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Influence of Growth Regulators on Growth, Seed Yield and Qualty of Radish (*Raphanus sativus* L.)

R. Bala[1], P. Rattan[2*] and A. H. Reddy[1]

[1]Dept. of Agricultural Sciences, DAV University, Jalandhar, Punjab (144 012), India

[2]Division of Vegetable Science, FOH&F, SKUAST-Jammu (180 009), India

Corresponding Author

P. Rattan

e-mail: rattanpooja16@gmail.com

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Abstract

The present investigation was carried out during 2021 at the experimental farm of Faculty of Agricultural Sciences, DAV University, Jalandhar. Radish is an important crop of Punjab region. Use of Plant Growth Regulators is one of the most recent trends in the field of agriculture science. Plant growth regulators are signal molecules, which occurs in plants naturally in very low concentration. In an attempt to find out the influence of growth regulators on growth, seed yield and quality of radish (*Raphanus sativus* L.) the experiment was planned and executed. It consisted of nine treatments *viz*., T_1 (Control), T_2 (GA_3 @ 5 ppm), T_3 (GA_3 @ 10 ppm), T_4 (GA_3 @ 15 ppm), T_5 (GA_3 @ 20 ppm), T_6 (NAA @ 5 ppm), T_7 (NAA @ 10 ppm), T_8 (NAA @ 15 ppm), T_9 (NAA @ 20 ppm) and was laid in Randomized block design (RBD) with three replications. Punjab Safed Mooli variety was used for the experiment. Observations were recorded on number of leaves per plant, leaf area per plant (cm^2), root length (cm), root diameter (cm), root weight (g), fresh weight of plant (g), dry weight of plant (g), plant height (cm), 100 seed weight (g), seed yield plant^{-1} (g), seed yield plot^{-1} (g), seed yield ha^{-1} (q ha^{-1}), TSS (°Brix), ascorbic acid (mg 100 g^{-1}), chlorophyll content (mg 100 g^{-1}) and germination percentage (%). Analysis of variance (ANOVA) revealed significantly differences among treatments for all the characters under study. It was concluded that the application of GA_3 @ 20 ppm showed superior performance in all growth, seed yield and quality parameters of radish.

Keywords: Radish, growth regulators, gibberellic acid, naphthalene acetic acid

1. Introduction

Radish (*Raphanus sativus* L.) commonly known as 'Mooli' came from latin word "radix" which means root that belongs to family Brassicaceae, the most popular root vegetable cultivated in India grown mainly during winter season. It is grown in tropical, sub-tropical and temperate regions of the world for its fleshy roots and leaves. Its roots have anti-diabetic properties so radish is used by diabetic patients (Banihani, 2017) and it is also useful in urinary related ailments, spleen and problem of piles (Brintha and Seran, 2009 and Dhananjaya, 2007). Its leaves are used to cure Jaundice through home remedies (Gohil et al., 2010). The juice of fresh leaves is used as laxative and diuretic. Radish is a good source of Vitamin C i.e. 15–40 mg per 100 g, also contains many nutrients and wide varieties of minerals and vitamins such as 0.7% protein, 3.4–6.8% carbohydrates, 0.2% fat, 0.8 g fiber per 100 g of fresh edible portion. Radish is an annual or biennial crop grown mainly during cool season. As compared to European type varieties of radish, Asiatic type varieties can tolerate higher temperature. Optimum temperature for its proper size, texture and better flavour is 15°C–18°C (Angell and Hillyer, 1962). In the mild climate, radish can be grown almost all year round except for few months in summer. Radish is mainly cultivated in Maharashtra, Assam, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh, Haryana, Jammu and Kashmir.

