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Enhancing Morpho-physiological Characters and Productivity of *Kharif* Groundnut Through Application of Plant Growth Retardants under East and South Eastern Coastal Zone of Odisha

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ABSTRACT

Background: Groundnut grown in *kharif* season incurs more vegetative growth with higher plant height which causes the upper aerial pegs not to reach the ground. So, less numbers of sound mature pods resulting in lower yield compared to other seasons. The aim of the following investigation was to examine the effect of different growth regulators on plant height including other morphological and physiological parameters of *kharif* groundnut.

Methods: The experiment was conducted during *kharif s*esaons of 2021 and 2022, taking three growth regulators with different concentrations in main plot *i.e.* Cycocel (CCC) @ 500 and 1000 ppm, Brassinosteroides (BR) @ 10 and 15 ppm, Maleic hydrazide (MH) @ 100 and 200 ppm and scheduling of applications in sub plots *i.e.* 30 DAS, 50 DAS and 30 and 50 DAS with an additional control for observation with cv. Dharani (TCGS-1043) variety.

Result: The application of cycocel @ 1000 ppm recorded lowest plant height with maximum no. of primary branches and leaves / plant compared to other growth regulators and control. All physiological parameters studied in the experiment were maximum under foliar spray with CCC @ 1000 ppm. The scheduled application of growth regulators at 30 and 50 DAS decreased plant height, increased branches and leaves/plant significantly at different growth stages and also all physiological parameters compared to single 30 DAS and 50 DAS.

Key words: Cycocel, Groundnut, Plant growth regulators (PGRs).

INTRODUCTION

Groundnut (*Arachis hypogea* L. 2n=4×=40) referring to the formation of pods in the soil. It ranks as the 13th most significant food crop and 4th most important oilseed globally. It is also known as peanut, earthnut, monkey nut and energy capsule. The groundnut seed contains 47-53% oil and 26% protein and 11.5% starch. The haulm and oil cakes are used as valuable organic manures and feeding material for livestock containing 7.3% N; 1.5% P_2O_5 and 1.3% K_2O. In India, it holds the title of “King of Vegetable Oil Seeds” and plays a crucial role in the national edible oil economy covering an area of 49.1 lakh ha in 2022-23 (Reddy, 2022). In India, it is grown in all the three seasons such as *kharif, rabi* and *summer*, but major portion of groundnut *i.e.* around 85% of it is cultivated in *kharif* season covering an area of 45.53 lakh ha with production of 83.69 lakh tonnes (*Kharif* 2022-23, agricoop.nic). Odisha covers around 68000 ha under *kharif* groundnut having a production and productivity 101 th MT and 1465 kg/ha, respectively, 1.23 lakh ha with productivity of 1982 kg/ha in *rabi* season (Odisha Agriculture Statistics, 2018-19). The productivity of *kharif* groundnut is low in comparison to other two season due to more vegetative growth with higher plant height because of rainfall, which causes the upper aerial pegs not to reach the ground. This results in production of less numbers of sound mature pods and in turn less yields. Having indeterminate growth habit type, the vegetative and reproductive stage goes on simultaneously till harvest of the crop. This can be altered by the application of specific growth regulators to regulate the plant metabolism and to modify apical dominance. Plant

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growth regulators are the organic compounds other than nutrients which in small amount promotes or inhibit or otherwise modify any physiological response in plants (Tukey *et al.* 1954). Cycocel (chlormequat), a plant growth regulator that inhibits plant growth, increases leaf density, retards stem elongation, extends shelf life and produces crops with shorter internodes, stronger stems, greener and thicker leaves. Brassinosteroids, steroid-based hormones in plants, regulate cell elongation, division, gravitropism, stress resistance and differentiation. Maleic hydrazide is a plant growth regulator used to reduce growth, increasing dry matter, chlorophyll content and promoting dormancy in seeds. With the above backgrounds in view, a field investigation was executed to evaluate the impact of several plant growth regulators at different concentration and scheduling on morphological and physiological parameters of *kharif* groundnut.

