia, Malaysia and Singapore to meet its domestic demand [24]. The continuous increase in demand for patchouli oil in both domestic and international market has compelled the country to increase its area under cultivation.

Very little research has been reported on the influence of organic manure and conjoint application of vermicompost and inorganic fertilizer on growth yield and quality of patchouli oil [9,25]. There is also paucity of information on the influence of organic and inorganic fertilizers on growth and yield of patchouli. Therefore, the present experiments were conducted to investigate the extent of chemical fertilizers that can be avoided by supplementing the nutritional requirement of the crop with vermicompost (VC) produced from the distillation waste and its effect on growth, yields, nutrient uptake and soil fertility status of patchouli grown in semi-arid tropical climate.

Experimental

Production of quality vermicompost

Central Institute of Medicinal and Aromatic Plants (CIMAP) has developed a technology for production of quality vermicompost utilizing distillation waste of aromatic crops [26-28,29]. Vermicompost was produced from distillation waste of geranium and *Ocimum* at the vermicompost production unit. The epigeic species of earthworm (adult clitellate *Eisenia foetida*) was introduced into vermicomposting unit. The substrate was turned-over every week to avoid thermophillic stage. Sprinkling of water was done on alternate day to keep the material moist. Harvesting was done when the compost was ready by its physical appearance, as judged by development of a dark brown to black colour with uniformly granular structure and at this stage watering was stopped. Two days later, the compost was removed from the vermicomposting unit along with worms and uniformly spread on plastic sheet under shade. The vermicompost was recovered through sieving (<2 mm). The produced vermicompost was kept under shade in air tight polyethylene bags to retain the moisture content prior to the application in organic plots. The harvested earthworms with cocoons were used for the next batch of vermicomposting process. Samples were collected from sieved vermicompost (about 50 g) and analysed for pH (soil: water 1:2.5) and major nutrient (NPK) concentration [30].

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Field study

Patchouli var. 'Johore' [19] nursery was raised from terminal stem cuttings (5 months old crop) in polyethylene bags (7.5 × 14 cm) filled with a mixture of soil and sand in the ratio 1: 1 (v/v). The experiment was conducted at CIMAP, Resource Centre, Bangalore, India. Bangalore is located at latitude 12º 58'N, longitude 77º 35'E and at an altitude of 930 m above mean sea level. The climate is semi-arid tropical. The soil was a red sandy loam (*Kandiustalf*) with a pH of 6.3, bulk density 1.65 g cm^{-3}, percent organic carbon 0.61, available N 195 kg ha^{-1}, Olsen's P_2O_5 10.6 kg ha^{-1}, exchangeable K_2O 123 kg ha^{-1} and soil microbial biomass 30.1 mg kg^{-1}. The field trials were composed of six treatments: Control (soil only), 100 % NPK (66:60:60 kg ha^{-1}), 25 % VC+75 % NPK (1.25t ha^{-1} vermicompost+ 49.5:45:45 kg ha^{-1}), 50 % VC+50 % NPK (2.50 t ha^{-1} vermicompost+33:30:30 kg ha^{-1}), 75 % VC+25 % NPK (3.75 t ha^{-1} vermicompost+ 16.5: 15:15 kg ha^{-1}) and 100 % VC (5 t ha^{-1} vermicompost); replicated five times adopting randomized complete block design (RCBD). The initial soil samples were collected to determine the physical, chemical and biological properties of soil. The 50-day old nursery was transplanted with a spacing of 60 × 45 cm in 2.7 × 2.7 m raised beds in fields. The patchouli crop was maintained in the same plots with same treatments for the period of 2-year. The chemical fertilizer treated plots received recommended dose of chemical fertilizers NPK through urea, single super phosphate and muriate of potash, respectively. The urea was applied in two split doses every alternate month. Ten plants were randomly tagged for growth from each plot and the mean value of ten plants was taken for statistical analysis from each plot. Plant height, spread and number of primary branches were recorded at the time of harvesting. The harvesting of the crop was done at an interval of 155-165 days after transplanting and biomass yield was recorded.