Use of Plant Growth Regulators is one of the most recent trends in the field of agriculture science. Plant growth regulators are signal molecules, which occurs in plants naturally in very low concentration. Plant growth regulators controls plant growth and development, embryogenesis (Mendez et al., 2019), regulation of organ size (Shigenaga and Argueso, 2016), pathogen defence (Burger and Chory, 2019), stress tolerance (Ku et al., 2018); Ullah et al., 2018) and reproductive development (Pierre et al., 2018). Plant growth regulators generally falls into five classes i.e., Auxin, Gibberellins, Cytokinin, ABA and ethylene. Plant growth regulators are reported to enhance germination in radish (Sarhang et al., 2023)

Gibberellins (GAs) are the plant hormones which are consisted of a large number of diterpenoid compounds (Hedden, 2020; Zhang et al., 2020). Gibberellins were discovered through foolish seedling disease caused by fungus *Gibberella fujikuroi* (Stowe et al., 1959). Gibberellins are naturally occurring plant hormone which stimulates both cell division and elongation in plants. Gibberellins control diverse effects of growth and development including seed germination, stem elongation, flowering, fruit development, and the regulation of gene expression (Bhattacharya, 2019). NAA is a synthetic plant hormone in the auxin family and it is toxic to plants in higher concentration. NAA is responsible for regulating cell division and elongation, adventitious root formation, tissue swelling, promoting cell wall loosening, callus initiation, growth and induction of embryogenesis (Muthukumar et al., 2007).

The productivity of radish is low mainly because of improper spacing and use of low-quality seeds. It has become difficult to meet even the minimum demand of quality seeds. In order to increase the seed production in radish, it is imperative to increase the yield by following improved cultural practices such as spraying of plant growth regulators, optimum plant population, manipulation of nutrients and control of pest and diseases. It is known that, among the cultural practices, suitable spacing with spraying of growth regulators is the most important from the point of high yields. These chemicals can be used in mostly two different ways- foliar application or seed treatment. GA_3 is known to increase the seed germination percentage whereas NAA is basically used for vegetative growth particularly flowering but NAA at higher concentrations enhance the yield of radish (Singh et al., 1989). Keeping all these points in view, the present investigation was executed.

2. Materials and Methods

The present study was carried out at the experimental farm of Faculty of Agricultural Sciences, DAV University, Jalandhar in October–May, 2021. The experiment was laid out in randomized block design (RBD) with three replications having nine treatments. The treatments included various concentration of GA_3 and NAA and Control viz. T_1 (Control), T_2 (GA_3 @ 5 ppm), T_3 (GA_3 @ 10 ppm), T_4 (GA_3 @ 15 ppm), T_5 (GA_3 @ 20 ppm), T_6 (NAA @ 5 ppm), T_7 (NAA @ 10 ppm), T_8 (NAA @ 15 ppm), T_9 (NAA @ 20 ppm). The variety Punjab Safed mooli was used in this experiment and the sowing of the seeds was done in the October i.e., 20 October with the spacing of 30×10 cm^2. Growth regulators were sprayed on the foliage at 20, 40 and 60 days after sowing. Standard dose FYM (10-15 t ha^{-1}) was incorporated with fertilizer i.e. N:P:K (100: 60: 60 kg ha^{-1}), irrigation was done at 10–15 days interval, while various intercultural operations like weeding followed by hoeing (2–3 times), and thinning was carried out after 25–30 days of sowing to avoid the overcrowding of plants. The observations were recorded on the basis of various growth and quality parameters such asnumber of leaves $plant^{-1}$, leaf area $plant^{-1}$ (cm^2), root length (cm), root diameter (cm), root weight (g), fresh weight of plant (g), dry weight of plant (g), plant height (cm), 100 seed weight (g), seed yield $plant^{-1}$ (g), seed yield $plot^{-1}$ (g), seed yield ha^{-1} (q ha^{-1}), TSS (°Brix), ascorbic acid (mg 100 g^{-1}), chlorophyll content (mg 100 g^{-1}) and germination percentage (%). Data analysis was done on OPSTAT software.

3. Results and Discussion

3.2. *Number of leaves*

Number of leaves $plant^{-1}$ is an important yield attribute. Higher the number of leaves more will the photosynthetic rate and production of photosynthates which leads to higher production. As depicted from (Table 1) maximum number of leaves $plant^{-1}$ was observed with higher concentration of GA_3@ 20 ppm. It might be due to the fact that GA_3 stimulates cell enlargement and cell division leading to enhanced number of leaves per plant (Noor et al., 2017). Similar results were obtained by Mahabir and Rajodia (1989) in radish. Sarkar et al. (2002) found that application of GA_3 @ 100 ppm in soyabean plant produced higher number of leaves $plant^{-1}$. Noor et al. (2017) found that higher number of leaves $plant^{-1}$ with the application of GA_3 in french bean. Hye et al. (2002); Tyagi et al. (2007); Patel et al. (2010); Tsiakaras et al. (2014); Govind et al. (2015) in onion, Verma et al. (2008) in spinach, and Uddain et al. (2009) in tomato, Avinash et al. (2019) also found same trend of result in radish.