MATERIALS AND METHODS

The present investigation was conducted at research field of AICRP on groundnut, Horticulture Research Station (HRS), Odisha University of Agriculture and Technology, Bhubaneswar in the *kharif* season, 2021 and 2022. The soil of the experimental plot was sandy loam in texture. The experimental site received 1135.2 and 1042.9 mm rainfall in 2021 and 2022, respectively during crop growth period. The average maximum and minimum temperature were (32.5 and 24.6°C) and (33.1 and 25.6°C) in 2021 and 2023, respectively. The nutrient status of soil was medium in nitrogen (301 N kg/ha), high in phosphorus (34.3 P_2O_5 kg/ha) and medium in potassium (230 K_2O kg/ha) and slightly acidic in nature having pH 5.6 and EC 0.42 dS/m. The experiment was laid out in split plot design with 18 treatment combinations. It consisted of three growth regulators at different concentrations in main plot *viz.* M_1: Cycocel (CCC) @ 500 ppm, M_2: Cycocel @ 1000 ppm, M_3: Brassinosteroides (BR) @ 10 ppm, M_4: Brassinosteroides @ 15 ppm, M_5: Maleic hydrazide (MH) @ 100 ppm, M_6: Maleic hydrazide @ 200 ppm and scheduling of applications in subplot *i.e.* S_1: 30 DAS, S_2: 50 DAS and S_3: 30 and 50 DAS with an additional control observation. Solutions of PGRs were prepared and sprayed on the foliage of plants at 30 and 50 DAS with the help of knapsack sprayer as per treatment while in untreated control distilled water was sprayed at 30 and 50 DAS. Groundnut cv. Dharani (TCGS-1043) variety was fertilized with uniform dose of (20-40-40 kg ha^{-1}) of N, P_2O_5 and K_2O, respectively and was grown with standard agronomic practices. For morphological parameters, observations were taken from ten plants, which were randomly selected from each net plot of each treatment from all the replications, then uprooted carefully on 45, 65 and 85 DAS and at harvest. The plant height (cm) was measured from ground level to the growing tip of freshly opened leaf emerging from the main shoot. The number of primary branches and number of functional leaves were recorded from the same observational plants. Physiological parameters were measured from 5 plants at several intervals starting from 45 DAS till harvest. The dry matter production and leaf area recorded at different stages of the crop were used to calculate the growth analysis indices as per the standard formulae (Radford, 1967). Data collected for various studies were subjected to the analysis of variance (ANOVA) appropriate to the design as given by Gomez and Gomez (1984). The Critical differences were worked out for the effects which are significant at 5% level of probability.

RESULTS AND DISCUSSION

Effect of plant growth regulators (PGRs) and time of application on morphological parameters

Plant height (cm)

The application of different plant growth regulators significantly reduced the plant height except BR compared to control. Application of CCC @ 1000 ppm significantly reduced plant height from 45 DAS till harvest compared to all other PGRs at different concentration and control. However, the spraying of BR @ 15 ppm increased the plant height, followed by BR @ 10 ppm. The time of administration of PGRs at 30 and 50 DAS significantly reduced the length of the plant from 45 DAS (36.8 cm) till harvest (66.8 cm) over other two time of application (Table 1). The application of CCC @ 1000 ppm at 30 and 50 DAS significantly reduced plant height from 45 DAS (30.1 cm) to the harvest (59.3 cm) in comparison to other growth regulators with time of applications. This might be due to the application of cycocel which decreased the apical dominance with less intermodal elongation by inhibition of gibberellin synthesis and promotes in case of brassinosteroides. These findings were similar to those of, Moulana *et al.* (2020); Sadeghi *et al.* (2014); Bhadane *et al.* (2020); Faldu *et al.* (2018); Sengupta *et al.* (2015); Lenka *et al.* (2023) and Karuppuswamy *et al.* (2021).

