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Effect of foliar application of plant growth regulators on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.)

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Abstract
The present investigation entitle Effect of foliar application of plant growth regulators on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.) was conducted at Research and instruction cum farm, Department of Horticulture, BTC, College of Agriculture and Research Station, Bilaspur (C.G.) during *rabi* season of 2022-23.

The experiment is carried out in RBD design with three replications and ten treatments. The treatments were created with different doses of plant growth regulators in cabbage var. Quick 48 (F_1 Hybrid cabbage). The treatment consists of three concentration of each plant growth regulators namely GA_3 (25, 50, 75 ppm), NAA (25, 50, 75 ppm), CCC (300, 500, 700 ppm) and one control plot. The treatments application as foliar spray at 30 and 45 DAT and the recommended package of practices in cabbage were followed as per requirement. Observations were recorded at 15,30,45 and 60 days after transplanting. The results revealed that treatment T_2 – GA_3 @ 50 ppm increase the plant height, number of leaves plant^{-1}, steam of length, diameter of stem and increase the yield gross weight of head, net weight of head and yield hectare^{-1}. It is also mentioned that highest B:C ratio of 2.55 was recorded.

Keywords: Growth, development, yield, GA3, NAA, CCC on cabbage

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.), belongs to the family Brassicaceae. It was originated in the Denmark, north-western part of France and sea coast of England. According to categorization cabbage is included in biennial crops but generally grown as annual crop. It is locally known as gobi and bandh-gobi, the edible portion of cabbage is head. It is one of the most popular vegetable throughout the world due to its nutritive and culinary uses. Cabbage is an economically important cole season crop grown extensively throughout the world, including India, which contains valuable antioxidants, vitamins, mineral compounds and secondary metabolites (glucosinolates). This vegetable also possesses anti-infammatory and anti-cancer properties.

Cabbage head is a rich source of vitamin A, B & C and contains a lot of carotene and minerals from a nutritional standpoint. It has been reported that 100 g of green edible portion of cabbage contains 92% water, 24 kilocalories of food energy, 1.5 g of protein, 4.8 g of carbohydrate, 40 mg of calcium, 0.6 mg of iron, 600 IU of carotene, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin C (Rashid. 1993) [13]. In addition, cabbage contains indole-3-carbinol, a substance that promotes DNA repair in cells and appears to stop the spread of cancer cells.

Globally, China, India and Pakistan are the largest cabbage producers. (Gerszberg A., 2018) [14]. Major cabbage growing states in India Odisha, West Bengal, Karnataka, Maharashtra, Gujarat, and Punjab. In India annual production of the cabbage in 2020-21 is 9,560.0 thousand tonnes from an area of about 412.0 thousand ha with the productivity of 23.2 MT ha^{-1}. (Anonymous, 2022) [1-2] and in the state of Chhattisgarh, major growing district are Balod, Raipur, Bastar, Balodabazar, Jashpur and Surguja. The cultivation area of cabbage is 22.22 thousand ha and the production is 420.35 thousand tonnes with productivity of 18.92 MT ha^{-1}.

To increase the yield of cabbage, various workers have recommended different doses of major and minor nutrients. Additionally, scientists have tried to increase the yield of cabbage through the development of high producing cultivars and cultural trials.

Similarly, application of plant growth regulator is also better to increase the yield of vegetable without hampering their quality. Growth regulators are organic matter that enhances inhibits or alters plant body processes and thus enhances yields with good quality. They facilitate the synthesis of metabolites and the transport of nutrients and metabolism into various components, ultimately leading to higher recovery. Plant growth regulators are used to modify crop growth rate and growth model during the various stages of development from germination to harvest. When treated with plant growth regulators, particularly GA_3 and NAA, cabbage was found to exhibit rapid growth, early head formation, and higher yield (Dhengle and Bhosale, 2008) [3].

