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Responses of plant growth regulators on physiological and growth parameters contributing to yield of patchouli (*Pogostemon cablin* Benth. L)

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Abstract
A field experiment was carried out to investigate the efficacy of different plant growth regulators and their combination of gibberellic acid (GA), Naphthalene Acetic Acid (NAA), Kinetin, Miraculan, their combinations and their mode of application on morpho-physiological traits and growth parameters of patchouli during 2014-2015 at research cum instructional farm of Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (C.G.). Plants were sprayed two times 60 and 75 days after planting. The experiment was carried out in a randomized block design (RBD) with eight treatments and three replications The results revealed that foliar application of PGRs significantly enhanced the morpho-physiological traits i.e. Plant height, number of branches, number of leaves, leaf area, leaf area index, SLA and SLW of patchouli compared with control. Plant growth regulators are efficiency including morphological characters and photosynthetic ability which depends on the chlorophyll content of plant and offer significant role in realizing higher crop yields and higher oil content which is specially collected in the leaf of patchouli.

Keywords: Patchouli, naphthalene acetic acid, gibberellic acid, kinetin, Miraculan, PGR, RBD, SLA, SLW

Introduction
Patchouli (*Pogostemon* patchouli Pellet.), a member of Lamiaceae, is the source of commercial patchouli oil. It is native to the Philippines and is now cultivated on a commercial scale in Indonesia, Malaysia, China, Brazil and India. Among these countries, Indonesia leads, with oil production of 600 tonnes, accounting for 80% of world production (Jadhav *et al*, 2002) [5]. The name of patchouli derives from the Tamil *patchai* (green), *ellai* (leaf). It is grown mainly in Indonesia, Malaysia and China. Patchouli was introduced to India during the year 1941 in Madhya Pradesh, Tamil Nadu, Kerala and Karnataka. It is cultivated in coastal areas of South India, Bengal, Assam, Gujarat, Goa, Maharastra, Andhra Pradesh and Orissa and is now becoming popular in Chhattisgarh. In Chhattisgarh, it is being promoted for cultivated in various districts *viz.* Surguja, Raigarh, Kabirdham, Durg, Korba, Bilaspur and Jagdalpur (NHM, 2006) [9]. The PGRs are considered as the new generation agrochemicals after fertilizers, pesticides and herbicides. The role of PGRs in modifying canopy structure and optimizing to stimulate and inhibit physiological processes, which directly or indirectly might affect crop yield attributes has proven by earlier researchers. Patchouli, being an aromatic crop, contains essential oil in its leaves and stem. It is possible to increase both herbage and oil yield by exogenous application of plant growth regulators. With this background, a field study was conducted to ascertain the effect of growth regulators on growth, herbage yield, essential oil content and oil yield in patchouli.

Plant growth regulators are known to have great potential ability to increase the productivity of horticulture crops. The response of plant or plant parts to growth regulators varies due to fluctuations in endogenous hormonal level of the plant and the manner in which the natural growth regulators interact with the applied growth regulator. So these investigation done for increase the patchouli oil content which is essential oil.

Methods and Materials

The field experiment was laid out at Research cum Instructional Farm, Department of Plant Physiology, Agricultural Biochemistry, Medicinal & Aromatic Plants, Indira Gandhi Agriculture University, Raipur (C.G) during 2014-15. The experiment was laid out in randomized block design with eight treatments in three replications. The one month old stem cuttings were planted in the main field as per the recommended spacing 60 x 60 cm. The experimental trials included various treatments of T1: NAA @ 20 ppm, T2: NAA @ 40 ppm, T3: Miraculan @ 100 ppm, T4: Miraculan @ 300 ppm , T5: GA @ 20 ppm , T6: GA @ 40 ppm, T7: Kinetin @ 200 ppm + GA @ 40 ppm and T8: Control, that were individually used as foliar spraying. The required weight of the PGRs was taken using electronic sensitive balance and solution was prepared by dissolving in 1 mg L^{-1}. The solution was poured into hand-held sprayer and was directly sprayed on the plants two times at 60 and 75 days after planting. Spraying was performed early in the morning to avoid rapid drying of the spray solution, due to transpiration. Data were collected from selected plants in the rows. The collected data includes Plant height, number of branches, number of leaves, leaf area, leaf area index, SLA and SLW. The data was analyzed using analysis of variance (ANOVA) by software and mean separation was carried out at 5% probability level (Fisher 1963) [4].

