



Effect of GA₃ and Potassium on Growth and Yield in Red Radish (*Raphanus sativus* L.) under Subtropical Conditions of Jammu

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST Jammu during Rabi season of 2022-2023. The experiment was laid out under factorial RBD design with three replications comprising of sixteen treatments. The treatments consisted of four doses of Potassium i.e., 40, 50, 60 and 70 kg/ha and four concentrations viz. 0,100,200 and

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300 ppm of GA₃. The growth and yield parameters maximum viz. shoot length (34.15 cm), root length (18.73 cm), number of leaves/root (14.30), root weight (220.49 g), shoot weight (119.47 g), root-shoot ratio (2.04), fresh root shoot yield (112.42 q/ha) were recorded with 200 ppm GA₃ application. Similarly, highest shoot length (29.06 cm), root length (17.53 cm), number of leaves/root (11.18), root weight (171.67 g), shoot weight (104.84 g), root-shoot ratio (1.87), fresh root shoot yield (92.31 q/ha), were recorded with 50kg/ha K₂O application. However; highest root length (19.20 cm), number of leaves/root (14.87), root weight (226.14 g), shoot weight (123.54 g), root-shoot ratio (2.10), fresh root shoot yield (115.90 q/ha) were recorded with treatment combination G3K2 (200 ppm GA₃ + 50 K₂O/ha). Based on the investigation, it can be concluded that the application of 200 ppm GA₃ at 30 days after sowing with 50 kg potassium/ha resulted in the highest growth parameters and yield.

Keywords: Growth regulator; potassium; radish; root shoot ratio.

1. INTRODUCTION

Radish (*Raphanus sativus* L.) is one of the most significant winter vegetable crop grown in both tropical and temperate region. It is popular choice for cultivation as it is easy to grow, fits well in crop rotation, and is rapidly maturing cash and catch crop. It is highly cross-pollinated crop that belongs to the family Cruciferae and finds its origin in Europe and Asia. The most popular edible part of radish is the tuberous root, which is consumed either cooked or raw, and tops can be used as leafy vegetable. It helps in the treatment of gastrodynia, gall bladder issues, sleep disorders, persistent diarrhea, neuralgic headaches, and urinary symptoms [1]. It is good source of Vitamin C and minerals (i.e., calcium, potassium, and phosphorus) [2]. 100 g fresh edible portion of radish contains 0.7% protein, 3.4-6.8% carbohydrates and 0.2% fat and 50 I.U. of vitamin A. Its tender roots provide about 50 mg of calcium, 22 mg of phosphorus and 0.5 mg of iron per 100 g of edible portion.

In India, radish occupied an area of 209 thousand hectares with an annual production of 3347 thousand metric tonnes [3]. It is cultivated in almost all states of India. The major radish producing states include West Bengal, Haryana, Punjab, Bihar and Assam. In Jammu & Kashmir, it is grown over an area of 3.20 thousand hectares with an annual production of 116.07 thousand metric tonnes [3].

In the recent past, due to significant increase in area under radish crop, the demand for quality seed has increased manifold. State Government and Government of India have laid out a lot of emphasis to improve availability of quality seed, which has not only increased production and productivity of this crop, however, it also provided new opportunities for export of quality seed. The nation's total production of vegetable seeds is

insufficient to fulfil the nation's rising demand. Currently, the demand for quality seeds is met to the extent of 20% only. Farmers themselves meet 75% seed demand through own saved seeds [4]. India continues to import vegetable seeds from foreign nations, the two main ones being cabbage and pea.

The physiological efficiency of plants, particularly photosynthetic capacity and efficient assimilate partitioning, can be improved by plant growth regulators [5]. By promoting the transfer of photo assimilates, vegetable crop productivity can be raised. In particular, it has been noted that GA₃ has amazing effects on promoting blooming and raising seed production in vegetable crops. Gibberellins are crucial for many aspects of plant growth and development, including seed germination. Gibberellic acid stimulates the cells of growing seeds to produce mRNA molecules, which controls the activity of hydrolytic enzymes. The use of GA₃ controls a number of physiological processes and causes metabolic changes that have an impact on the quantity and quality of the intended product. An increase in seed quality parameters due to greater accumulation of food reserves by the application of GA₃ has been reported [6]. The use of potassium fertilizer is an effective way to increase radish productivity. Potassium regulates the opening and closing of stomata. It activates enzymes that are required for generation of ATP. Starch and protein synthesis are facilitated by potassium in plants. It is also required for transport of sugar to the storage organs [7]. That the growth and yield of red radish can successfully be produced under Jammu conditions however, the quantity of the growth and yield is less. Therefore, to increase the quantity and quality of growth and yield through application of growth regulators and nutrients, the present study has been designed.