Table 1: Analysis of variance for growth and yield parameters of radish

Observations	Replication	Treatments	Error
No. of leaves $plant^{-1}$	57.619	89.866*	7.295
Leaf area (cm^2)	1176.153	991.331*	16.188
Root length (cm)	167.387	390.443*	37.445
Root weight (g)	313.442	1187.932*	61.711
Root diameter (mm)	1.754	12.453*	0.504
Plant height (cm)	94.572	5772.169*	45.566
Fresh weight of plant (g)	2410.7469	6751.298*	372.807
Dry weight of plant (g)	932.923	623.276*	363.514
Seed yield $plant^{-1}$ (g)	11.157	72.063*	0.994
Seed yield $plot^{-1}$ (g)	46.071	56365.491*	2.033
Seed yield ha^{-1} (q ha^{-1})	1.614	11.259*	2.423
100 seed weight (g)	0.001	2.585*	0.001
Ascorbic acid (mg 100 g^{-1})	17.299	14.294*	6.601
Chlorophyll content (mg 100 g^{-1})	0.028	0.64*	0.029
TSS (°Brix)	6.01	6.272*	1.077
Germination percentage (%)	68.074	1029.852*	6.593

3.3. Leaf area (cm²)

Maximum leaf area (cm²) was observed when GA_3 @ 20 ppm is applied to the plants (Table 2). Increase in leaf area with the higher concentration of GA_3could be due to increased auxin production leading to increased rate of cell division. Leaf area growth determines light interception and is an important parameter in determining plant productivity (Gifford et al. (1984); koester et al. (2014) in soybean). The results corroborate with the findings of Malhotra and Choudhary (2001) in radish. Higher leaf area with application of GA has also been reported by Choudhary et al. (2006) in chilli, (Akhtar et al. 2008) in spinach and Bhat et al. (2011) in grapes. Enhanced leaf area with the application of GA was also reported in maize by Sarwar et al. (2017), Noor et al. (2017) in French bean; Miceli et al. (2019) in lettuce.

3.4. Plant height (cm)

Table 2 reveals that all the treatments significantly increased the plant height as compared to control, but the effect of GA_3 at 20 ppm was more pronounced than rest of the treatments. The plant height increased with higher concentration of GA_3 which can be attributed to the faster elongation and rapid proliferation of cells in growing portion of the plant results in encouragement of new growth leading to an absolute increase in plant height (Shruthi et al., 2016). Leite et al. (2013) also reported increase in plant height with the application of GA_3. Sadana et al. (2015) also reported increase in plant height with the increased doses of GA_3 in radish and they concluded that this could be due to stem elongation. The GA_3 increases auxin production apex and accelerates the cell division in cambium or other tissues which results in increase in height of plants. Similar findings were also reported by Mahabir and Rajodia (1989) in radish, Prasad et al. (2013) in tomato, Baliah et al. (2018) in green gram, and Avinash et al. (2019) in radish.

Table 2: Influence of growth regulators on growth parameters in radish

Treatments	No. of leaves	Leaf area (cm²)	Plant height (cm)	Fresh weight (g)	Dry weight (g)	Root length (cm)	Root diameter (mm)	Root weight (g)
Control	13.2	173.02	76.5	179.26	62.29	24.76	2.22	112.92
GA_3 @ 5 ppm	15.47	176.54	77	180.27	67.93	25.66	2.8	113.55
GA_3 @ 10 ppm	14.63	178.5	77.8	182.1	66.95	25.98	3.29	115.23
GA_3 @ 15 ppm	13	180.66	102.1	189.92	71.56	25.85	4.28	118.35
GA_3 @ 20 ppm	18.2	192.68	114.77	222.34	79.69	35.5	4.47	140.93
NAA @ 5 ppm	16.4	185.33	107.33	207.4	65.94	31.5	3.91	135.25
NAA @ 10 ppm	12.88	187.44	111.93	212.56	70.11	32.47	3.63	132.14
NAA @ 15 ppm	17.47	189.68	104.93	217.47	74.41	33.8	3.04	127.63
NAA @ 20 ppm	14.4	182.7	98.2	200.08	71.67	29.5	3.74	133.16
SEm±	0.55	0.58	0.97	22.79	2.75	1.24	0.1	1.6
CD (p=0.05)	0.39	1.76	2.95	8.43	7.32	0.88	0.31	3.43