Number of main branches/plant

The numbers of branches/plant were significantly higher in the foliar application of the CCC @ 1000 ppm (5.8) which was at par with the BR @ 10 ppm (5.6). The lower numbers of branches/plant were recorded with the application of MH @ 200 ppm (4.3). The scheduled application of PGR at 30 and 50 DAS increased the number of branches/plant (5.4) significantly at different intervals of growth stages compared to 30 DAS and 50 DAS (Table 1). The heightened presence of branches, particularly in higher hormone concentrations during the peak vegetative stage, can be attributed to the influence of Cycocel on physiological processes like cell division, ion absorption, enzyme activities, photosynthetic efficiency and source-sink regulation. Similar increases in branch numbers were reported by Kaur *et al.* (2015); Faldu *et al.* (2018); Netwal *et al.* (2018); Mohanabharathi *et al.* (2019); Kurmi *et al.* (2020); Patil *et al.* (2008); Lakshmi *et al.* (2015) and Lenka *et al.* (2023).

Number of leaves/plant

Among different PGRs, application of the CCC @ 1000 ppm significantly increased the number of leaves/plant consecutively from 45 DAS (42.6), to the till the time of harvest (72.9), being maximum at 85 DAS (107.8). The number of leaves/plant increased significantly from 45 DAS (45.0) till 85 DAS (107.9), then decreased at harvest (74.1) as a result of spraying growth regulators at the time of 30 and 50 DAS (Table 1). The application of CCC @ 1000 ppm at 30 and 50 DAS significantly increased the number of leaves/plant at all the growth stages till 85 DAS (79.7) (Table 3). The leaves/plant is crucial as it serve as channel for supplying photosynthates to the pod development site, making a higher leaf count conducive to higher yield of groundnut. These results were supported with findings of, Prakash *et al.* (2006); Sengupta *et al.* (2015); Netwal *et al.* (2018); Sagar *et al.* (2020) and Siri *et al.* (2020).

Physiological parameters

Leaf area index (LAI)

The foliar application of the cycocel @ 1000 ppm significantly increased the LAI compared to other growth retardants from 45 DAS to 75 DAS. The LAI significantly increased with the application of PGRs at 30 and 50 DAS at all successive growth stages to 75 DAS (Fig 1) and decreased thereafter due to senescence and ageing of leaves. This may be due to good number of leaves with LAI, which was resulted higher production of photosynthates and then more partitioning of dry matter transported from leaf to pods and ultimately gave higher pod yield. Similar results were also cited by Upadhyay and Ranjan (2015); Prakash *et al.* (2006); Fatima *et al.* (2015); Sengupta *et al.* (2015) and Sagar *et al.* (2020).

Crop growth rate (g^{-2} day^{-1})

A perusal of data on crop growth rate showed that it increased up to 65 days and thereafter followed a decreasing trend. At 30-45 DAS, CGR significantly increased in the BR @ 15 ppm (9.8 gm^{-2} day^{-1}) but at par with the BR @ 10 ppm (9.1 gm^{-2} day^{-1}). But from 45-65 DAS to 85 DAS-harvest, there was significant increase in crop growth rate with CCC @ 1000 ppm compared to other treatments. The spraying schedule of 30 and 50 DAS significantly increased CGR from 30-45 days (9.2 gm^{-2} day^{-1}) till 85 DAS-harvest (5.2 gm^{-2} day^{-1}) compared to 30 DAS and 50 DAS (Table 2). CGR is an indicator of productive efficiency of a crop and depends on genetic variables such as leaf area index, photosynthetic rate and leaf orientation and used as an indicative of light absorption. The crop growth increased during the peak period at 65 days and thereafter followed a decreasing trend due to transport of photosynthates towards pod during pod development stage. These results aligned with finding of Jadhav and Bhamburdekar (2014) and Meena *et al.* (2023).

Table 1: Effect of different levels of plant growth regulators and time of application on morphological parameters in *kharif* groundnut at successive stages of growth.