2. MATERIALS AND METHODS

The present investigation was carried out on Effect of GA₃ and Potassium on the growth and yield in Red Radish (*Raphanus sativus* L.) under subtropical conditions of Jammu was carried out at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST Jammu during Rabi season of 2022-2023. The investigation was conducted at Chatha which is located at an elevation of 332 m above mean sea level having geographical bearing of 32.3° North latitude and 74.53° East longitude. The experiment was laid out under factorial RBD design with three replications comprising of sixteen treatments. The treatments consisted of four doses of Potassium i.e., 40, 50, 60 and 70 kg/ha and four concentrations viz. 0, 100, 200 and 300 ppm of GA₃ are shown in Chart 1.

Chart 1. Details of treatment

GA₃ application (04)	Potassium doses (04)
G ₁ : 0 ppm	K ₁ : 40 kg/ha
G ₂ : 100 ppm	K ₂ : 50 kg/ha
G ₃ : 200 ppm	K ₃ : 60 kg/ha
G ₄ : 300 ppm	K ₄ : 70 kg/ha

The detail of various cultural operations carried out during the crop growing have been given below:

2.1 Land Preparation for Mother Block

The field was ploughed twice followed by planking to attain good tilth. Field layout and preparation of ridges was done manually with the help of rope and spade. Well rotten FYM @ 20 tonnes per hectare was applied in the field before sowing. Recommended dose of N, P @ 60, 30 kg per hectare and four dose of K treatment @ 40, 50, 60, 70 kg per hectare was applied as a basal dose at the time of sowing. The seeds were sown on ridges by dibbling methods in 5 November 2022. The GA₃ were sprayed at 30 Days after sowing in mother block. Proper aftercare operations in respect of irrigation, plant protection was undertaken till the roots were ready for the transplanting.

2.2 Preparation of Spray Solution

GA₃ stock solutions of 100 ppm was prepared by dissolving 1 g of pure GA₃ in small quantity of alcohol and then making the final volume up to 1 liter by adding distilled water.

The solutions were prepared fresh at the time of each spray and dilutions of required concentrations were made using stock solution. The GA₃ sprayed at 30 Days after sowing. The growth and yield parameters viz. shoot length, root length, number of leaves/root, root weight, shoot weight, root- shoot ratio, fresh root shoot yield.

2.3 Statistical Analysis

The data recorded on various parameters of the present study after proper tabulation were put to statistical analysis as per the randomized complete block method prescribed by (Panse and Sukhatme, [8] to draw the inferences of the study. The significance of treatment effects was tested through variance ratio and the significance of difference between any two means was judged with the critical difference (C.D) at 5 per cent level of significance was worked out. Data for the parameters were put to statistical analysis by using OPSTAT software developed by O.P. Sheoran *et al.* (1998) of CCS HAU, Hissar.

3. RESULTS

3.1 Shoot Length (cm)

It was evident from Table 1 that the Growth regulators (GA₃) and potassium have significantly influenced the shoot length. Maximum shoot length 34.15 cm was in G₃ which was at par with G₄. Lowest shoot length 18.73 cm was recorded in G₁ which was significantly lower than all of the treatments. Similarly, The Potassium levels had significant effect on shoot length. Maximum shoot length was obtained K₂ 29.06 cm which had at par results with K₃ and K₄ and Minimum shoot length was recorded in K₁ 26.70 cm was recorded in K₁ which was significantly lower than all of the treatments.

However, the interaction between GA₃ and Potassium with respect to shoot length was found to be non- significant.

3.2 Root Length (cm)

It was evident from Table 2 that the Growth regulators (GA₃) and potassium have significantly influenced the root length of red radish. Maximum root length (18.73 cm) was obtained in G₃ which exhibited at par results with G₄. Lowest root length 14.78 cm was recorded in G₁ which was significantly lower than all of the treatments. Similarly, The Potassium levels had significant effect on root length. Maximum root

length was obtained K₂ dose (40kg/ha) 17.53 cm which had at par results with K₃ and K₄ Minimum root length was recorded in K₁ 16.38 cm was recorded in K₁ which was significantly lower that all of the treatments.