3.5. Fresh weight (g)

The data (Table 2) clearly indicates that there was huge variation in fresh weight of root due to application of both plant growth regulators which significantly differ from control. Maximum fresh weight of plant observed by applying GA_3 @ 20 ppm. Increased fresh weight of the plant with the enhanced application of GA_3 can be attributed to the enhanced photosynthetic activities within the plants which resulted in higher production of carbohydrates and other photosynthetic products leading to enhanced fresh weight of the plant. The results are supported by Mahabir and Rajodia (2001); Sadana et al. (2015); Shweta et al. (2018) in radish; Mondal and Shukla (2005) in onion; Bawkar et al. (2011) in carrot; Baliah et al. (2018) in green gram.

3.6. Dry weight (g)

Dry weight of the plants showed the similar trend as observed in fresh weight of the plant (Table 2). The results corroborate with the findings of Abu grab et al. (2000), Quzounidon et al. (2011); Govind et al. (2015) in onion, Hoque and hoque (2002) in mung bean, Akhter et al. (2007) in mustard, Singh et al. (2012) in coriander, Zang et al. (2016) in blueberry, Baliah et al. (2018) in green gram, and Pandey et al. (2021) in wheat.

3.7. Root length (cm) and diameter (mm)

Data presented in Table 2 depicts that GA_3 @ 20 ppm resulted in maximum root length and diameter. These features are directly proportional to the yield as more the length of roots higher will the probability of enhanced yield. Higher plant height, number of leaves plant^{-1} and leaf area with the application of GA_3 led to enhanced photosynthetic activity within plant resulting in more production of carbohydrates and the other photosynthetic products. This increase in carbohydrates could have resulted in increased root length and diameter. The results are in tune with the findings of Sadana et al. (2015), Shweta et al. (2018) in radish who stated that increase in carbohydrates directly influenced root diameter and length. These results also corroborate with the findings of Singh and Rajodia (2001) in radish, Mondal and Shukla (2005) in onion and Baliah et al. (2018) in green gram.

3.8. Root weight (g)

The maximum weight of roots was recorded by GA_3 @ 20 ppm (Table 2). The data clearly depicted that there was huge variation in fresh weight of root due to application of plant growth regulators which significantly differ from control. The fresh weight of root was maximum in highest concentration of GA_3 this might be due to the reason that the three factors dry matter addition, cell division and expansion result in increased fresh weight of roots (Hopkins, 1999). These findings were supported by (Shweta et al., 2018); (Avinash et al., 2019) in radish. Islam et al. (2007); Yadagiri (2017); Sarkar et al. (2018) in onion, Kumar et al. (2018) in tomato and Kaur and Mal (2018) in cauliflower.

3.9. Effect of GA_3 on seed yield

Spraying GA_3 @ 20 ppm, resulted in significantly increased seed yield (Plant $plot^{-1}$ ha^{-1}) of radish as shown in Table 3. This might be due to the fact that GA_3 sprayed plants remained physiologically more active and built-up sufficient food reserves for developing seeds. Higher seed yield might be resulted due to the effect of auxin to cause physiological modifications in plants leads to synthesis and translocation of metabolites from source to the seeds which ultimately resulted in high siliqua and seed set. These findings are in tune with Malhotra and Chaudhry (2001), Hoque and Hoque (2002) in mungbean, Patil et al. (2008) in brinjal, Hilli et al. (2010) in ridge gourd, Singh et al. (2012) in coriander, Shahid et al. (2013) in okra and Shruthi et al. (2016) in radish.

