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Gibberellic acid mediated biomass production of patchouli (*Pogostemon patchouli*)

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Abstract
The present study was conducted on the role of gibberellic acid (GA_3) on the biomass growth, herbage and other yield attributes of patchouli (*Pogostemon patchouli*) in *Terai* zone of West Bengal. The design of the experiment followed was Randomized Block Design with 7 treatments replicated thrice, thus covering 21 plots of 2 m × 1 m. The treatments comprised of: T_1 (control) i.e. no application of GA_3, T_2 (GA_3 @ 50 ppm), T_3 (GA_3 @ 100 ppm), T_4 (GA_3 @ 150 ppm), T_5 (GA_3 @ 200 ppm), T_6 (GA_3 @ 250 ppm) and T_7 (GA_3 @ 300 ppm). GA_3 was applied as foliar spray at monthly interval with the aim to study the effect of gibberellic acid (GA_3) on biomass production of patchouli. GA_3 @ 200 ppm recorded highest monthly increment in plant height (19.52 cm) while maximum number of leaf production month^{-1} (86.99) and dry leaf yield (shade dried) (6.2 ton annum^{-1}) were observed in GA_3 @100 ppm. Benefit: Cost ratio (on the basis of dry leaf yield) became profit oriented (0.60) from GA_3 @100 ppm. Hence, it can be concluded that higher doses of GA_3 (>250 ppm) is detrimental for the crop growth and may not be recommended for patchouli cultivation. It can be applied in patchouli up to 200 ppm, though GA_3 @ 100 ppm is beneficial from economic point of view and hence the dose of the plant growth regulator GA_3 can be reduced upto 100 ppm.

Keywords: Patchouli, gibberellic acid, hormone, leaf yield, biomass

Introduction
India is the natural reservoir of medicinal and aromatic plants due to its varied agro-climatic regions. The famous Chinese traveler Fa-Hien wrote about aromatic plants that they were used for making perfumes and other cosmetic products by the royal society of India. Among those, Patchouli [(*Pogostemon cablin* Benth.) syn. (*Pogostemon patchouli*)] is one of the important tropical, perennial, bushy, herbaceous plants belonging to the family Lamiaceae. It was originated from Philippines and now is cultivated in countries like China, Indonesia, Malaysia, Thailand, Mauritius, West Africa, Vietnam and India. Indonesia occupies the leading position in the world market for sharing maximum amount of patchouli oil (Lawrence, 2009) [5] followed by China and Malaysia whereas India produces about 10-15 ton of patchouli oil per annum (Chakrapani *et al.*, 2013) [4]. Patchouli essential oil (PEO) is obtained by steam distillation or hydro-distillation of the dried leaves of *Pogostemon cablin* (Van Beek and Joulain, 2017) [13]. The plant was first outlined by botanist Pelletier-Sautelet in 1845 and tagged it as *Pogostemon patchouli*. 'Patchouli' plant was first time introduced to India in 1834 in the Royal Botanic Garden, Calcutta. It was later commercially grown in India by Tata Oil Mills in 1942; however, systematic cultivation was started by the CIMAP regional centre at Bangalore in 1962.

From economic point of view, the crop is gaining importance day-by-day. Hence, proper crop management practices have been adopted to maintain the plant growth as well as leaf production. Researchers use different plant growth regulators (PGRs) that are naturally produced by plants to regulate their growth and development and also used in rooting of cuttings.

Gibberellic acid (GA_3) is a natural hormone having tetracyclic, diterpenoid compounds. It plays a major role in altering stem elongation, germination, eradication of dormancy, flowering, sex expression, enzyme activation and leaf and fructification and senescence. With the scrutiny of its working principle, GA_3 has earned attention all over the world due to its effectiveness.

Considering the market status of patchouli at present, the potential beneficence of gibberellic acid (GA_3) increases the scope to enhance the yield of patchouli in order to meet the increasing demands in the market.

In the present study, efforts had been made to observe the role of a plant growth regulator called gibberellic acid (GA_3) on patchouli to monitor the biomass growth, herbage yield and other yield attributes of the plant.