Interaction studies depicts that a combination of G₃K₂ maximum root length (19.20 cm) which was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃ and G₄K₄. Lowest root length was recorded in a treatment combination of G₁K₁ (13.19cm) which was significantly lower that all of the treatment combinations.

3.3 Number of leaves per root

It was evident from Table 3 that the number of leaves per root of red radish was significantly influenced by the Growth regulators (GA₃) and potassium. G₃ had the maximum number of leaves per root 14.30, which was at par with G₄. The Lowest number of leaves per root 6.07, was recorded in G₁, which was significantly lower than all of the treatments. Similarly, the number of leaves per root was significantly affected by the Potassium levels. K₂ had the Maximum number of leaves per root 11.18, which had at par results with K₃ and K₄. The Minimum number of leaves per root 10.41, was recorded in K₁,

which was significantly lower than all of the treatments.

The interaction studies depicted that the treatment combination of G₃K₂ had the maximum number of leaves per root 14.87 cm, which was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃, and G₄K₄. The lowest number of leaves per root was recorded in the treatment combination of G₁K₁ 5.30 cm, which was significantly lower than all of the treatment combinations.

3.4 Root Weight (g)

It was evident from Table 4 that the Growth regulators (GA₃) and potassium have significantly influenced the root weight of red radish. Maximum root weight (220.49 g) was in G₃ which was at par with G₄. Lowest root weight (112.33 g) was recorded in G₁ which was significantly lower than all of the treatments. Similarly, The Potassium levels had significant effect on root weight. Maximum root weight was obtained K₂ (171.67g) which had at par results with K₃ and K₄ and Minimum root weight was recorded in K₁ (164.55g) was recorded in K₁ which was significantly lower than all of the treatments.

Table 1. Effect of GA₃ and potassium on shoot length (cm) in red radish (SJRR-01)

Treatments	Shoot length (cm)				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	17.54	18.66	18.29	20.41	18.73
G ₂	25.14	26.66	26.62	26.71	26.28
G ₃	31.92	34.92	34.84	34.93	34.15
G ₄	32.18	35.98	34.26	33.99	34.10
Mean	26.70	29.06	28.50	29.01	
	SEm±			CD (0.05)	
G	0.62			1.79	
K	0.62			1.79	
(G×K)	1.24			NS	

Table 2. Effect of GA₃ and potassium on Root length (cm) in red radish (SJRR-01)

Treatments	Root length (cm)				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	13.19	15.31	15.33	15.30	14.78
G ₂	16.10	17.17	17.10	17.07	16.86
G ₃	18.23	19.20	18.80	18.70	18.73
G ₄	18.00	18.43	18.67	18.93	18.51
Mean	16.38	17.53	17.48	17.50	
	SEm±			CD (0.05)	
G	0.13			0.37	
K	0.13			0.37	
(G×K)	0.26			0.74	

G₁-0 ppm, G₂-100 ppm, G₃- 200 ppm, G₄-300 ppm, K₁-40 kg/ha, K₂-50 kg/ha, K₃-60 kg/ha, K₄-70 kg/ha

Table 3. Effect of GA₃ and potassium on Number of leaves per root in red radish (SJRR-01)

Treatments	Number of leaves per root				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	5.30	6.20	6.00	6.77	6.07
G ₂	8.82	9.47	9.20	9.23	9.18
G ₃	13.77	14.87	14.30	14.27	14.30
G ₄	13.77	14.20	14.83	14.27	14.27
Mean	10.41	11.18	11.08	11.13	
	SEm±			CD (0.05)	
G	0.11			0.31	
K	0.11			0.31	
(G×K)	0.21			0.62	

G₁-0 ppm, G₂-100 ppm, G₃- 200 ppm, G₄-300 ppm, K₁-40 kg/ha, K₂-50 kg/ha, K₃-60 kg/ha, K₄-70 kg/ha

Interaction studies depicts that a combination of G₃K₂ maximum root weight (226.14 g) which was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃ and G₄K₄. Lowest root weight and shoot weight was recorded in a treatment combination of G₁K₁ (111.17g) which was significantly lower than all of the treatment combinations.