Soil physical parameters were analyzed by taking undisturbed soil cores from each plot of the experimental field. The rhizosphere soil samples were collected at a depth of 0-15 cm at 5 random points adjacent to plant roots with the help of soil auger after harvesting of crop from each replicated treatments. Pooled soil samples (5 random points) were stored in sealed plastic bags under refrigeration (4ºC) prior to assay of chemical and microbiological properties of soil.

Soil physical, chemical and biological analysis

Soil samples were analysed for TOC (%), Available N (kg/ha), Available P (Olsen's P_2O_5, kg ha^{-1}) and Available K (exchangeable K_2O, kg/ha) following Jackson [30]. Undisturbed soil cores collected from each plot with soil sampling rings of known volume were weighed and then dried in an oven and reweighed for bulk density assays [31]. The pH was determined in a 1:10 (w/v) vermicompost / rhizo-soil: water suspension. Vermicompost was analysed on oven dry basis for percent total organic carbon [TOC (%)] following the Walkley-Black method [32] and total Kjeldhal nitrogen (TKN), total phosphorus (TP) and total potassium (TK) by methods described by Jackson [30]. Soil microbial biomass carbon was determined using the chloroform fumigation extraction methods [33].

Essential oil estimation of herb

A sample of the herb was shade dried for three days by spreading in shade and the oil content in it was determined using Clevenger's apparatus [34]. The oil samples were analysed for major constituents using Varian CP 3800 gas chromatograph. The chromatograph was fitted with a CP - 5 SIL 30 m × 0.25 mm column and programmed 100º C (2º C), 8ºC, 200ºC (3 min.). The carrier gas was nitrogen at a flow rate of 0.4 ml/min. and the injector and the flame ionization detector were maintained at 250ºC and 300ºC, respectively. 0.2 µl samples were injected with a split ratio 1:80. Peaks were identified by co-injection with authentic pure samples. The percentages of the main components of patchouli oil, namely, β-patchoulene, caryophyllene, α-guaiene, seychellene, α-δ-patchoulene, α-bulnesene and patchouli alcohol were determined.

Statistical analysis

The collected data were subjected to statistical analysis for analysis of variance method

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(ANOVA), suitable to randomized complete block design (RCBD) for field experiment, with the help of software ASSISTAT Version 7.6 beta (2012) - http://www.assistat.com. Significant differences among treatments were based on the *F*-test in ANOVA and treatment means were compared using least significant difference (LSD) at $P \leq 0.05$. The standard error (SE) of the mean in vertical bar charts was computed with Sigma Plot 10 (http://www.sigmaplot.com). The results and discussion are based on the mean data of experimental trial.

Results and discussion

Effect of vermicompost and chemical fertilizers on growth characteristics of patchouli

Plant growth parameters (plant height/ spread and number of branches), in general, significantly improved with alone and combinations of vermicompost and chemical fertilizers treated plots compared to control (soil only) (Table 1). Maximum plant height (15 %), plant spread (33 %) and number of branches (54 %) were achieved in treatment with 75 % VC+25 % NPK over control. There was no significant difference was observed in the case of plant height between 100 % NPK and 75 % VC+25 % NPK treatments, however, plant spread and number of branches was significantly enhanced by 9 % and 7 %, respectively with 75 % VC+25 % NPK treatments compared to 100 % NPK (Table 1). Similar observations were also made by Singh *et al.*[9-11] in patchouli and *Coleus*. Puttanna *et al.*[25] reported that alone and in combinations of organic and inorganic fertilizers were non-significant in respect of growth parameters of patchouli whereas the present study clearly demonstrated that the use of 75 % organic manure with 25 % chemical fertilizers significantly improved the growth parameters of patchouli over 100 % organic manure (VC).