Result and Discussions

Plant height (cm): A maximum plant height (72.07) was obtained in case of NAA @ 20 ppm at 90 DAP at par with NAA @ 40 ppm (71.00), Kinetin @ 200 ppm + GA @ 40 ppm (70.07), GA @ 20 ppm (68) and GA @ 40 ppm which recorded plant height (66.47). However, control significantly recorded lower plant height. At 120 DAP, NAA @ 20 was continued to maintain higher plant height (81.80) at par with NAA @ 40 (79.33), Kinetin @ 200 ppm + GA @ 40 ppm which recorded plant height of (76.20) and GA @ 20 ppm (74.93). However, Miraculan @ 100 ppm and 300 ppm significantly recorded higher plant height compared to control. Similar findings were also reported by Misra (1995) [7], Bhaskar *et al*. (1997) [3] and Anil kumar (2005) [5] in patchouli.

Number of branches plant^{-1}: The numbers of branches plant^{-1} significantly differ between the treatments excluding the 60 DAP. At 90 DAP, the highest number of branches (17.2) branches plant^{-1} which was noticed in treatment GA @ 20 ppm at par with GA @ 40 ppm (16.60) and Kinetin @ 200 ppm + GA @ 40 ppm (16.20), while in case of treatment with control and Miraculan @ 300 ppm were found (12.37) and (12.90) branches plant^{-1} respectively which were lower.

At 120 DAP, GA @ 20 ppm continue to bear highest branches plant^{-1} (20.33) at par with GA @ 40 ppm and Kinetin @ 200 ppm + GA @ 40 ppm. Treatment of control plants bear minimum branches plant^{-1} (14.20), it is also found that plants bear equal branches (15.10) branches plant^{-1} in treatment of both Miraculan concentrations. The foliar application of all treatments significantly increased plant height as compared with control, as following the result the same trend also reported by Mousa and Emary (1983) [8] in patchouli and Vasundhara *et al*. (1992) [13] in marjoram.

Number of leaves plant^{-1}: The number of leaves plant^{-1} significantly difference between the treatments except the 60 DAP. At 90 DAP, it was noticed the highest number of leaves plant^{-1} (507) in treatment with GA @ 20 ppm at par with GA @ 40 ppm (499), Kinetin @ 200 ppm + GA @ 40 ppm (486.67), NAA @ 20 ppm (480.07) and NAA @ 40 ppm (478.33), Where in case of treatment with control (394) and Miraculan @ 300 ppm (399) were found lower leaves plant^{-1} respectively. The same trend was also noticed at 120 DAP.

At Harvest, GA @ 20 ppm plants continue to bear highest number of leaves (1173.6) at par with GA @ 40 ppm (1145.6),NAA @ 20 ppm, NAA @ 40 ppm and Kinetin @ 200 ppm + GA @ 40 ppm however, the plants bear minimum number of leaves (932.3) leaves plant^{-1} in control. Foliar application of plant growth hormones increases the number of leaves. Significantly maximum number of leaves recoded under treatment T5 (GA @ 20 ppm). Shahine *et al*. (1992) [10] in fenugreek and Kewalanand *et al*. (1998) [6] in mint also confirmed the same finding.

Leaf area plant^{-1}

The data on leaf area significant differences between the treatments at all the growth stages except at 60 DAP. At 90 DAP highest leaf area (4714.67) was obtained in the treatment Kinetin @ 200 ppm + GA @ 40 ppm which was at par with GA @ 20 ppm (4670.67) and GA @ 40 ppm (4575) and all other treatments significantly differed with each other whereas, lowest leaf area was observed in control (3595.33).