3.10. Total soluble solid (TSS)

Maximum Total Soluble Solid was observed when GA_3 @ 20 ppm was sprayed on the plants (Table 3). Graham and Ballesteros (2006) reported that GA_3 increased proteins, soluble carbohydrates, ascorbic acid, starch and b carotene in tomato. Findings was supported by Saleh et al. (1989) in onion, Meena (2008); Saha et al. (2009); Verma et al. (2014); Pramanik et al. (2018) in tomato and Moniruzzaman et al. (2020) in broccoli.

3.11. Ascorbic acid (mg 100 g^{-1})

Table 3 showed that ascorbic acid content of radish was significantly increased with the application of GA_3. The augmentation of ascorbic acid content might be due to either increased ascorbic acid biosynthesis or to protection of synthesized ascorbic acid from oxidation through ascorbic acid oxidase. Glucose and fructose content seems to be enhanced. Findings was supported by Chaudhary et al. (2006) in chilli, Ouzounidou et al. (2010) in capsicum, Saha et al. (2009) and Pramanik et al. (2018) in tomato, Moniruzzaman et al. (2020) in broccoli and Godha et al. (2020) in wheat.

3.12. Chlorophyll content (mg 100 g^{-1})

Maximum chlorophyll content was found when GA_3 @ 20 ppm was applied to the plants (Table 3). This might be due to application of GA_3. Leafarea and number of leaves were increased resulting in more chlorophyll content and this resulting in increased photosynthetic activity ultimately leading to increased root diameter, length, weight and good yield. The results are in tune with the findings of Hilli et al. (2010) in ridgegourd, Singh et al. (2012) in corriander, Geeta et al. (2014) in bittergourd, Sadana et al. (2015) in radish and Baliah et al. 2018 in green gram.

3.13. Germination percentage (%)

The seed germination per cent varied significantly among different growth regulators. The results presented in Table 3 indicated that maximum seed germination percentage was observed when GA_3 @ 20 ppm was applied on the plants. This

Table 3: Influence of growth regulators on seed yield and quality parameters in radish

Treatments	seed yield $plot^{-1}$ (g)	seed yield ha^{-1} (q ha^{-1})	TSS (°B)	Ascorbic content (mg 100 g^{-1})	Chlorophyll content (mg 100 g^{-1})	Germination percentage (%)
Control	150.74	2.52	2.97	11.03	0.42	76.33
GA_3 @ 5 ppm	154.05	3.23	2.83	12.4	0.45	78
GA_3 @ 10 ppm	220.46	3.71	4.13	12.87	0.35	84
GA_3 @ 15 ppm	227.26	4.19	3.2	12.87	0.53	93.33
GA_3 @ 20 ppm	300.33	5.02	4.37	13.54	0.76	94
NAA @ 5 ppm	208.69	4.07	3.23	13.17	0.51	92.33
NAA @ 10 ppm	255.68	4.34	3.2	12.3	0.51	90
NAA @ 15 ppm	261.08	4.35	3.37	11.67	0.56	88
NAA @ 20 ppm	212.21	3.53	3.37	12.8	0.44	83.33
SEm±	0.2	0.20	0.15	0.52	0.03	0.74
CD (*p*=0.05)	0.62	0.62	0.45	0.37	0.08	1.12

might be due to the fact that gibberellins play a vital role in synthesis of hydrolytic enzymes especially, á – amylase, which in turn convert starch into sugar and is utilized by the growing embryo (Shruthi et al., 2016). The application of growth regulators might improve the metabolism and resulted in accumulation of photosynthates ultimately yielding seeds of large size with better germination. Similar result was obtained by Gedam et al. (1998) in bittergourd, Hoque and Hoque (2002) in mungbean, Priya et al. (2012) in chilli.

4. Conclusion

Among all the growth regulators, GA_3 @ 20 ppm accomplished best results which improves the growth in terms of number of leaves, leaf area, plant height, root length, root diameter, root weight, fresh weight of plant and dry weight. It is also revealed the highest seed yield, TSS, Ascorbic acid, Chlorophyll content and germination percentage was also observed by the application of GA_3 @ 20 ppm.

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