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Studies on effect of different plant growth regulators on growth and yield of radish (*Raphanus sativus* L.) in Chhattisgarh plains

Adarsh Gopal, Dr. Nisha Jangre, Manoj Kumar Sahu, Suman Pandey and Deepshikha

Adarsh Gopal
M.Sc. Scholar, Department of Vegetable Science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dr. Nisha Jangre
Department of Vegetable science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Manoj Kumar Sahu
Department of Vegetable science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Suman Pandey
Department of Vegetable science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Deepshikha
Department of Vegetable science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Adarsh Gopal
M.Sc. Scholar, Department of Vegetable Science College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Abstract
Present investigation was conducted during *Rabi* season 2022-23 at farm of Krishi Vigyan Kendra, (Raipur) under department of vegetable science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh to study the "Studies on effect of different plant growth regulators on growth and yield of radish (*Raphanus sativus* L.) in Chhattisgarh plains". The field experiment was conducted in randomized block design with three replications, consisting a control and nine treatments of three plant growth regulators i.e., GA_3 @ 10, 20 and 30 ppm, NAA @ 10, 20 and 30 ppm and IBA @ 10, 20 and 30 ppm as foliar application at 10, 30, 60 DAS. The results showed that the application of GA_3 @ 30 ppm gave maximum plant height (73.35 cm), maximum number of leaves (17.53), length of root (35.25 cm), diameter of root (5.53 cm), fresh weight of root (226.33 g) and root yield plot^{-1} (38.13 kg), root yield ha^{-1} (27.23 t).

Keywords: Plant growth regulators, growth, yield, radish, *Raphanus sativus* L.

Introduction

The radish, scientifically known as (*Raphanus sativus* L.,) ranks among the favored underground crops, cultivated for its large edible roots. This vegetable, with a long history of cultivation, remains a popular choice in both tropical and temperate regions. Its tender leaves and shoots are commonly consumed as leafy greens (Alam *et al.*, 2010) [4]. Belonging to the Brassicaceae family, with a diploid chromosome number of 2n = 18, the radish is a swiftly growing annual herb. Botanically speaking, its spindle-shaped edible roots can be either red or white in hue. Displaying biennial traits, certain Asian varieties, well-suited for tropical conditions, yield edible roots in the initial season and seeds in the second. The basal leaves take on a rosette shape and are covered in sturdy bristles. The assortment of roots varies in type, size, and length (Singh and Vishal, 2012) [24].

Rich in vitamin C (14.8 mg/100 gm of edible portion) and minerals, the radish offers a sharp taste attributed to isothiocyanate (Kushwah, 2019) [17]. The fresh leaves and roots serve as abundant sources of vitamins A and C, additional minerals (Jilaniet *et al.*, 2010) [14], and antioxidants (Noreen & Ashraf, 2009) [20]. Maharashtra, Assam, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh, Haryana, and Jammu and Kashmir are the primary cultivators of radish. In Chhattisgarh, radish occupies a cultivation area of 13.569 ha, resulting in a production of 243.251 MT. Leading in this region is Kondagaon district with an area of 4.728 ha and a production of 80.384 MT, followed by Mahasamund, Durg, and Rajnandgaon (Anonymous, 2022) [5].

An emerging facet of agricultural science involves the utilization of plant growth regulators. These compounds, such as IAA (natural auxin), occur naturally in plants and, when administered in small doses, trigger various physiological processes (Bhatia and Parashar, 1988) [7]. Commonly referred to as phytohormones, these substances encompass auxins, cytokinins, ethylene, and abscisic acid. While these can be applied to leaves or seeds, seed treatment is usually more fitting for radish crops. NAA is mainly employed for promoting vegetative growth, especially flowering, whereas GA_3 is recognized for enhancing seed germination rates. Interestingly, higher concentrations of NAA lead to increased radish yield (Singh *et al*., 1989) [1].

Indole-3-butyric acid (IBA) acts as a growth stimulant, expediting root development in young plant cuttings, promoting flower and fruit growth, and ultimately enhancing agricultural yields.

Through IBA application, early root initiation is observed. Radish plants treated with IBA exhibit a noteworthy increase in fresh leaves and roots per plant, subsequently resulting in substantial yield improvements (Ashraf *et al*., 2018) [6].

Materials and Methods

Present investigation was conducted during *Rabi* season 2022-23 at farm of Krishi Vigyan Kendra, (Raipur) under department of vegetable science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The field experiment was conducted in randomized block design with three replications, consisting a control and nine treatments of three plant growth regulators i.e., GA_3 @ 10, 20 and 30 ppm, NAA @ 10, 20 and 30 ppm and IBA @ 10, 20 and 30 ppm as foliar application at 10, 30, 60 DAS. Seeds were sown on 12th December 2022. The observation was recorded on the basis of various growth and yield parameter such as plant height, Number of leaves, length of root, diameter of root, fresh weight of root and root yield per plot, root yield per hectare.