Materials and Methods

The study was carried out during 2019-2020 at the *Terai* zone of West Bengal, India at the instructional farm of Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal.

10-15 cm long stem cuttings with 4-5 nodes from the semi-woody portion of a matured plant were taken with 2-3 leaves intact. The cuttings were dipped in a rooting hormone (IBA 1500 ppm) for early establishment or rooting of the plant before placing them in the polybags of 1:1 ratio of soil and sand. The design of the experiment followed was Randomized Block Design with 7 treatments replicated thrice, thus covering 21 plots of 2 m × 1 m separated by an irrigation channel of 50 cm. The treatments comprised of: T_1 (control) i.e. no application of GA_3, T_2 (GA_3 @ 50 ppm), T_3 (GA_3 @ 100 ppm), T_4 (GA_3 @ 150 ppm), T_5 (GA_3 @ 200 ppm), T_6 (GA_3 @ 250 ppm) and T_7 (GA_3 @ 300 ppm). GA_3 was applied as foliar spray at monthly intervals with the aim to study the effect of gibberellic acid (GA_3) on biomass production of patchouli.

An effort was made to determine the optimum dose of gibberellic acid (GA_3) for better growth, yield and other attributes of patchouli. A monthly evaluation was done to determine the growth increment of the plants for the period of August, 2019 to March, 2020. Experimental observations were taken on growth parameters including plant height, number of nodes, leaf length and breadth, leaf area, number of primary and secondary branches, stem and leaf girth; yield parameters like number of leaves, fresh and dry weight of leaves etc. Benefit: Cost ratio was calculated on the basis of current market price of the shade dried leaves since it is the economic part of the crop.

The data generated throughout the course of the study were calculated in average values and were analyzed by Fisher's analysis of variance (ANOVA) method. The significance of differences between the mean variations of different treatments was estimated using critical difference at 5% based on the probability, $p \leq 0.05$.

Results and Discussion

Morphological observations on vegetative growth parameters: The impacts of different doses of gibberellic acid (GA_3) on biomass production of patchouli are presented in Table 1. The results indicated that GA_3 @ 200ppm recorded maximum plant height (Average monthly increment), number of nodes in main stem and stem girth. The successive increase in the average monthly increment of plant height was due to the application of gibberellic acid (GA_3) that upheld the vegetative growth of the plants by active cell division, cell elongation and cell enlargement. The data from the present experiment was almost similar to that of Tannirwar *et al.* (2011) [12]. In contrast to the number of nodes parameter, it was also led by GA_3 @ 200 ppm. This was justified by Reddy and Sulladmath (1983) [10] who in their studies were in fine agreement with the fact that the increase in average monthly increment of plant height was activated by the growth in internodal length proving the theory of cell division and cell elongation on usage of GA_3. Accordingly, there was a simultaneous increase in stem girth along with the plant height observed during the course of the study. The results obtained in the experiment was in favour of Leite *et al.* (2003) [6] who studied the effect of GA_3 on soybean and were in an agreement with the fact that the stem diameter was thickened on foliar application of the plant hormone.

In the present experiment, it was also observed that the largest leaf area was gained by treating with GA_3 @ 300 ppm. The results indicated that higher doses of GA_3 could enhance the leaf size that might be due to the enhancement of cell division by promoting DNA synthesis. The trend was similar to that of Akter *et al.* (2007) [1] in mustard. Monthly production of primary and secondary branches was recorded maximum with GA_3 @ 150 ppm. The results from present research were symmetrical with Padmapriya and Chezhiyan (2002) [9] who evidenced the upsurge in number of branches on treating *Dendranthema grandiflora* with GA_3 @ 150 ppm, although they had conjointly used salicylic acid @ 100 ppm.