3.5 Shoot Weight (g)

It was evident from Table 5 that the Growth regulators (GA₃) and potassium have significantly influenced the shoot weight of red radish. Maximum shoot weight (119.47 g) was obtained in G₃ which exhibited at par results with G₄. Lowest shoot weight (78.20 g) was recorded in G₁ which was significantly lower than all of the treatments. Similarly, The Potassium levels had significant effect on shoot weight. Maximum shoot weight was obtained K₂ dose (104.84g) which had at par results with K₃ and K₄. Minimum shoot weight was recorded in K₁ (99.36g) was recorded in K₁ which was significantly lower than all of the treatments.

Interaction studies depicts that a combination of G₃K₂ maximum shoot weight (123.54g) which was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃ and G₄K₄. Lowest shoot weight was recorded in a treatment combination of G₁K₁ (75.90 g) which was significantly lower than all of the treatment combinations.

3.6 Root-Shoot Ratio

The root shoot ratio of red radish was significantly influenced by the Growth regulators (GA₃) and potassium as evident from Table 6. The maximum root shoot ratio of 2.04 was observed in G₃, which was at par with G₄. The lowest root shoot ratio of 1.38 was recorded in G₁, which was significantly lower than all of the

treatments. Similarly, the root shoot ratio was significantly affected by the Potassium levels. The maximum root shoot ratio of 1.87 was obtained in K₂, which had at par results with K₃ and K₄. The minimum root shoot ratio of 1.75 was recorded in K₁, which was significantly lower than all of the treatments.

It was observed from the interaction studies that the treatment combination of G₃K₂ (2.10) was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃, and G₄K₄. The lowest root shoot ratio of 1.28 was recorded in the treatment combination of G₁K₁, which was significantly lower than all of the treatment combinations.

3.7 Fresh Root Shoot Yield (q/ha)

It was evident from Table 7 that the Growth regulators (GA₃) and potassium have significantly influenced the fresh root shoot yield of red radish. Maximum fresh root shoot yield 98.75 q/ha was in G₃ which was at par with G₄. Lowest fresh root shoot yield 72.96 q/ha was recorded in G₁ which was significantly lower than all of the treatments. Similarly, The Potassium levels had significant effect on fresh root shoot yield. Maximum fresh root shoot yield was obtained K₂ 92.06 q/ha which had at par results with K₃ and K₄ and Minimum fresh root shoot yield was recorded in K₁ 84.69 q/ha was recorded in K₁ which was significantly lower than all of the treatments.

Interaction studies depicts that a combination of G₃K₂ (103.58 q/ha) fresh root shoot yield which was at par with the treatment combinations of G₃K₃, G₃K₄, G₄K₃, and G₄K₄. Lowest fresh root shoot yield was recorded in a treatment combination of G₁K₁ (71.83 q/ha) which was significantly lower than all of the treatment combinations.

Table 4. Effect of GA₃ and potassium on Root weight (g) in red radish (SJRR-01)

Treatments	Root weight (g)				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	111.17	113.67	113.12	111.34	112.33
G ₂	124.67	127.75	126.44	126.66	126.38
G ₃	204.84	226.14	225.74	225.22	220.49
G ₄	217.52	219.10	219.68	219.50	218.95
Mean	164.55	171.67	171.24	170.68	
	SEm±			CD (0.05)	
G	1.16			3.36	
K	1.16			3.36	
(G×K)	2.33			6.72	

Table 5. Effect of GA₃ and potassium on Shoot weight (g) in red radish (SJRR-01)

Treatments	Shoot weight (g)				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	75.90	79.81	78.43	78.65	78.20
G ₂	92.88	96.96	95.45	94.52	94.95
G ₃	110.90	123.54	121.03	122.39	119.47
G ₄	117.78	119.04	120.54	119.81	119.29
Mean	99.36	104.84	103.86	103.84	
	SEm±			CD (0.05)	
G	0.74			2.13	
K	0.74			2.13	
(G×K)	1.48			4.27	

G₁-0 ppm, G₂-100 ppm, G₃- 200 ppm, G₄-300 ppm, K₁-40 kg/ha, K₂-50 kg/ha, K₃-60 kg/ha, K₄-70 kg/ha

Table 6. Effect of GA₃ and potassium on Root-Shoot ratio (weight bases) in red radish (SJRR01)

Treatments	Root-shoot ratio				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	1.28	1.40	1.42	1.43	1.38
G ₂	1.76	1.98	1.84	1.91	1.87
G ₃	1.96	2.10	2.05	2.05	2.04
G ₄	1.99	2.00	2.09	2.02	2.02
Mean	1.75	1.87	1.85	1.85	
	SEm±			CD (0.05)	
G	0.01			0.04	
K	0.01			0.04	
(G×K)	0.03			0.09	