Results and Discussion

Plant height (cm)

The application of GA3 at 30 ppm resulted in the tallest plant measuring 18.30 cm at 20 DAS, followed by measurements of 43.73 cm at 40 DAS and 73.35 cm at 60 DAS. Conversely, the control group exhibited the lowest plant heights, with measurements of 31.73 cm at 20 DAS and 58.47 cm at 60 DAS. Notably, the treatment with GA3 at 30 ppm led to significant height increases at all observed time points (20 DAS, 40 DAS, and 60 DAS), in contrast to the control group which exhibited the least growth. The primary factor contributing to the heightened growth was the hormonal influence on both cell division and cell elongation. Moreover, GA3 was found to influence processes like protein biosynthesis, translocation, and transpiration at the genetic level, thereby promoting increased plant height (Key, 1969) [16]. These outcomes align with the research of Priyanka and KN Nagaich (2019), Ganapathi (2006) [11], Kutijabi (2007) [18], and Abbas (2011) [2] in relation to carrot growth.

Table 1: Effect of growth regulators on plant height (cm) at 20, 40, and 60 DAS

Treatments	Plant height (cm)		
	"20 DAS"	"40 DAS"	"60 DAS"
T_1 GA_3-10 ppm	16.73	37.63	66.45
T_2 GA_3-20 ppm	17.27	39.75	70.08
T_3 GA_3-30 ppm	18.30	43.73	73.35
T_4 NAA-10 ppm	15.40	34.83	64.77
T_5 NAA- 20 ppm	16.58	36.59	65.90
T_6 NAA-30 ppm	17.11	37.80	67.27
T_7 IBA-10 ppm	15.82	34.14	64.32
T_8 IBA-20 ppm	16.37	36.11	65.54
T_9 IBA-30 ppm	16.83	36.68	66.11
T_{10} control	14.55	31.73	58.47
SE(m)	0.57	0.70	0.73
C.D. at 5%	1.69	2.07	2.17

Number of leaves

At 20 DAS, 40 DAS, and 60 DAS, the application of GA3 at 30 ppm resulted in the highest leaf counts per plant, measuring 10.27 cm, 15.40 cm, and 17.53 cm, respectively. Conversely, in the control group, the minimum leaf counts were observed, measuring 5.97 cm at 20 DAS, 8.51 cm at 40 DAS, and 9.67 cm at 60 DAS. In comparison to the control group, the treatment with GA3 at 30 ppm demonstrated a notably increased number of leaves at the specified time points. The positive impact of gibberellic acid on vegetative growth played a pivotal role in this phenomenon, as indicated by Davis and Nunez. [9] This trend aligns with findings from (2000) and Abbas (2011) [2], as well as research conducted by Singh and Rajodia (2001) [25], Dhariwal (2005) [10], Karuppaiah *et al*. (2007) [15], Shweta *et al*. (2018) [23], and Mishra *et al*. (2019) [19] in the context of radish growth.

Table 2: Effect of growth regulators on number of leaves at 20, 40, and 60 DAS

Treatments	Number of leaves		
	"20 DAS"	"40 DAS"	"60 DAS"
T_1 GA_3-10 ppm	7.40	12.40	14.67
T_2 GA_3-20 ppm	8.53	13.47	15.87
T_3 GA_3-30 ppm	10.27	15.40	17.53
T_4 NAA-10 ppm	7.25	11.73	13.53
T_5 NAA- 20 ppm	8.13	12.20	14.43
T_6 NAA-30 ppm	8.40	13.05	15.20
T_7 IBA-10 ppm	7.10	11.17	12.80
T_8 IBA-20 ppm	8.10	11.88	13.38
T_9 IBA-30 ppm	8.31	12.90	14.51
T_{10} control	5.97	8.51	9.67
SE(m)	0.16	0.33	0.55
C.D. at 5%	0.47	0.97	1.65

Length of root

The results clearly indicated that the highest average root length was observed with the application of GA3 at 30 ppm (measuring 35.25 cm), surpassing all other growth regulator concentrations. The next highest root length was seen with GA3 at 20 ppm (measuring 32.57 cm). In contrast, the control group exhibited the shortest root length, measuring 25.94 cm. The findings highlighted significant variations in root length among the different treatments. Notably, higher concentrations of GA3 led to increased root length, potentially due to enhanced cell development and elongation within the root system. This aligns with the findings of Sarkar *et al*. (2018) and is consistent with observations made by Jatav (2007) [13], Karuppaiah *et al*. (2007) [15], Verma *et al*. (2008) [26], and Patel *et al*. (2017) [21] in the context of radish growth. Similar trends were also noted by Shweta *et al*. (2018) [23].

Diameter of root

The influence of various treatments on the average root diameter exhibited substantial variability. The data clearly indicates that growth regulators significantly affect the root diameter per plant in comparison to the control group. Among the treatments, the highest root diameter per plant was observed with the application of GA3 at 30 ppm (measuring 5.53 cm), while the lowest root diameter per plant was recorded in the GA3 at 20 ppm treatment under control conditions (measuring 4.49 cm). These outcomes are consistent with the findings reported by Singh and Rajodia (2001) [25], Verma *et al*. (2008) [26], and Patel *et al*. (2017) [21].