Treatments	Plant height (cm)				Main Branches/plant				Leaves/plant			
	45 DAS	65 DAS	85 DAS	Harvest	45 DAS	65 DAS	85 DAS	Harvest	45 DAS	65 DAS	85 DAS	Harvest
Main plots - Plant growth regulators												
M_1: CCC @500 ppm	33.7	43.7	56.1	65.7	4.4	4.4	4.5	4.7	38.3	61.55	100.1	69.6
M_2: CCC @1000 ppm	31.4	41.4	52.7	62.2	4.4	5.1	5.4	5.8	42.6	63.05	107.8	79.2
M_3: BR @ 10 ppm	40.9	54.5	65.2	72.8	4.0	4.9	5.3	5.6	44.1	65.45	104.4	75.6
M_4: BR@ 15 ppm	43.8	57.6	68.2	75.6	4.2	4.6	4.8	5.1	47.1	67.75	103.2	70.7
M_5: MH@100 ppm	36.3	48.2	59.7	68.4	4.0	4.3	4.4	4.7	36	58.8	95.1	65.1
M_6: MH @200 ppm	36.0	45.5	56.8	65.2	4.0	4.3	4.6	4.9	39.2	57.2	96.2	63.2
SEm±	0.36	0.73	0.71	0.71	0.05	0.04	0.04	0.05	0.31	0.565	1.05	0.32
CD (P=0.5)	1.12	2.30	2.25	2.23	0.14	0.13	0.12	0.15	0.96	1.75	3.24	0.99
Sub plots - Time of application												
S_1: 30 DAS	36.9	49.2	60.7	69.5	4.3	4.5	4.8	5.1	43.4	58.8	95.0	68.84
S_2: 50 DAS	37.4	48.9	60.3	68.7	3.8	4.5	4.8	5.1	33.5	62.6	100.6	71.44
S_3: 30 and 50 DAS	36.8	47.4	58.3	66.8	4.5	4.9	5.2	5.5	45	67.5	107.9	74.14
SEm±	0.23	0.49	0.48	0.49	0.04	0.03	0.05	0.05	0.315	0.63	0.81	0.34
CD (P=0.05)	0.62	1.31	1.29	1.34	0.10	0.09	0.12	0.14	0.91	1.83	2.36	1.00
Control	40.0	51.5	62.8	71.3	3.8	4.1	4.4	4.6	31	56.4	89.8	63.7

Relative growth rate (gg^{-1} day^{-1}) (RGR)

The application of BR @ 15 ppm significantly noted higher RGR at 30-45 DAS (0.051 gg^{-1} day^{-1}), being at par with the CCC @ 1000 ppm. From 45-65 DAS till 85 DAS-harvest, CCC @ 1000ppm registered significantly higher RGR over all other treatments along with control. The foliar spraying of PGRs at 30 and 50 DAS significantly increased RGR at all the successive growth stages over other scheduling of applications. However, there was no significant difference between scheduling of growth regulators application at time of harvest (Fig 2). The increase in RGR (increase in dry matter of crop per unit of existing dry matter over time) through foliar application of growth regulator over control could be attributed to enhanced photosynthetic efficiency achieved through increased leaf thickness, cholorophyll content and improved translocation of carbon. Foliar application of growth retardant in groundnut resulted peak relative growth rate prior to pod initiation, followed by decrease during pod filling period over control. Similar results were also reported by Bharud and Pawar (2005) and Meena *et al.* (2023).

Net assimilation rate (mg $cm^{-2}day^{-1}$) (NAR) and absolute growth rate (g day^{-1}) (AGR)

Foliar application of CCC @ 1000 ppm significantly enhanced the NAR and AGR from 30-45 DAS till 45-65 DAS over all other PGRs and then followed a declining trend till harvest. Similar trend was also observed with spraying schedule of 30 and 50 DAS (Fig 3). Net assimi-slation rate is a measure of photosynthesis of leaves in crop community due to optimum LAI. Increase in NAR and AGR at 65 DAS *i.e.* at pod development stage might be due to increased efficiency of leaves for photosynthesis