Morphological observations on yield parameters: The leaves are the economic part of the plant and it was noticed that the leaf yield was highest with GA_3 @ 100 ppm in terms of monthly production of leaves and dry leaf production ha^{-1} $year^{-1}$ while the higher doses of GA_3 i.e. 250 ppm and 300 ppm showed the adverse effects (Table 2). Singh *et al*., (1999) [11] documented in their experiment that ethrel and 1359ibberellic acid influence the partitioning of primary photosynthetic metabolites and hence modify the plant growth and essential oil accumulation.

Miceli *et al.* (2019) [7] also observed the negative impact of use of higher doses of GA_3 on plants probably due to morphological changes. The reason behind the poor performance of the plants treated with GA_3 @ 250 ppm and 300 ppm might be due to the morphological differences among the treatments which showed that both the treatments produced least number of primary and secondary branches that ultimately affected the leaf yield. On the other hand, the dry leaf production ha^{-1} $year^{-1}$ led by GA_3 @ 100ppm may be due to the increased production of leaves as well as the higher dry weight of shade dried leaves from the plants treated with GA_3 @ 100 ppm. Regarding the impact of GA_3 mechanism on leaf yield, there were evidences which signified the promising effects of GA_3 on the biomass production of vegetative parts which was facilitated by DNA, RNA, protein synthesis (Bejerano and Lips, 1970) [3] as well as improved enzymatic activity.

Satisfactory result was derived from leaves in both fresh and dried form from shade drying (149.28 and 20.90g, respectively) under room temperature from foliar application of GA_3 @ 100ppm. Although, significant variation was seen in the results (Table 2) obtained from stem and branches and roots with that of the leaves but conclusively, the impact of gibberellic acid (GA_3) had a positive impact towards progressive growth of patchouli than non-treated plants. Muralidhara *et al.* (2014) [8] pointed out a direct relation between leaf length and leaf weight which was quite in resemblance to the present research work. It was noticed that the root yield was influenced by GA_3 application when compared with the results of the fresh and dry weight of roots to the plants with zero application of GA_3.

The present research revealed that the highest Benefit Cost ratio **(**0.60) was recorded by the plants treated with GA_3 @ 100 ppm (Table 3). In this treatment, it was recorded that Rs.

1,35,806.26 was the total cost involved in the cultivation of patchouli in one hectare of land and 6.2 t/ha dry leaves was obtained. Bahl *et al.* (2018) [2] reported that in general, a net profit of about Rs 60,000 can be expected from a patchouli plantation raised in 1 ha.

Table 1: Effect of different treatments of gibberellic acid (GA_3) on vegetative growth parameters of patchouli

Treatments	Plant height (cm)	No. of nodes	Leaf area (sq. cm)	No. of primary branches	No. of secondary branches	Stem girth (mm)
T_1: Control	14.40^{e}	2.50 ^{b}	20.66 ^{cd}	3.07 ^{c}	4.66 ^{e}	1.93 ^{e}
T_2: GA_3 @ 50 ppm	15.55^{d}	2.49 ^{b}	19.62 ^{e}	3.04 ^{c}	6.44 ^{cd}	2.09 ^{d}
T3: GA3 @ 100 ppm	16.75^{c}	2.57 ^{ab}	22.10 ^{ab}	3.20 ^{bc}	7.96 ^{b}	2.28 ^{c}
T_4: GA_3 @ 150 ppm	18.41^{b}	2.55 ^{ab}	21.21 ^{bc}	3.48 ^{a}	8.72 ^{a}	2.36 ^{b}
T_5: GA_3 @ 200 ppm	19.52^{a}	2.66 ^{a}	22.02 ^{ab}	3.37 ^{ab}	6.23 ^{d}	2.48 ^{a}
T_6: GA_3 @ 250 ppm	18.52^{b}	2.58 ^{ab}	20.07 ^{de}	2.57 ^{d}	4.46 ^{e}	2.08 ^{d}
T_7: GA_3 @ 300 ppm	18.34^{b}	2.30 ^{c}	22.36 ^{a}	2.56 ^{d}	6.71 ^{c}	2.32 ^{bc}
C.D (P=0.05)	0.69	0.08	1.01	0.15	0.35	0.05
SEm ±	0.22	0.03	0.32	0.05	0.11	0.02