Fresh weight of root

The impact of various treatments on the average fresh weight of the roots exhibited considerable variability. Different concentrations of treatments demonstrated a significant influence on root weight. The treatment with the highest concentration of GA3, specifically GA3 at 30 ppm, yielded the greatest root weight (measuring 226.33 g). The subsequent concentration, GA3 at 20 ppm, resulted in a slightly lower root weight (218.30 g), while the control group exhibited the lowest root weight (155.27 g). Notably, the highest GA3 concentrations corresponded to the greatest fresh root weight. This phenomenon could be attributed to the interplay of three processes: dry matter accumulation, cell division, and expansion, all contributing to increased root weight (Hopkins, 1999) [12]. These findings align with the research conducted by Datta *et al*. (2018).

Table 3: Effect of growth regulators on Root length (cm), Diameter of root (cm), Fresh weight of root (gm)

Treatment	Root length	Root diameter	Fresh wt. of root
T_1 GA_3-10 ppm	30.37	3.73	190.17
T_2 GA_3-20 ppm	32.57	4.49	218.30
T_3 GA_3-30 ppm	35.25	5.53	226.33
T_4 NAA-10 ppm	29.69	3.48	180.00
T_5 NAA- 20 ppm	30.95	3.99	186.33
T_6 NAA-30 ppm	31.33	4.17	216.67
T_7 IBA-10 ppm	28.37	3.33	176.63
T_8 IBA-20 ppm	29.96	3.67	183.17
T_9 IBA-30 ppm	31.09	4.00	197.13
T_{10} control	25.94	2.95	155.27
SE(m)	0.92	0.14	1.56
C.D. at 5%	2.74	0.42	4.63

Root yield per plot (kg)

Among the range of growth regulators, the treatment involving GA_3 at 30 ppm achieved the most substantial root yield per plot, measuring 38.13 kg. This was followed by the GA3 at 20 ppm treatment with a root yield of 35.15 kg, and the NAA at 30 ppm treatment with a yield of 33.62 kg. In contrast, the control group displayed the lowest root yield per plot, measuring 23.03 kg. These findings closely correspond to the outcomes documented in the studies conducted by Mahabir Singh and Rajodia (1989) [1] on radish, Abdul *et al*. (2002) [3] on onion, Chauhan and Tandel (2010) [6] on cabbage, and also Shruthi *et al*. (2016) [22].

Root yield per ha (Tonne)

The highest yield was attained through the foliar application of GA3 at 30 ppm, resulting in a yield of 27.23 t ha-1, followed by GA3 at 20 ppm with a yield of 25.10 t ha-1, and NAA at 30 ppm with a yield of 24.01 t ha-1. On the other hand, the control group exhibited the lowest yield of 16.45 t ha-1. These plant growth regulators play a significant role in enhancing essential physiological processes for plants, such as photosynthesis and nitrogen metabolism. Whether applied as foliar sprays or seed treatments, plant growth regulators have demonstrated noteworthy contributions to both the productivity and quality of vegetable crops. Additionally, Ries and Houtz (1983) noted that gibberellic acid, in comparison to other treatments, notably improved the morpho-physiological traits of the plants. This enhancement in yield could potentially be attributed to improved carbon absorption and carbohydrate accumulation in the economically valuable plant parts. These outcomes align with the findings reported by Mahabir Singh and Rajodia (1989) [1] for radish, Abdul *et al*. (2002) [3] for onion, Chauhan and Tandel (2010) [6] for cabbage, and Shruthi *et al*. (2016) [22].

Table 4: Effect of growth regulators on Yield per plot (kg) Yield per ha (T)

Treatment	Yield per plot (kg)	Yield per ha (T)
T_1 GA_3-10 ppm	31.00	22.14
T_2 GA_3-20 ppm	35.15	25.10
T_3 GA_3-30 ppm	38.13	27.23
T_4 NAA-10 ppm	29.07	20.76
T_5 NAA- 20 ppm	31.38	22.95
T_6 NAA-30 ppm	33.62	24.01
T_7 IBA-10 ppm	26.17	18.69
T_8 IBA-20 ppm	28.17	20.12
T_9 IBA-30 ppm	32.10	22.92
T_{10} control	23.03	16.45
SE(m)	0.79	0.86
C.D. at 5%	2.33	2.56

Conclusion

On the basis of the result obtained from present investigation, it can be concluded that among all the growth regulator's, GA_3 @ 30 ppm accomplished best results followed by GA_3 @ 20 ppm which improves the growth and yield character such as plant height, number of leaves, root length, root diameter, fresh weight of root, root yield per plot (kg), root yield per hectare (Tonne). Hence GA_3 @ 30 ppm can be used for radish grown in winter season to increase yield and yield attributing character and also recommended to farmers for increasing their productivity.

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