Effect of organic and inorganic fertilizers on biomass, essential oil quality and yield of patchouli

Fresh herb biomass yield of patchouli was significantly enhanced (107-235 %) with alone and in combinations of vermicompost and chemical fertilizers over control but the highest yield was achieved with 100 % NPK (235 %) followed by 75 % VC+25 % NPK (234 %) compared to control (soil only) (Table 2) though no significant difference was observed between them. Also, there were no significant differences were observed in essential oil content of patchouli among the treatments (Table 2) although an increase of 6 % in essential oil content was achieved in treatment with 75 % VC+25 % NPK and 25 % VC+75 % NPK followed by 50 % VC+50 %

Table 1. Effect of organic and inorganic fertilizers on growth of patchouli

Treatment	Plant height (cm)	Plant spread (cm)	Number of branches
Control (soil only)	46.60c	42.70d	9.64f
100 % NPK	52.70a	52.12b	13.94b
25 % VC+75 % NPK	50.90ab	51.32b	11.49e
50 % VC+50 % NPK	51.50a	52.12b	12.20d
75 % VC+25 % NPK	53.37a	56.67a	14.85a
100 % VC	48.57bc	48.42c	12.65c

Mean value in vertical column followed by the same latter do not differ statistically between themselves at $P \leq 0.05$

100 % NPK= 66:60:60 kg ha^{-1}

25 % VC+75% NPK = 1.25 t ha^{-1} vermicompost+49.5:45:45 kg ha^{-1}

50 % VC+50% NPK = 2.50 t ha^{1} vermicompost+33:30:30 kg ha^{-1}

75 % VC+25% NPK = 3.75 t ha^{-1} vermicompost+16.5:15:15 kg ha^{-1}

100 % VC=5 t ha^{-1} vermicompost

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Table 2. Effect of organic and inorganic fertilizers on yield of patchouli

Treatment	Fresh herb yield (t ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Control (soil only)	2.60d	2.07a	6.47d
100 % NPK	8.72a	2.15a	22.55a
25 % VC+75 % NPK	5.37c	2.20a	14.12c
50 % VC+50 % NPK	6.43b	2.17a	16.71b
75 % VC+25 % NPK	8.68a	2.20a	23.02a
100 % VC	5.55bc	2.07a	14.19c

Mean value in vertical column followed by the same latter do not differ statistically between themselves at $P \leq 0.05$
100 % NPK= 66:60:60 kg ha^{-1}
25 % VC+75 % NPK = 1.25t ha^{-1} vermicompost+49.5:45:45 kg ha^{-1}
50 % VC+50 % NPK = 2.50t ha^{1} vermicompost+33:30:30 kg ha^{-1}
75 % VC+25 % NPK = 3.75t ha^{-1} vermicompost+16.5:15:15 kg ha^{-1}
100 % VC=5t ha^{-1} vermicompost

NPK (5 %) but the effect was non-significant (Table 2). As a consequence of higher herbage yield, the essential oil yield was significantly improved by all the treatments as compared to control but the maximum oil yield was recorded in treatment with 75 % VC+25 % NPK (256 %) followed by100 % NPK (249 %) (Table 2). The quality of essential oil was not significantly affected by treatments (Table 3). Similar observations were recorded in patchouli [9]. In another trial with medicinal plant (*Coleus forskohlii*) a significant increase was observed in forskolin content with organic manure treated plots [9-11].

Effect of organic and inorganic fertilizers on physical, chemical and biological properties of soil and uptake by patchouli crop

No significant difference was observed in pH of soil with alone and combinations of vermicompost and chemical fertilizers treated plots compared to control (Table 4). Also, there were no significant differences examined between 100

Table 3. Gas Chromatography (GC) profile of patchouli oil in field condition

Treatments	Mean chemical composition						
	β-Patchou -lene	Caryoph -yllene	α-Guaiene	Seych-ellene	α,δ-Patchou-lene	α-Bulne -sene	Patchouli alcohol
Control (soil only)	1.24a	3.33a	8.19a	5.54a	4.55a	13.97a	42.70a
100% NPK	1.25a	3.35a	8.14a	5.58a	4.40a	13.62a	41.26a
25% VC+75% NPK	1.23a	3.73a	7.99a	5.51a	4.39a	13.98a	42.69a
50% VC+50% NPK	1.24a	3.77a	8.24a	5.60a	4.38a	13.11a	43.19a
75% VC+25% NPK	1.22a	3.78a	8.23a	5.64a	4.53a	13.82a	42.83a
100% VC	1.25a	3.91a	8.21a	5.65a	4.54a	13.67a	43.55a