Table 2: Effect of different treatments of gibberellic acid (GA_3) on leaf yield and other yield attributing characters of patchouli

Treatments	No. of leaves plant^{-1} month^{-1}	Fresh weight of leaves plant^{-1} (g)	Dry leaf yield plant^{-1} (g)	Projected dry leaf yield (Kg ha^{-1})	Stem and branches weight plant^{-1}		Root weight plant^{-1}	
					Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)
T_1: Control	70.82 ^{e}	100.31 ^{e}	13.32 ^{e}	3948.54 ^{e}	144.03 ^{e}	21.94 ^{f}	17.64 ^{f}	5.10 ^{d}
T_2: GA_3 @ 50 ppm	73.77 ^{d}	107.25 ^{d}	14.43 ^{d}	4278.12 ^{d}	139.37 ^{f}	25.62 ^{e}	63.87 ^{b}	20.29 ^{b}
T3: GA3 @ 100 ppm	86.99 ^{a}	149.28 ^{a}	20.90 ^{a}	6197.15 ^{a}	166.20 ^{d}	27.07 ^{d}	63.97 ^{b}	21.27 ^{a}
T_4: GA_3 @ 150 ppm	83.95 ^{b}	145.45 ^{b}	20.40 ^{b}	6048.03 ^{b}	179.99 ^{b}	37.14 ^{b}	77.00 ^{a}	20.18 ^{b}
T_5: GA_3 @ 200 ppm	81.26 ^{c}	109.82 ^{c}	15.41 ^{c}	4570.42 ^{c}	170.78 ^{c}	31.95 ^{c}	49.78 ^{e}	15.93 ^{c}
T_6: GA_3 @ 250 ppm	53.92 ^{g}	99.40 ^{e}	11.41 ^{f}	3381.14 ^{f}	107.75 ^{g}	20.12 ^{g}	53.78 ^{c}	16.11 ^{c}
T_7: GA_3 @ 300 ppm	68.40 ^{f}	47.00 ^{f}	5.61 ^{g}	1663.47 ^{g}	196.86 ^{a}	42.28 ^{a}	51.71 ^{d}	16.29 ^{c}
C.D (P=0.05)	0.92	1.94	0.37	108.67	1.13	0.96	1.60	0.84
SE m ±	0.30	0.62	0.12	34.88	0.36	0.31	0.51	0.27

Table 3: Benefit cost ratio of patchouli cultivation

Treatments (ppm)	GA_3 doses (mg)	Fixed cost (Rs.)	Treatment cost (Rs.)	Total cost (Rs.)	Projected dry leaf yield (Kg ha^{-1})	Price of dry leaves (Rs Kg^{-1})	Gross return (Rs)	Net return (Rs)	B:C ratio
T_1: Control	0	134281.3	0	134281.3	3.9	35	136500	2218.7	0.02
T_2: GA_3 @ 50 ppm	45	134281.3	762.5	135043.8	4.3	35	150500	15456.2	0.11
T3: GA3 @ 100 ppm	90	134281.3	1524.96	135806.26	6.2	35	217000	81193.7	0.60
T_4: GA_3 @ 150 ppm	135	134281.3	2287.44	136568.74	6.0	35	211155	74586.3	0.55
T_5: GA_3 @ 200 ppm	180	134281.3	3049.92	137331.22	4.6	35	159845	22513.8	0.16
T_6: GA_3 @ 250 ppm	225	134281.3	3812.4	138093.7	3.4	35	117845	-20248.7	--------
T_7: GA_3 @ 300 ppm	270	134281.3	4574.9	138856.2	1.7	35	58345	-80511.2	---------

Conclusion

Hence, from the present experiment it can be concluded that higher doses of GA_3 (>250 ppm) is detrimental for the crop and may not be recommended for patchouli cultivation. It can be applied in patchouli up to 200 ppm, though GA_3 @ 100 ppm is beneficial from economic point of view and hence the dose of the plant growth regulator GA_3 can be reduced to 100 ppm.

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