Napthalene acetic acid (NAA) is a synthetic plant hormone in the auxin group and is an ingredient in many commercial plant rooting horticultural products. It is affects body processes, speeds up maturation and improves the quality of vegetables and fruits. NAA has a significant impact on the fruit retention of numerous vegetables and horticulture crops, significantly increasing yield (Younis and Tigani, 1977) [12].

GA_3 as a metabolic by- product of the plant pathogen *Gibberella fujikuroi*. It is a pentacyclic diterpene acid promoting growth and elongation of cells. GA_3 also increases the plant height, weight of shoot and root of the plant. It also stimulates the cells of germinating seeds to produce mRNA molecules that code for hydrolytic enzymes. It is a very potent hormone whose natural occurrence in plants control their development. The production of cabbage can be increased by using GA_3 (Islam *et al*., 1993) [4].

Cycocel is growth retardants and commonly applied to limit stem elongation and produce a more compact plant. Production of high quality, compact plants may be achieved through the use of plant growth retardants, including cycocel (Tayama *et al*., 1990) [16]. Plant growth retardants can delay cell division and elongation of aerial parts the plant as well restrict gibberellins biosynthesis, resulting in reduced internodes and vegetative growth (Magnitskiy *et al.*, 2006) [6].

Plant growth regulators work with very low concentration when used in the active (vegetable) growth stage of the plant. The advantage of crop growth promoters is that they increase the yield of many cabbage varieties, as some of them promote growth. Crop growth regulators are helpful and available in the market but their use and focus will still be improved. In India, a few research workers have studied the effects of crop growth regulators on various vegetable crops, especially in seed treatment, seedling treatment and leaf use.

Materials and Methods

The experiment was conducted at Horticulture Research cum Instructional Farm, Department of Vegetable Science, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh in Rabi 2022-23. Bilaspur district is situated at Latitude 22.09˚N and Longitude, 82.15˚E. The region falls under the Eastern plateau and hill region (Agro-climatic zone-VII) of India. Chhattisgarh state is classified into three agro-climatic zones, in which Bilaspur falls under the Chhattisgarh plains zone of the state. The experimental field was well drained with uniform topography. The experiment was laid out in Randomized block design (RBD) with ten treatments and three replications. The treatments were randomly allotted to different plots. The experimental material for this study comprised of different growth regulators namely GA3, NAA and CCC, in Quick – 48 (Hybried) variety of Cabbage. Plant growth regulators namely GA_3 (25, 50, 75 ppm), NAA (25, 50, 75 ppm), CCC (300, 500, 700 ppm) and one control plot. The treatments application as foliar spray at 30 and 45 DAT and the recommended package of practices in cabbage were followed as per requirement. All the standard packages and practices were followed. The plant transplanted in row to row 60 cm and plant to plant 45 cm full dose inorganic fertilizer of RDF (120:60:60 Kg NPK ha^{-1}).

Entire full dose of P and K along with ⅓ part of N should be applied as basal dose. Reaming N may be applied one month after sowing. The observations were recorded on growth and yield parameter of cabbage. The growth parameters *viz*., plant height (cm), number of leaves $plant^{-1}$, length stalk (cm), diameter of length (cm). The yield and yield attributes *viz*., Gross weight of head $^{-1}$ kg, net weight of $head^{-1}$ kg, and yield $hectare^{-1}$ (q), economics of crop cultivation were recorded after harvest. Statistical analysis of the data was done by using Analysis of Variance (ANOVA) technique.

Results and Discussion

The result of the present experiment indicates that foliar application of GA3and NAA significantly increased the growth and yield parameters of Cabbage. The plant height was recorded at 15, 30, 45 and 60 DAT. At 45 DAT the significant differences were found in respect of plant height, the significantly maximum plant height (29.96 cm) was recorded in the treatment (T_2) GA_3 50 ppm, and minimum plant height (20.03 cm) was recorded in the treatment (T_9) CCC 700 ppm. At 60 DAT the significantly maximum plant height (33.03 cm) was recorded in the (T_2) treatment GA_3 50 ppm. However, statistically significant and minimum plant height (22.47 cm) was recorded in treatment CCC 700 ppm (T_9). Similar results were reported by Lendve *et al.* (2010) [5] and Sitapara *et al.* (2011) [9].