At 120 DAP, Kinetin @ 200 ppm + GA @ 40 ppm continued to record significantly higher leaf area (5123) which was at par with GA @ 20 ppm and GA @40 ppm followed by all remaining treatments which were different from each other significantly while, minimum leaf area observed in control in patchouli. A similar trend was continued between the treatments at harvest.

Leaf Area Index (LAI)

The LAI differed significantly due to the influence of various treatments of plant growth regulators at different crop growth 60 DAP to harvest. The leaf area index recorded at 60 DAP showed non-significant results in all the treatments.

At 90 DAP the significantly highest leaf are was exhibited by treatment Kinetin @ 200 ppm + GA @ 40 ppm (1.31) at par with GA @ 20 ppm (1.29), GA @40 ppm (1.28) and NAA @ 20 ppm (1.27) followed by all remaining treatments which were different from each other however, lowest LAI was observed in control (1.06).

At 120 DAP, Kinetin @ 200 ppm + GA @ 40 ppm recorded significantly higher LAI (1.45) which was at par with GA @ 20 ppm (1.68), GA @ 40 ppm, NAA @ 20 ppm, NAA @ 40 ppm and Miraculan @ 100 ppm, remaining all other treatments significantly differed with each other. Whereas, the minimum LAI was noted in control (1.07) followed by Miraculan @ 300 ppm (1.11), same as in harvest. Similarly Shedeed *et al*. (1990) [11] reported that increased leaf area and leaf area index from GA and Kinetin application. Bate *et al*. (2007) [2] in patchouli also reported same statement.

Specific Leaf Area (cm^2 gm^{-1})

Specific leaf area and specific leaf weight were another two parameters influenced by growth regulators treatments only at 90 DAP and at later stages treatments failed to impart significant differences in SLA and SLW.

The SLA differed non significantly due to various treatment combinations of PGRs at different crop growth stages in

patchouli except 90 DAP, where Kinetin @ 200 ppm + GA @ 40 ppm recorded significantly higher SLA (67.16) which was at par with GA @ 20 ppm (66.60), GA @ 40 ppm NAA @ 20 ppm (64.26) and NAA @ 40 ppm (62.71) whereas, control observed as a treatment with lowest SLA (53.11) followed by Miraculan @ 100 ppm and 300 ppm. This showed that GA application might have increased growth by altering dry matter distribution to increase total leaf area or specific leaf area by increasing photosynthetic rate unit^{-1} area of leaf.

Specific Leaf Weight (gm cm^{-2}): Specific leaf weight (SLW) as exhibited by the application of different treatments. SLW was increases from 60 DAP to 90 DAP. Treatments differed significantly only at 90 DAP and no significant difference was observed with treatments at 60 DAP and 120 DAP. Significantly highest SLW was exhibited by treatment Kinetin @ 200 ppm + GA @ 40 ppm (0.0324) at par with GA @ 20 ppm (0.0307), GA @ 40 ppm (0.0293) and NAA @ 20 ppm (0.028) while, minimum SLA was noted in control (0.023). Maximum SLW was noted under treatment T7 (Kinetin @ 200 ppm + GA @ 40 ppm) of plant growth regulators at 60-90 DAP. The faster increase in SLW during early stages of crop growth might be attributed to low demand of photo-assimilates. The same trend also reported by Singh and Misra (2001) [12] that plant growth regulator GA increased specific leaf weight (SLW) on mentha.

Table 1: Impact of plant growth regulators on morpho-physiological parameters in patchouli at 60 DAP