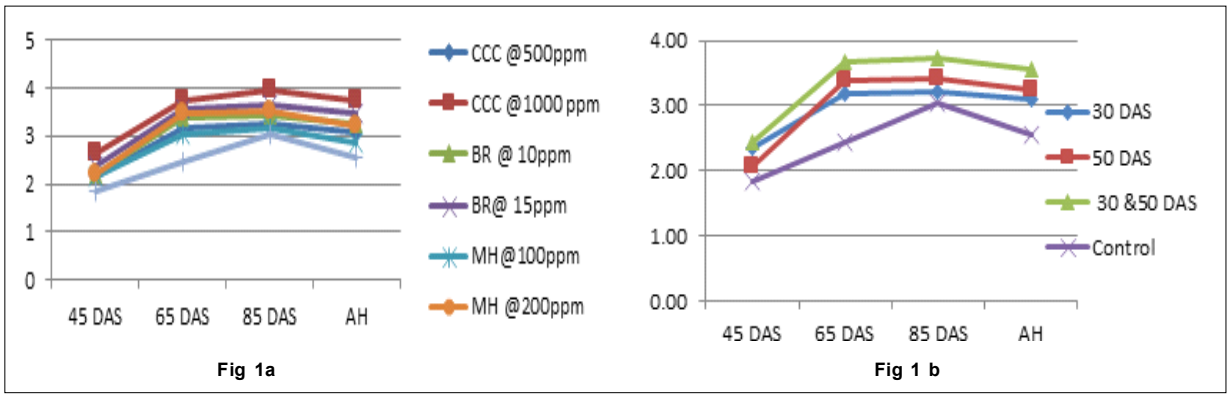


Fig 1a Fig 1 b

Fig 1: Effect of different levels of plant growth regulators and time of application on leaf area index in *kharif* groundnut at successive stages of the growth.

Table 2: Effect of different levels of plant growth regulators and time of application on pod yield (kg/ha), haulm yield (kg/ha) and shelling percentage (%) in *kharif* groundnut.

Treatments	Pod yield(kg/ha)	Haulm yield(kg/ha)	Shelling%
Plant growth regulator (M)			
M_1: CCC@ 500 ppm	1551.9	3544.5	71.8
M_2: CCC@ 1000 ppm	1847.1	3677.8	72.9
M_3: BR @ 10 ppm	1771.5	4348.7	72.4
M_4: BR @15 ppm	1681.4	4652.3	71.8
M_5: MH @100 ppm	1552.4	3516.9	71.6
M_6: MH @ 200 ppm	1747.9	3550.0	72.1
SEm±	32.4	56.8	0.22
CD(P=0.05)	102.1	179.0	0.68
Time of application(S)			
S_1: 30 DAS	1560.5	3947.7	71.3
S_2: 50 DAS	1718.7	4053.6	72.5
S_3: 30 and 50 DAS	1796.8	4193.8	72.6
SEm±	21.9	58.0	0.12
CD(P=0.05)	59.3	156.8	0.32
Control	1432	4757.2	70.8

resulting in higher production of photosynthates as a response of photosynthetic apparatus to increase the demand for assimilates by growing pod. Similar findings on increase in NAR by PGRs were also reported by Meshram *et al.* (2018) and Saheen *et al.* (2019).

Leaf area ratio ($cm^2 g^{-1}$)

The treatment imposed with foliar application CCC @ 1000 ppm incurred significantly maximum LAR at 30-45 DAS and decreased in subsequent intervals till harvest under all growth regulators. The spraying of PGRs at 30 and 50DAS significantly increased LAR at 30-45 DAS, followed by decreasing trend till harvest (Table 2). This trend of result implies that cellular level of developmental process were mostly completed before flowering. Management of nutrition and hormone during this growth phase can add to growth and productivity of *kharif* groundnut by effectively regulating metabolic processes. The present findings were in close conformity of Sagar *et al.* (2020).