Number of leaves $plant^{-1}$ At 45 DAT the significant differences were found in respect number of leaves $plant^{-1}$. The significantly maximum number of leaves $plant^{-1}$ (19.45) was recorded in the treatment (T_2) GA_3 50 ppm. However, statistically significant and minimum number of leaves $plant^{-1}$ (14.38) was recorded in treatment (T_{10}) control plot. At 60 DAT the significantly maximum number of leaves $plant^{-1}$ (23.48) was recorded in the treatment (T_2) GA_3 50 ppm, and minimum number of leaves $plant^{-1}$ (17.05) was recorded in treatment (T_{10}) control plot. Same result were noted by Meena *et al.* (2018) [7].

Length of stem (cm).The highest length of stem (7.68 cm) was obtained by (T_2) GA_3 50 ppm, statistically significant and minimum length of stem (3.41 cm) was recorded in treatment (T_9) CCC 700 ppm. The results obtained in the present study are supported the findings reported by Roy and Nasiruddin (2011) [8] in cabbage.

All yield and yield attributes characters the highest Gross weight of head $plant^{-1}$ (1.55 kg) was obtained by (T_2) GA_3 50 ppm, and minimum gross weight of head (0.99 kg) was recorded in treatment (T_{10}) Control plot. Also reported by Dhengle and Bhosale (2007) [15], Lendve *et al.* (2010) [5], Reza *et al.* (2015) [17] and Vishwakarma *et al.* (2017) [11].

Net weight of head $plant^{-1}$ The highest Net weight of head $plant^{-1}$ (1.32 kg) was obtained by GA_3 50 ppm (T_2), However, statistically significant and minimum net weight of head (0.75 kg) was recorded in treatment (T_{10}) Control plot. Similar result is close refers with the finding of Sonam *et al.* (2020) [10].

Head Diameter (cm) The highest diameter of head plant^{-1} (47.45 cm) was obtained by (T_2) GA_3 50 ppm, However, statistically significant and minimum diameter of head (47.4 cm) was recorded in treatment (T_{10}) Control plot. In conformity with the findings of Kotecha *et al.* (2011) [18] and Vishwakarma *et al*. (2017) [11].

Yield of ha $^{-1}$ (q) The highest yield of ha^{-1}(q) (368.11) was obtained by (T_2) GA_3 50 ppm, However, statistically significant and minimum yield of ha^{-1}(q) (209.62) was recorded in treatment (T_{10}) Control. Similar results were obtained in respect of Dhengle and Bhosale (2008) [3], Roy and Nasiruddin (2011) [8] In cabbage.

Economics

The cost of cultivation was maximum (₹72843) under the treatment $T_3$and minimum total cost of cultivation are recorded (₹70375) under the treatment T_{10} control plot. The maximum gross profit ha^{-1} was recorded in T_2 (₹257677), where as minimum gross profit ha^{-1} was recorded in T_{10} (₹146734).

The maximum net profit ha^{-1} was recorded under T_2 (₹185269).While minimum net profit ha^{-1} was obtained under T_{10} (₹76359). Thus, the maximum income (both gross profit and net profit) was obtained by T_2 and the lowest gross profit and net profit in T_{10} (control plot).

The maximum B:C Ratio was found in T_2 (GA_3 50 ppm) 2.55 and the lowest B:C Ratio was found in both T_{10} (control plot), 1.08 because in T_{10} (control plot) the yield was low. T_2 (GA_3 50 ppm) gives higher gross return because of higher yield.