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area plant^{-1}	Leaf Area Index (LAI)	Specific Leaf Area (cm^2 gm^{-1})	Specific Leaf Weight (gm cm^{-2})
T1:NAA @ 20 ppm	37.03	10.83	180.1	999.67	0.28	53.59	0.0059
T2:NAA @ 40 ppm	38.13	10.73	183.3	959.33	0.26	52.04	0.0060
T3:Miraculan @ 100 ppm	38.93	11.37	183.5	983.33	0.27	52.45	0.0062
T4:Miraculan @ 300 ppm	36.93	11.13	179.3	956.00	0.26	51.70	0.0061
T5:GA @ 20 ppm	35.73	10.97	178.2	934.00	0.24	55.27	0.0058
T6:GA @ 40 ppm	35.97	10.73	180.9	950.67	0.26	53.99	0.0057
T7:Kinetin @ 200 ppm + GA @ 40 ppm	39.53	11.03	180.1	920.67	0.24	54.83	0.0059
T8:Control	37.67	10.50	182.5	935.67	0.26	51.00	0.0058
Mean	37.49	10.91	181.0	954.92	0.26	53.11	0.0059
S.Em±	1.86	0.35	8.92	46.20	0.013	2.465	0.0002
CD at 5%	NS	NS	NS	NS	NS	NS	NS

Table 2: Impact of plant growth regulators on morpho-physiological parameters in patchouli at 90 DAP

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf Area plant^{-1}	Leaf Area Index (LAI)	Specific Leaf Area (cm^2 gm^{-1})	Specific Leaf Weight (gm cm^{-2})
T1:NAA @ 20 ppm	72.07	13.73	480.0	4343.33	1.27	64.26	0.0282
T2:NAA @ 40 ppm	71.00	14.80	478.3	4108.67	1.16	62.71	0.0266
T3:Miraculan @ 100 ppm	53.07	13.60	426.6	4068.67	1.11	55.37	0.0260
T4:Miraculan @ 300 ppm	50.33	12.90	399.0	3734.67	1.10	53.33	0.0233
T5:GA @ 20 ppm	68.00	17.20	507.0	4670.67	1.29	66.60	0.0307
T6:GA @ 40 ppm	66.47	16.60	499.0	4575.00	1.28	64.33	0.0293
T7:Kinetin @ 200 ppm + GA @ 40 ppm	70.07	16.20	486.6	4714.67	1.31	67.16	0.0324
T8:Control	47.83	12.37	394.0	3594.33	1.06	53.11	0.0230
Mean	62.35	14.68	458.8	4226.25	1.20	60.86	0.0274
S.Em±	2.60	0.42	23.67	52.49	0.049	2.441	0.0016
CD at 5%	7.88	1.29	71.8	159.24	0.148	7.40	0.0050

Table 3: Impact of plant growth regulators on morpho-physiological parameters in patchouli at 120 DAP

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area plant^{-1}	Leaf Area Index (LAI)	Specific Leaf Area (cm^2 gm^{-1})	Specific Leaf Weight (gm cm^{-2})
T1:NAA @ 20 ppm	81.80	16.57	771.0	4829.33	1.39	62.92	0.0220
T2:NAA @ 40 ppm	79.33	16.23	768.3	4665.00	1.36	61.71	0.0219
T3:Miraculan @ 100 ppm	69.00	15.10	704.6	4428.33	1.33	58.71	0.0216
T4:Miraculan @ 300 ppm	66.40	15.10	692.3	4211.67	1.11	55.67	0.0215
T5:GA @ 20 ppm	74.93	20.33	840.3	5109.00	1.42	64.61	0.0243
T6:GA @ 40 ppm	72.13	18.27	829.0	4991.67	1.39	63.33	0.0229
T7:Kinetin @ 200 ppm + GA @ 40 ppm	76.20	19.43	820.0	5123.00	1.45	64.50	0.0246
T8:Control	66.33	14.20	665.6	4125.67	1.07	53.45	0.0210
Mean	73.27	16.90	761.4	4685.46	1.31	60.61	0.0225
S.Em±	2.96	0.47	35.8	56.20	0.085	2.817	0.0010
CD at 5%	8.98	1.43	108.8	170.48	0.259	NS	NS

Table 4: Impact of plant growth regulators on morpho-physiological parameters in patchouli at Harvesting