Yield and yield component

Compared to the control, the application growth regulators significantly enhanced the pod yield and yield attributes in *kharif* groundnut. The application of the CCC @ 1000 ppm significantly increased the pod yield (1847.1 kg/ha) and shelling% (72.9%) and haulm yield was higher under control (4757.2 kg/ha). The foliar spray growth retardants at the time of 30 and 50 DAS significantly increased the pod yield and shelling% to 1796.8 kg/ha and 2.6%, respectively. Groundnut pod yield is a function of dry matter accumulation and yield attributes. In groundnut, the application of the plant growth retardants significantly increased the yield and yield components compared to the control.The application of plant growth regulators increased the total biomass and then might have resulted in increased transport of assimilates from source to sink and their ultimate conversion into final reserved food (Vardhini and Rao, 1999). These results were supported with the findings

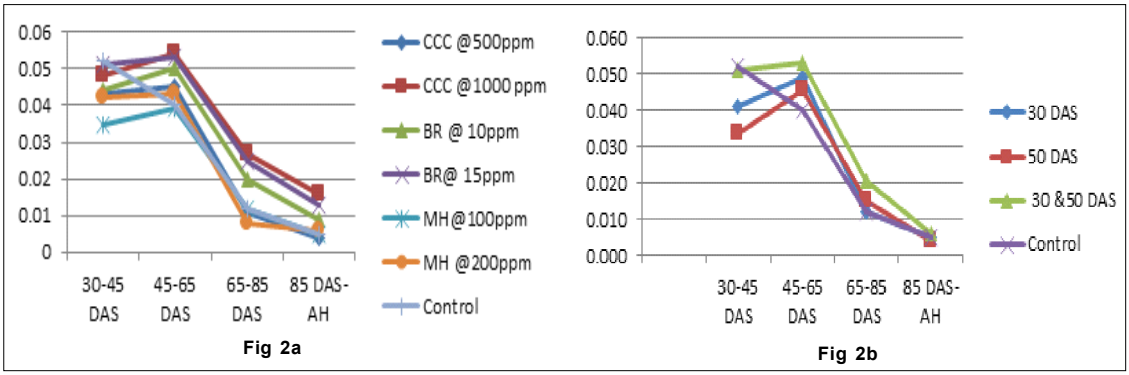


Fig 2: Effect of different levels of plant growth regulators and time of application on relative growth rate (g g^{-1} day^{-1}) in *kharif* groundnut at successive stages of the growth.

Table 3: Effect of different levels of plant growth regulators and time of application on crop growth rate and leaf area ratio in *kharif* groundnut at successive stages of growth.

Treatments	Crop growth rate ($g^{-2}day^{-1}$)				Leaf area ratio (cm^2 g^{-1})			
	45 DAS	65 DAS	85 DAS	Harvest	45 DAS	65 DAS	85 DAS	Harvest
Main plots - Plant growth regulators								
M_1: CCC@500 ppm	6.7	16.3	12.6	4.0	39.4	29.5	26.4	24.5
M_2: CCC@1000 ppm	7.6	26.4	15.2	5.6	47.4	28.3	25.0	24.3
M_3: BR@10 ppm	9.1	17.8	14.3	4.6	41.6	28.1	26.0	24.5
M_4: BR@15 ppm	9.8	22.6	12.9	4.5	39.7	29.8	25.7	24.2
M_5: MH@100 ppm	5.7	16.5	12.6	3.8	41.2	31.8	26.9	25.7
M_6: MH@200 ppm	6.9	17.0	14.2	4.4	40.6	28.8	25.8	23.8
SEm(±)	0.23	0.24	0.32	0.18	0.147	0.113	0.10	0.097
CD (P=0.5)	0.69	0.73	0.96	0.56	0.431	0.337	0.312	0.285
Sub plots - Time of application								
S_1: 30 DAS	8.5	16.3	12.5	4.2	43.0	28.1	25.5	23.6
S_2: 50 DAS	4.8	20.5	13.6	4.7	38.1	29.3	26.1	24.5
S_3: 30 and 50 DAS	9.2	21.3	14.8	5.2	44.5	31.4	27.5	26.3
SEm±	0.09	0.08	0.13	0.07	0.690	0.425	0.405	0.415
CD (P=0.05)	0.26	0.23	0.38	0.20	1.987	1.215	2.502	1.155
Control	9.7	18.0	13.9	4.8	39.4	29.5	26.4	24.5

