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Impact of Plant Growth Regulators on Yield Attributes of Patchouli (*Pogostemon cablin*) in Shisham Based Agroforestry System

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Abstract
The present study was conducted to evaluate the impact of different plant growth regulators (PGRs) on the yield attributes of patchouli (*Pogostemon cablin*) cultivated under a Shisham (*Dalbergia sissoo*)-based agroforestry system. The experiment was laid out in a Randomized Block Design with eight treatments, including various concentrations of NAA, Miraculan, GA, and Kinetin, along with a control. Plant growth regulators were applied as foliar sprays during the early vegetative stage, and standard agronomic practices were followed uniformly across treatments. Data on fresh weight, dry weight, and essential oil content were recorded at harvest and analyzed statistically. Results indicated significant differences among treatments, with NAA @ 20 ppm and Kinetin @ 200 ppm showing superior performance in terms of fresh biomass and oil yield. Miraculan @ 100 ppm recorded the highest dry weight. The findings suggest that appropriate application of PGRs under agroforestry systems not only enhances growth and yield attributes of patchouli but also contributes to sustainable utilization of interspaces in tree-based farming systems. This approach offers a promising strategy for improving productivity and profitability in medicinal and aromatic plant cultivation.

Keywords: Agroforestry, Patchouli, Shisham, PGR, Yield, Oil content

Introduction
The amount of shade received by medicinal plants growing beneath forest and plantation canopies significantly influences their growth and chemical composition. In recent years, there has been increased interest in diversified medicinal plant production systems compared to monoculture cropping, due to their ability to optimize resource utilization. These systems promote more efficient resource management and often result in higher total intercrop yields than sole crops of the same species cultivated under identical conditions (Kumar *et al*., 2018) [2]. Such systems enable effective utilization of the vertical and horizontal space between trees and crops, enhancing land productivity, promoting crop diversification, and supporting the cultivation of high-demand medicinal species (Verma *et al*., 2016) [8]. However, natural populations of medicinal plants face increasing threats from overharvesting and exploitation, necessitating sustainable cultivation strategies (Rathore *et al*., 2017) [5].

Patchouli (*Pogostemon cablin*), a shade-loving member of the Lamiaceae family, is widely known for its aromatic and medicinal properties. It is primarily cultivated for its essential oil, which is extracted from shade-dried leaves via steam distillation. The oil is recognized for its distinctive woody, earthy, and camphoraceous aroma, noted for its longevity. Globally, patchouli oil holds high commercial value, especially in aromatherapy, perfumery, cosmetics, incense production, and the food flavoring industry. Patchouli is a perennial, shrubby plant that can reach a height of approximately 1 meter. It has broad, aromatic leaves that are oppositely arranged on branching stems, oval in shape, irregularly toothed, and densely hairy. The plant also produces small, light purple to white flowers with long stamens, borne in woolly spikes. Propagation is typically done through cuttings. Patchouli thrives in regions with moderately heavy and evenly distributed rainfall ranging from 150 to 300 cm annually. It is a hardy species adaptable to a range of soil types, preferring deep, fertile, well-drained loamy soils that are slightly acidic and rich in organic matter.

Dalbergia sissoo Roxb. is a fast-growing, hardy, deciduous tree species known for its multipurpose uses. It provides high-quality timber, high-calorie fuelwood, and protein-rich fodder (Sharma *et al*., 2017; Gupta & Meena, 2021) [3, 1]. Due to these qualities, it is widely acknowledged as a suitable agroforestry tree in Central India (Mishra *et al*., 2017; Yadav & Bhargava, 2016) [4, 10].