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area plant^{-1}	Leaf Area Index (LAI)	Specific Leaf Area (cm^2 gm^{-1})	Specific Leaf Weight (gm cm^{-2})
T1:NAA @ 20 ppm	83.80	25.30	1104.3	5946.00	1.64	53.59	0.0059
T2:NAA @ 40 ppm	82.67	24.67	1068.3	5527.00	1.53	52.04	0.0060
T3:Miraculan @ 100 ppm	73.00	24.50	1004.6	5064.33	1.40	52.45	0.0062
T4:Miraculan @ 300 ppm	69.07	22.57	951.1	4661.67	1.29	51.70	0.0061
T5:GA @ 20 ppm	79.93	30.43	1173.6	6092.00	1.68	55.27	0.0058
T6:GA @ 40 ppm	78.13	30.27	1145.6	5981.67	1.66	53.99	0.0057
T7:Kinetin @ 200 ppm + GA @ 40 ppm	80.53	30.20	1020.0	6186.33	1.70	54.83	0.0059
T8:Control	68.67	21.23	932.3	4421.67	1.21	51.00	0.0058
Mean	76.98	26.15	1050.0	5485.08	1.51	53.11	0.0059
S.Em±	3.15	1.57	52.80	66.10	0.101	2.465	0.0002
CD at 5%	9.56	4.77	160.1	200.53	0.308	NS	NS