Table 7. Effect of GA₃ and potassium on Fresh root shoot yield (q/ha) in red radish (SJRR01)

Treatments	Fresh root shoot yield (q/ha)				Mean
	K ₁	K ₂	K ₃	K ₄	
G ₁	71.83	75.26	72.50	72.27	72.96
G ₂	84.95	93.38	92.20	91.96	90.62
G ₃	87.03	103.58	102.19	102.19	98.75
G ₄	94.95	96.01	100.20	100.29	97.86
Mean	84.69	92.06	91.77	91.68	
	SEm±			CD (0.05)	
G	1.15			3.31	
K	1.15			3.31	
(G×K)	2.29			6.62	

G₁-0 ppm, G₂-100 ppm, G₃- 200 ppm, G₄-300 ppm, K₁-40 kg/ha, K₂-50 kg/ha, K₃-60 kg/ha, K₄-70 kg/ha

4. DISCUSSION

It was observed that GA₃ and potassium had a significant effect on the growth traits of red radish. When 200 ppm GA₃ was sprayed and 50 kg potassium per hectare was applied, the shoot length was recorded as 34.15 cm and 29.06 cm, respectively. However, the interaction studies 200 ppm GA₃ + 50 kg potassium per hectare did not show a significant effect on shoot length. Similarly, the root length was significantly affected by both GA₃ and potassium. The maximum root length recorded was 18.73 cm and 17.53 cm when 200 ppm GA₃ and 50 kg potassium per hectare were applied, respectively. The interaction had a statistically significant effect, resulting in a root length of 19.20 cm when the combination of 200 ppm GA₃ and 50 kg potassium per hectare was applied. The number of leaves per root was significantly influenced by both GA₃ and potassium. The highest number of leaves per root (14.30 and 11.18) was recorded when 200 ppm GA₃ and 50 kg potassium per hectare were applied, respectively. The interaction also had a significant effect on the number of leaves per root, with a recording of 14.87 when the treatment combination of 200 ppm GA₃ and 50 kg potassium per hectare was applied.

The increase in shoot length, root length, and number of leaves per root observed in response to GA₃ application may be attributed to the stimulation of cell division, cell size, and metabolic activities in the plant. The enhanced growth observed at optimum levels could be attributed to the pivotal role of potassium in activating enzymes, regulating stomata, and facilitating photosynthesis. These findings are supported by similar results reported by Sharma [9] Mehta & Patnayak [10] Jatav *et al.* [11] Abou EL-Nasr (2008), Kiran [12] and Shweta *et al.* [13].

The root and shoot yield traits of red radish were significantly influenced by GA₃ and potassium. The maximum root weight (220.49 g), shoot weight (119.47 g), root-shoot ratio (2.09), and fresh root-shoot yield (98.75 q/ha) were recorded when 200 ppm GA₃ was sprayed. Similarly, the maximum root weight (171.67 g), shoot weight (109.89 g), root-shoot ratio (1.87), and fresh root-shoot yield (92.06 q/ha) were recorded when 50 kg potassium per hectare was applied. The interaction effect between GA₃ and potassium was found to be significant for all yield traits. The maximum root weight (226.14 g), shoot weight

(123.54 g), root-shoot ratio (2.10), and fresh root-shoot yield (103.58 q/ha) were recorded when the treatment combination of 200 ppm GA₃ and 50 kg potassium per hectare was applied.

The enhancement in yield attributes, such as root weight, shoot weight, root-shoot ratio, and fresh root-shoot yield, can be attributed to the stimulation of cell division, cell size, and expansion resulting from the application of GA₃. Similarly, increased yield attributes observed with an optimum level of potassium can be attributed to its role in carbohydrate synthesis and translocation, cell extension, and improved fertilizer use efficiency. These findings align with the results reported by Sharma *et al.* [9] Anjaiah & Padmaja [14] Patel [15] Bawkar *et al.* [16] Khan *et al.* [17] Shweta *et al.* [13] Nagaich and Mishra [18].

5. CONCLUSIONS

Based on the investigation, it can be concluded that the application of 200 ppm GA₃ at 30 days after sowing with 50 kg potassium/ha resulted in the highest growth parameters and yield. This treatment combination significantly improved the highest growth parameters and yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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