Mean value in vertical column followed by the same latter do not differ statistically between themselves at $P \leq 0.05$
100 % NPK= 66:60:60 kg ha^{-1}
25 % VC+75 % NPK = 1.25t ha^{-1} vermicompost+49.5:45:45 kg ha^{-1}
50 % VC+50 % NPK = 2.50t ha^{1} vermicompost+33:30:30 kg ha^{-1}
75 % VC+25 % NPK = 3.75t ha^{-1} vermicompost+16.5:15:15 kg ha^{-1}
100 %VC=5t ha^{-1} vermicompost

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% NPK and control (soil only) in the case of bulk density, total organic carbon and soil microbial biomass (Table 4). However, as the gradual enhancement in vermicompost doses significantly improved the bulk density (negatively affected from 0.61- 12.73 %), total organic carbon (3.3-34.4 %) and soil microbial biomass (3-149 %) but maximum being observed with 100 %VC followed by 75 % VC+25 % NPK (Table 4). Availability of N, P and K in rhizospheric soil was significantly influenced by all the treatments over control however, the upper most limit of N, P, and K was observed in treatment with 75 % VC+25 % NPK (20 %, 103 % and 64 %, respectively) (Table 4). Kalra *et al.*[4] observed the similar trend in mint-rice-wheat cropping system. Puttanna *et al.*[25] and Singh *et al.*[9-14] showed significant in chemical properties of soil managed by organic and inorganic means.

All the treatments (alone and combinations of vermicompost and chemical fertilizers significantly enhanced the nutrient uptake of the crop compared to control (Fig.1) however the highest major nutrient (N, P and K) uptake was found in treatment with 100 % NPK (78 %, 67 % and 54 %, respectively) followed by 75 % VC+25 % NPK (76 %, 63 % and 51 %, respectively) (Fig. 1). The similar trend was observed by Puttanna *et al.*[25] and Singh *et al.*[9].

Overall, integrated nutrient management (INM)