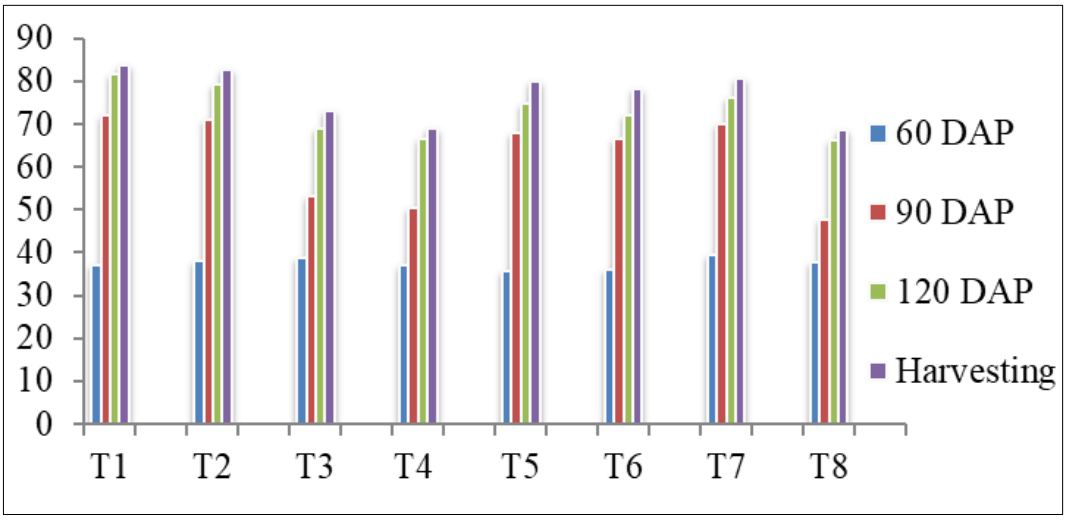

Fig 1: Impact of plant growth regulators on plant height (cm) in patchouli

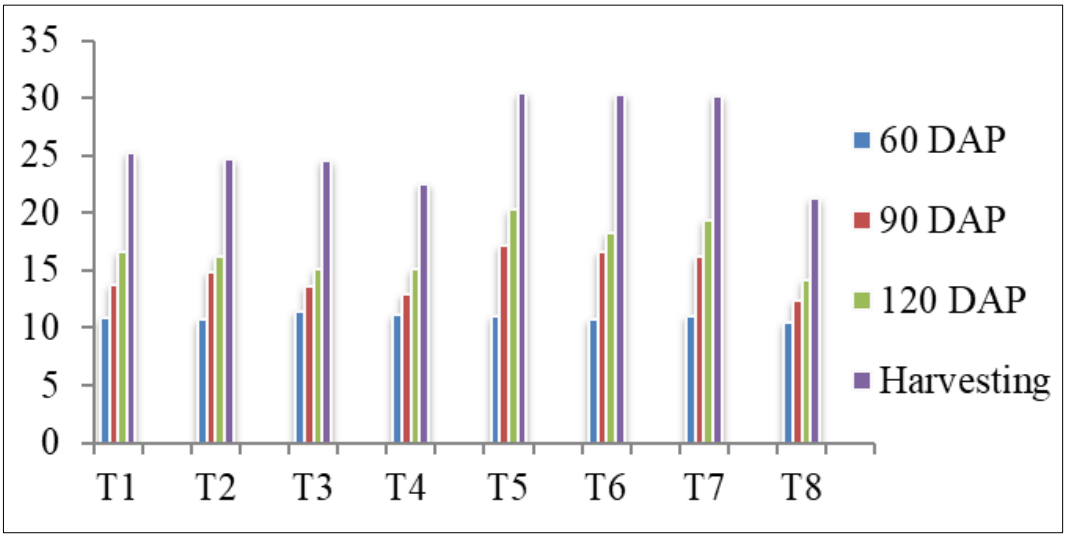

Fig 2: Impact of plant growth regulators on number of branches plant^{-1} in patchouli

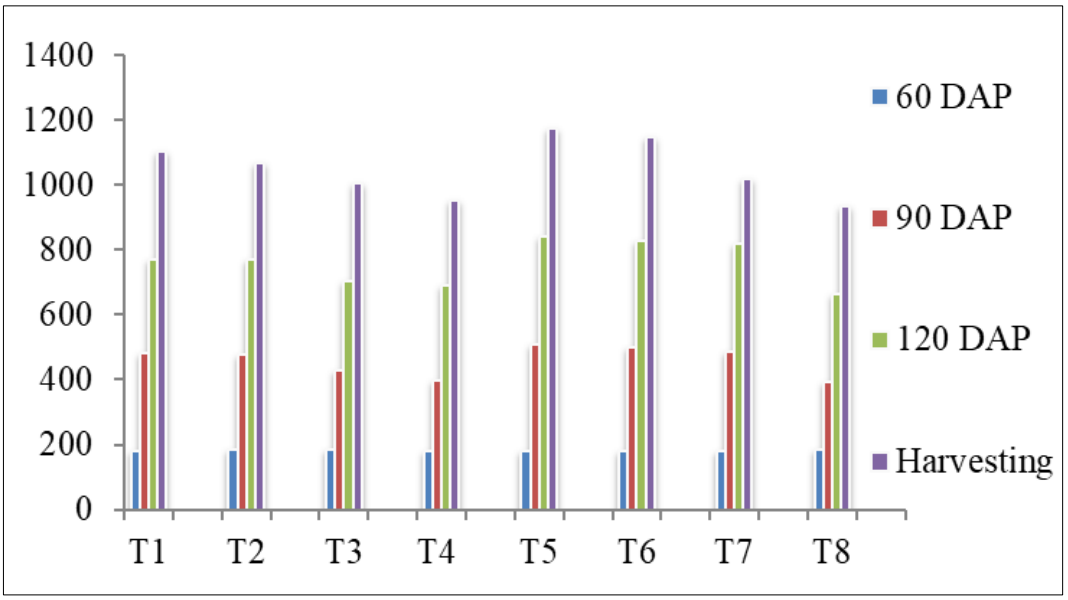

Fig 3: Impact of plant growth regulators on number of leaves plant^{-1} in patchouli