Materials and Methods

The present experiment was conducted at the Herbal Garden located in Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, under a Shisham-based agroforestry system to evaluate the effect of different plant growth regulators (PGRs) on the yield attributes of patchouli (Pogostemon cablin). The soil was deep, loamy, well-drained, slightly acidic, and rich in organic matter, providing suitable conditions for patchouli cultivation. The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. Each treatment plot received uniform spacing between plants to ensure equal exposure to light and canopy shade. The treatments consisted of foliar application of plant growth regulators at various concentrations: T_1 (NAA @ 20 ppm), T_2 (NAA @ 40 ppm), T_3 (Miraculan @ 100 ppm), T_4 (Miraculan @ 300 ppm), T_5 (GA @ 20 ppm), T_6 (GA @ 40 ppm), T_7 (Kinetin @ 200 ppm), and T_8 (Control with no PGR application). Healthy cuttings of patchouli were used as planting material, and standard agronomic practices, such as irrigation, manual weeding, and pest management, were uniformly followed across all treatments. The PGRs were applied as foliar sprays using a hand-held sprayer at the early vegetative stage, 30 days after planting. Sprays were carried out during early morning hours to maximize absorption and minimize evaporation loss. Control plots received plain water sprays without any PGRs. Data on yield attributes were recorded at the time of harvest, approximately 120 days after planting. Parameters measured included fresh weight (g/plant), dry weight (g/plant), and oil content (%). Fresh weight was recorded immediately after harvesting, while dry weight was obtained after oven drying the samples at 65°C until a constant weight was achieved. Oil content was determined from shade-dried leaves using a Clevenger apparatus by hydro distillation over six hours, and the results were expressed as a percentage of dry matter. The data collected from the experiment were subjected to statistical analysis using analysis of variance (ANOVA) to determine the significance of treatment effects. Standard Error of Mean (SEm), Coefficient of Variation (CV), and Critical Difference (CD) at a 5% level of significance were calculated to assess variability and draw meaningful comparisons between treatments.

Results and Discussion

The study investigated the impact of various plant growth regulators (PGRs) on the yield attributes of patchouli (*Pogostemon cablin*) grown in a Shisham-based agroforestry system. The results revealed significant variations in fresh weight, dry weight, and oil content among the treatments. The application of NAA at 20 ppm (T_1) resulted in the highest fresh weight (30.81 g) and oil content (30.81%), indicating its strong influence on vegetative growth and essential oil biosynthesis. Kinetin at 200 ppm (T_7) and NAA at 40 ppm (T_2) also recorded substantial improvements in fresh weight and oil content compared to the control. The lowest values for all yield parameters were consistently observed in the untreated control (T_8), with fresh weight at 13.71 g, dry weight at 3.23 g, and oil content at 13.71%, emphasizing the role of PGRs in enhancing patchouli productivity.