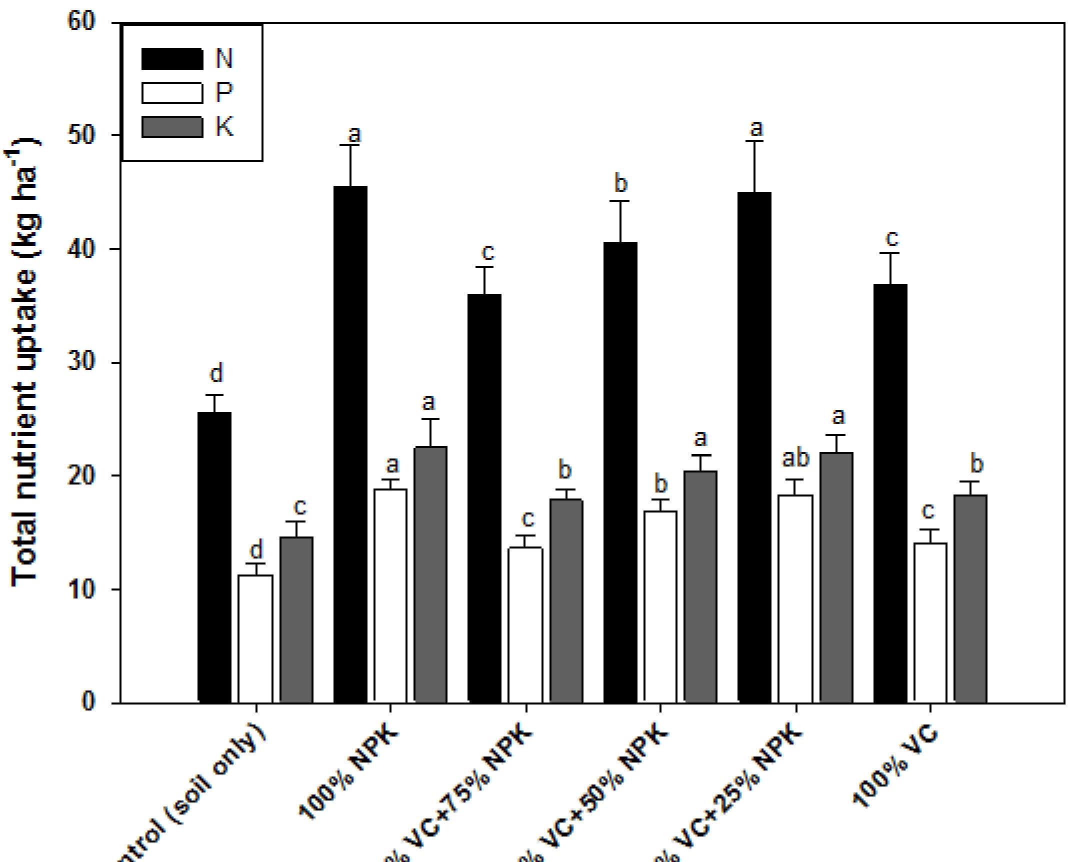

Fig. 1. Effect of organic and inorganic fertilizers on major nutrient uptake by patchouli during field conditions; error bars are presented as standard error of mean; different letters above the error bars show significant differences at $P \leq 0.05$; 100 % NPK= 66:60:60 kg ha^{-1}; 25 % VC+75 % NPK = 1.25 t ha^{-1} vermicompost+49.5:45:45 kg ha^{-1}; 50 % VC+50 % NPK = 2.50 t ha^{1} vermicompost+33:30:30 kg ha^{-1}; 75 % VC+25 % NPK = 3.75 t ha^{-1} vermicompost+16.5:15:15 kg ha^{-1}; 100 %VC=5t ha^{-1} vermicompost.

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Table 4. Effect of organic and inorganic fertilizers on physical, chemical and biological properties of soil

Treatments	Mean physical, chemical and biological properties of patchouli rhizospheric soil						
	pH	Bulk density (g^{-1} cm^{-3})	Total organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Soil microbial biomass carbon (mg kg^{-1})
Control (soil only)	6.4a	1.65a	0.61d	195.6d	10.7c	123.2f	30.4e
100 % NPK	6.4a	1.64a	0.61d	215.8bc	21.6a	151.2e	30.2e
25 % VC+75 % NPK	6.5a	1.55b	0.63d	214.7c	21.7a	162.4d	39.4d
50 % VC+50 % NPK	6.6a	1.51c	0.67c	232.1a	18.7b	195.4c	45.9c
75 % VC+25 % NPK	6.6a	1.45d	0.74b	235.4a	21.7a	201.7a	65.8b
100 % VC	6.7a	1.44d	0.82a	218.3b	19.4b	198.6b	75.7a

Mean value in vertical column followed by the same latter do not differ statistically between themselves at $P \leq 0.05$
100 % NPK= 66:60:60 kg ha^{-1}
25 % VC+75% NPK = 1.25t ha^{-1} vermicompost+49.5:45:45 kg ha^{-1}
50 % VC+50% NPK = 2.50t ha^{1} vermicompost+33:30:30 kg ha^{-1}
75 % VC+25% NPK = 3.75t ha^{-1} vermicompost+16.5:15:15 kg ha^{-1}
100 % VC=5t ha^{-1} vermicompost

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does not aim to remove fertilizer totally in the short run but to reduce the negative impacts of overuse of fertilizers containing N, P, and other elements. The INM system promotes low chemical input but improved nutrient-use efficiency by combining natural and man made sources of plant nutrients in an efficient and environmentally prudent manner. This will not sacrifice high crop productivity in the short term nor endanger sustainability in the long term [35].

Conclusion

The present study clearly indicated that the use of organic manure like vermicompost significantly improved the growth and essential oil yield of industrially important aromatic crop patchouli. Also sustain the health of soil which is the prime need for percent and future agriculture practices. The use of 75 % organic fertilizer (vermicompost) with 25 % inorganic fertilizers produced almost similar yield as compared to 100 % chemical fertilizers treated plots; therefore by the integration of 75 % organic manure we can avoid the use of approximately 75 % of chemical fertilizers.

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