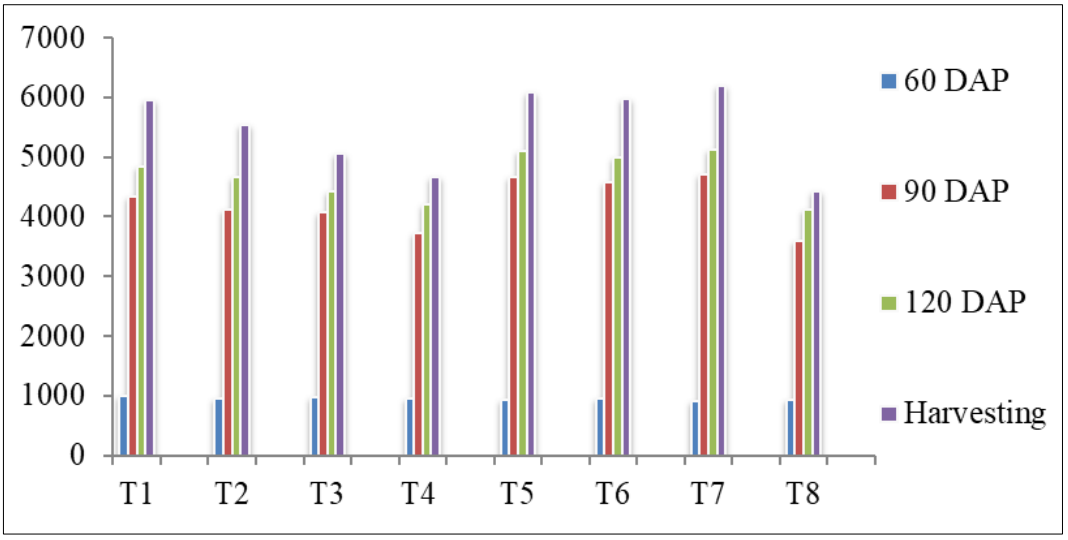

Fig 4: Impact of plant growth regulators on leaf area (cm^2 plant^{-1}) in patchouli