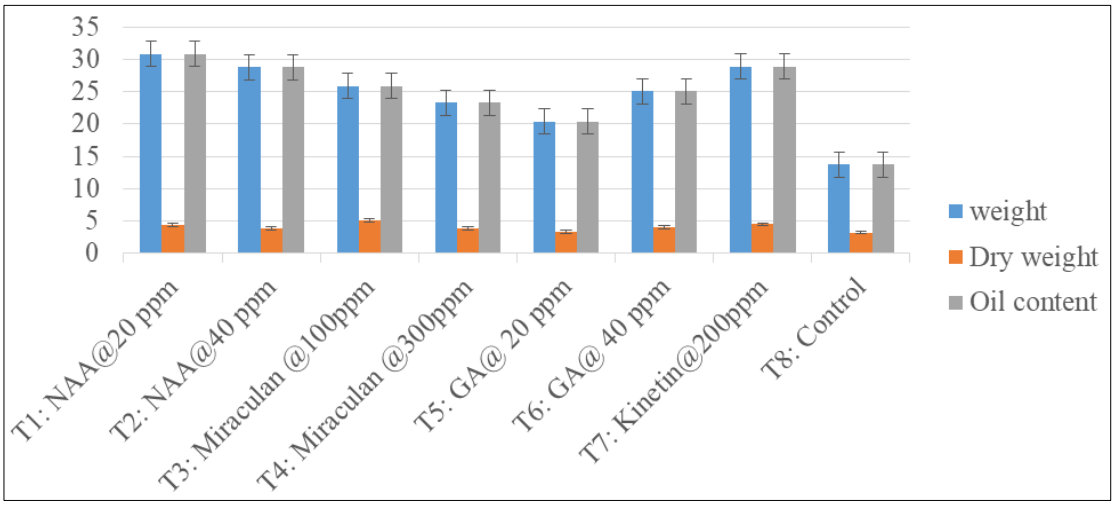

Fig 1: Yield attributes of Patchouli under Shisham based Agroforestry System

Table 1: Yield attributes of Patchouli under Shisham based Agroforestry System

Treatments	weight	Dry weight	Oil content
T_1: NAA@20 ppm	30.81	4.36	30.81
T_2: NAA@40 ppm	28.81	3.83	28.81
T_3: Miraculan @100ppm	25.91	5.08	25.91
T_4: Miraculan @300ppm	23.27	3.87	23.27
T_5: GA@ 20 ppm	20.39	3.33	20.39
T_6: GA@ 40 ppm	25.05	4.03	25.05
T_7: Kinetin@200ppm	28.9	4.5	28.9
T_8: Control	13.71	3.23	13.71
SEm	1.65	0.26	1.6
CV	11.6	12.15	11.24
CD	5	0.79	4.84

Interestingly, Miraculan at 100 ppm (T_3) recorded the highest dry weight (5.08 g), suggesting its effectiveness in promoting structural biomass accumulation, potentially through improved nutrient uptake and stress tolerance mechanisms. The application of GA at both 20 ppm and 40 ppm (T_5 and T_6) produced moderate responses in all parameters, indicating a less pronounced but still positive effect on growth and yield. The statistical analysis confirmed that the differences among treatments were significant, as evidenced by the critical difference (CD) values of 5.00 for fresh weight, 0.79 for dry weight, and 4.84 for oil content. The coefficient of variation (CV) values remained within acceptable limits, indicating consistency and reliability in the experimental data.

Overall, the application of plant growth regulators, particularly NAA and Kinetin, demonstrated a clear potential

to enhance the yield and oil productivity of patchouli in an agroforestry setup. These findings align with previous research suggesting that PGRs at optimal concentrations stimulate physiological and biochemical processes in aromatic crops, leading to improved growth and secondary metabolite production. The Shisham-based agroforestry system likely contributed additional benefits through microclimate regulation and soil enrichment, which may have further supported the positive response of patchouli to growth regulator treatments.

The application of plant growth regulators (PGRs) led to an increased number of leaves and higher leaf biomass, which in turn contributed to enhanced essential oil yield. This improvement can be attributed to the direct influence of PGRs on monoterpene metabolism, primarily through the upregulation of key enzymes involved in terpenoid biosynthesis, resulting in greater accumulation of essential oils. Such effects have been observed in several aromatic plant species within the Lamiaceae family (Singh *et al*., 2020; Sharma & Meena, 2017) [3]. Similar findings were reported by Kumar *et al*. (2018) [2], who noted that the application of gibberellic acid significantly enhanced growth parameters, herbage yield, and essential oil content in patchouli, highlighting the role of PGRs in improving secondary metabolite production in aromatic crops.

Summary

The present study assessed the effect of different plant growth regulators on the yield attributes of patchouli (*Pogostemon cablin*) under a Shisham-based agroforestry system. Significant improvements were observed in fresh weight, dry weight, and oil content in treated plants compared to the control. Among the treatments, NAA at 20 ppm showed the most notable enhancement in both fresh weight and oil content, while Miraculan at 100 ppm resulted in the highest dry weight. Kinetin at 200 ppm also produced substantial increases in yield parameters, confirming its efficacy. The untreated control consistently showed the lowest values across all measured parameters. Statistical analysis supported the reliability of the observed differences, indicating the effectiveness of PGRs in enhancing the growth and productivity of patchouli in agroforestry conditions.

Conclusion

The study concludes that the application of plant growth regulators, particularly NAA at 20 ppm and Kinetin at 200 ppm, significantly enhances the growth and yield attributes of patchouli in a Shisham-based agroforestry system. These PGRs improve biomass production and oil content, thereby increasing the economic value of the crop. Miraculan at 100 ppm also proves effective, particularly in promoting dry matter accumulation. The findings underscore the potential of integrating appropriate growth regulators with agroforestry practices to sustainably boost the productivity of aromatic plants like patchouli. This approach can contribute to enhanced resource use efficiency and economic returns for farmers engaged in agroforestry-based cultivation systems.

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