Table 1: Plant height (cm), number of leaves^{-1}, diameter of stem (cm), length of stem (cm) their treatments details and results

S.N.	Treatment	Plant height(cm)		Number of leaves-1		Diameter of stem(cm)		Length of stem(cm)
		45 DAT	60 DAT	45 DAT	60 DAT	45 DAT	60 DAT	At harvest
T_1	Gibberellic acid(GA_3) @ 30ppm	26.33	29.70	17.30	20.90	17.30	2.80	5.41
T_2	Gibberellic acid (GA_3) @ 50 ppm	29.96	33.03	19.45	23.48	19.45	3.63	7.68
T_3	Gibberellic acid (GA_3) @ 80 ppm	28.73	31.04	18.18	21.92	18.18	3.46	6.92
T_4	Naphthalene acetic acid (NAA) @ 30 ppm	25.53	28.13	16.43	20.71	16.43	2.18	5.32
T_5	Naphthalene acetic acid (NAA) @ 50 ppm	28.86	32.06	18.23	22.83	18.23	3.55	7.58
T_6	Naphthalene acetic acid (NAA) @ 80 ppm	27.93	30.70	17.88	21.53	17.88	3.37	6.72
T_7	Cycocel(CCC) @ 300 ppm	21.93	25.81	16.27	18.77	16.27	2.47	4.22
T_8	Cycocel (CCC) @ 500 ppm	21.73	24.10	16.47	18.90	16.47	2.53	3.81
T_9	Cycocel (CCC) @ 700 ppm	20.03	22.47	16.57	19.11	16.57	2.58	3.41
T_{10}	Control plot	1.19	1.33	14.38	17.05	1.66	2.24	4.33
	S.Em ±	1.19	1.33	0.80	0.94	0.09	0.13	0.25
	CD (0.05)	3.54	3.95	2.38	2.81	0.29	0.41	0.76

Table 2: Gross weight of head of head, net weight of head, diameter of head, yield and benefit cost ration (B:C Ratio) their treatments details and results

S. N	Treatment	Gross weight of head $^{-1}$	Net weight of head^{-1}	Diameter of head(cm)	Yield ha^{-1}	B:C Ratio
T_1	Gibberellic acid (GA_3) @ 30 ppm	1.36	1.10	43.11	305.17	1.96
T_2	Gibberellic acid (GA_3) @ 50 ppm	1.55	1.32	51.35	368.11	2.55
T_3	Gibberellic acid (GA_3) @ 80 ppm	1.44	1.29	47.45	358.11	2.44
T_4	Naphthalene acetic acid (NAA) @ 30 ppm	1.32	1.07	42.60	298.23	1.91
T_5	Naphthalene acetic acid (NAA) @ 50 ppm	1.47	1.31	49.40	360.25	2.51
T_6	Naphthalene acetic acid (NAA) @ 80 ppm	1.40	1.27	46.25	348.66	2.39
T_7	Cycocel (CCC) @ 300 ppm	1.21	0.92	39.66	254.88	1.47
T_8	Cycocel (CCC) @ 500 ppm	1.31	0.93	40.47	258.60	1.49
T_9	Cycocel (CCC) @ 700 ppm	1.37	1.01	41.04	260.19	1.50
T_{10}	Control	0.98	0.75	37.40	209.62	1.08
	S.Em ±	0.06	0.05	2.10	13.96	
	CD (0.05)	0.18	0.15	6.26	41.49	

Conclusion

Based on results of one season experiment, it can be concluded that application of plant growth regulators are very effective in cabbage.

Application of GA_3 50 ppm (T_2), was show most effective increment in growth characters, such as plant height (cm), number of leaves plant^{-1}, length of stem (cm), diameter of stem (cm).and yield and yield attributes, gross weight of head plant $^{-1}$, net weight of head plant $^{-1}$, head Diameter (cm) and yield of ha $^{-1}$ (q), as compared to control plot (T_{10}).

With respect to economics, higher net return (₹159867) as well as gross return (₹221262) noted under the T_2 (GA_3 50 ppm). The cost of cultivation was maximum (₹61830) under the treatment T_3 (GA_3 80ppm), maximum B:C Ration (2.60) was obtained under the T_2 (GA_3 50 ppm), and minimum B:C Ration (1.11) was obtained under the treatment (T_{10}) control plots.

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