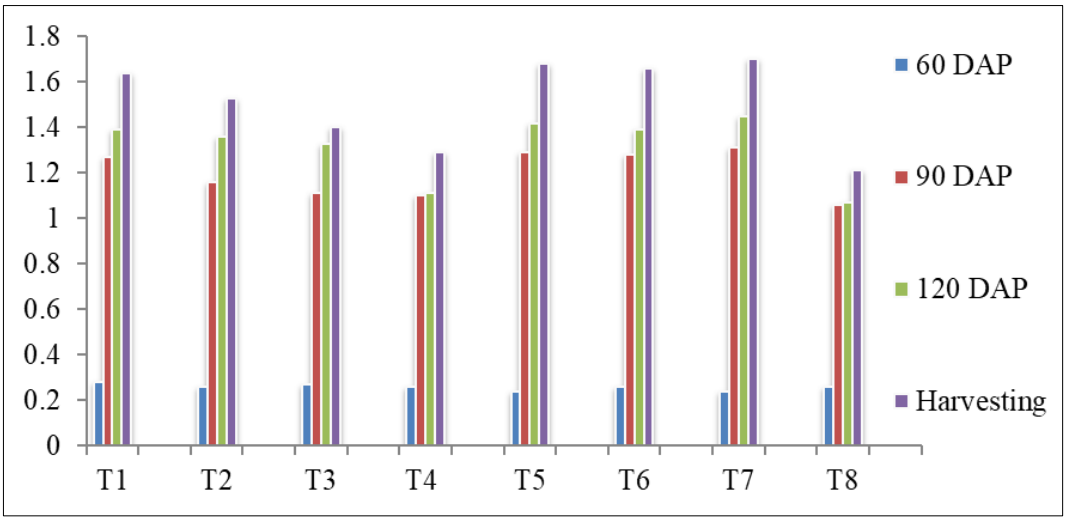

Fig 5: Impact of plant growth regulators on leaf area index in patchouli

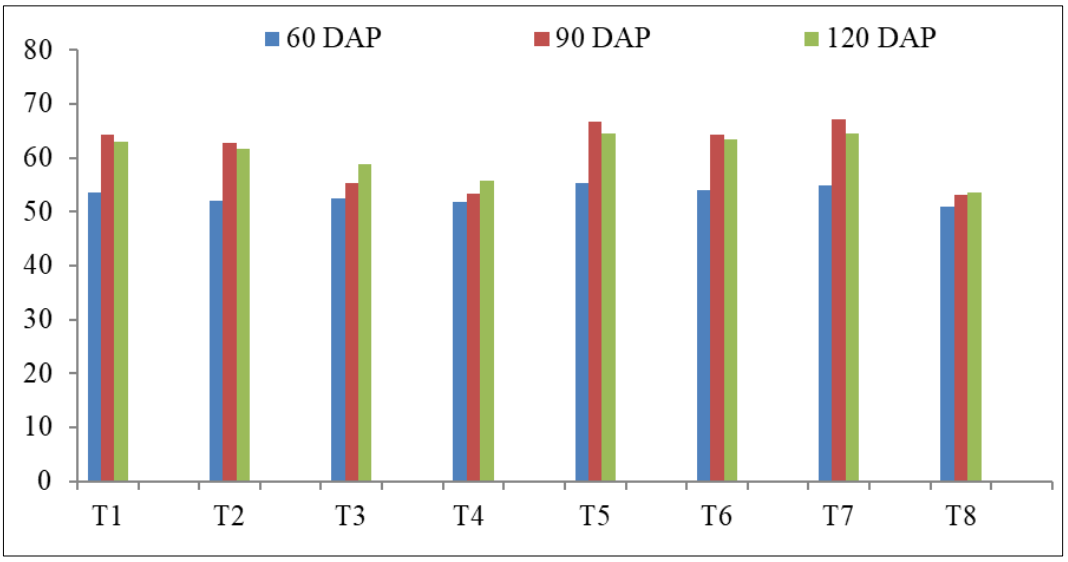

Fig 6: Impact of plant growth regulators on specific leaf area (cm^2 gm^{-1}) in patchouli

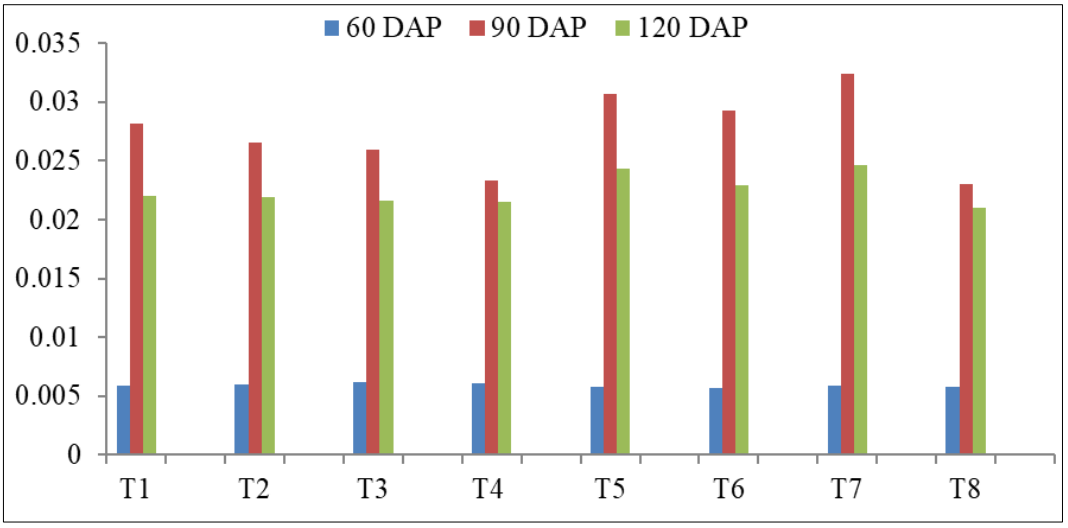

Fig 7: Impact of plant growth regulators on specific leaf weight (gm cm^{-2}) in patchouli

Conclusions

Results showed that foliar spray of plant growth regulators increases the all morphological and growth parameters, showed variation with all the growth regulators. Growth parameters were significantly higher with GA @ 20 ppm, GA @ 40 ppm and Kinetin @ 200 ppm + GA @ 40 ppm, when compared with all the remaining treatments. On the basis of trial experiment, it is concluded that plant growth regulators especially Kinetin @ 200 ppm + GA @ 40 ppm, NAA @ 20 ppm and both concentration of GA, was proved to be potent PGR to enhance the different growth components of patchouli due to better partitioning and efficient translocation of photo-assimilates towards the economic sink and increasing the biochemical property and yield potential.

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