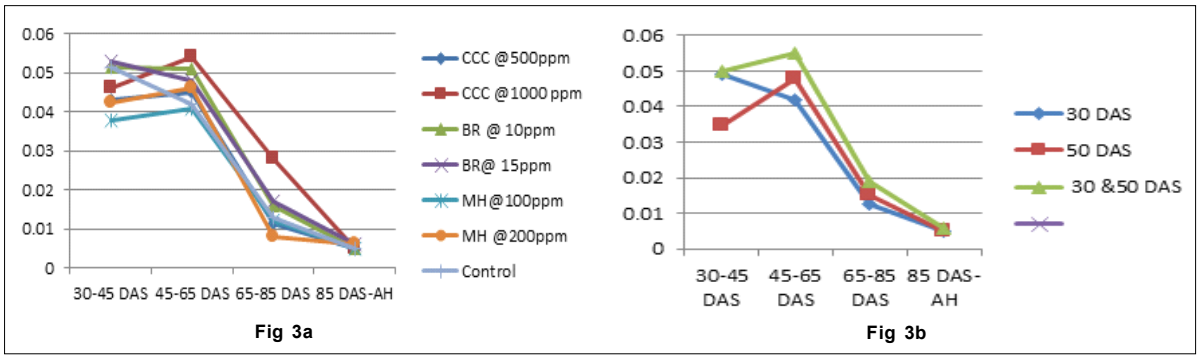


Fig 3: Effect of different levels of plant growth regulators and time of application on net assimilation rate (cm^2 day^{-1}) in *kharif* groundnut at successive stages of the growth.

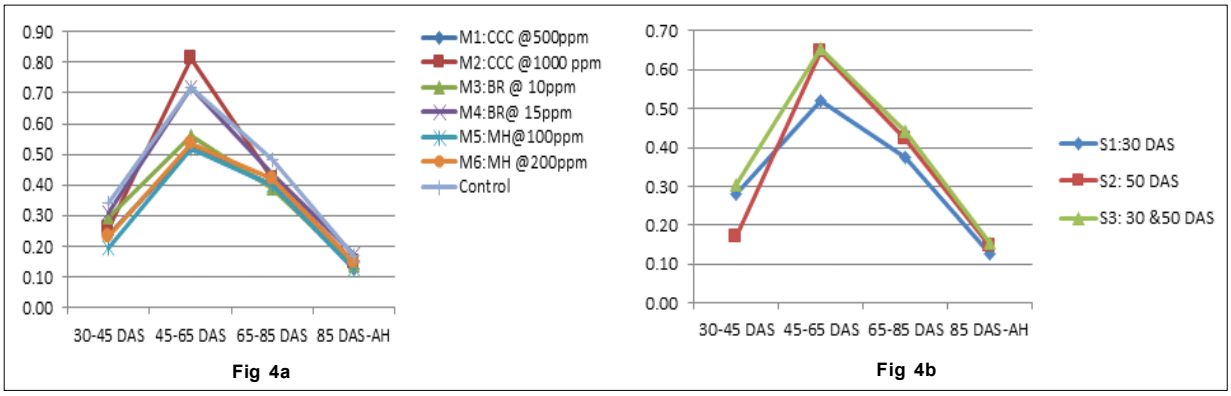


Fig 4: Effect of different levels of plant growth regulators and time of application on absolute growth rate (g day^{-1}) in *kharif* groundnut at successive stages of the growth.

of Janarjuna *et al.* (2001); Sadeghi *et al.* (2014); Khalilzadeh *et al.* (2016); Patel *et al.* (2019) and Kurmi *et al.* (2020).

CONCLUSION

The application of plant growth regulators has a significant effect on the morphological and physiological parameters of *kharif* groundnut. Foliar application of CCC @ 1000 ppm at 30 and 50 DAS reduced the plant height and enhanced primary branches, leaves per plant and several physio-logical parameters such as LAI, CGR and NAR over other growth regulators, adding to groundnut growth and productivity in *kharif* season.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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