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Synergistic influence of GA_3 and potassium on yield and quality of radish seed production

Ganesh Ram[1], Sandeep Chopra[1], Shivanjali Sarswat[1], Arjun Lal Ola[2] and Vinod Prajapat[3]
[1]Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, 180009, India

ABSTRACT

The experiment was laid out under a factorial RBD design, with three replications comprising 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 GA_3. The data analysis revealed that the minimum days to seed harvest (111.79 days), number of seeds/siliqua (6.25), length of siliqua (5.90cm), 1000-seed weight (9.55 g), seed yield/plant (18.09 g), seed yield/ha (2.19 q), germination percentage (93.13%) and seed vigour index (249.06) were recorded with 200 ppm GA_3 application. Similarly, minimum days to seed harvest (118.66 days), number of seeds/siliqua (5.55), length of siliqua (5.13 cm), 1000 seed weight (9.12 g), seed yield/plant (15.16 g), seed yield/ha (1.88 q), germination (86%) and seed vigour index (200.12) were recorded with 50kg/ha K_2O application. The combination of 200 ppm GA_3 along with 50 K_2O/ha proved to be the most superior treatment combination for minimum days to seed harvest (109.35 days), number of seeds/siliqua (6.33), length of siliqua (6.03 cm), 1000-seed weight (9.80 g), seed yield/plant (18.50 g), seed yield/ha (2.26 q), germination (95%) and seed vigour index (255.33).

Key words: Seed weight, growth regulator, root:shoot ratio, germination, seed vigour index.

INTRODUCTION

Radish (*Raphanus sativus* L.) is an extensively cultivated winter vegetable crop widely grown in both tropical and temperate climates. It fits nicely with crop rotations, and is easy to grow, and matures rapidly. The most widely used portion is the tuberous root, which can be eaten raw or cooked. Radish is the most frequently consumed root vegetable in different parts of India because its roots and leaves are rich sources of carbohydrate, vitamin A, vitamin C, and minerals. The characteristic pungent flavour of radishes is due to the presence of volatile isothiocyanate (trans-4-methylthiobrate). Radish is best adapted to a cool or moderate climate. Radish is useful in liver and gall bladder troubles. In homoeopathy, they are used for neurologic headaches and sleeplessness. Roots and leaves are active against gram-positive bacteria. The roots are useful in urinary complaints, piles and in gastrodynia. The juice of fresh leaves is used as diuretic and laxative. Pink -skinned radish is generally richer in ascorbic acid than the white-skinned ones (Ola *et al.,* 15). In India, the annual production is 3,347 thousand metric tonnes across 209 thousand hectares (NHB, 13). The need for high-quality seed has grown significantly in recent years because of the significant expansion in the area under radish crop. The Indian government and state governments have placed a strong focus on expanding the supply of high-quality seed, which has raised agricultural productivity and output and opened up new markets for the export of high-quality seed. To meet the country's growing demand, the nation's overall supply of vegetable seeds is insufficient. Currently, only 20% of the current demand for high-quality seeds is satisfied. 75% of the seed demand is satisfied by farmers using their own stored seeds (Poonia, 17). Vegetable seed production is a very profitable industry. It is a labor-intensive process, the cultivation of vegetable seeds employs one million people on average (Sharma, 18).

Plant growth regulators can enhance the physiological efficiency of plants, namely their photosynthetic capacity and effective assimilate partitioning (Solaimalai *et al.,* 19). It has been shown that GA_3 significantly increases the amount of seeds produced by vegetable crops. Gibberellins are essential to various aspects of plant development and growth, including the germination of seeds. Gibberellic acid regulates the activity of hydrolytic enzymes by stimulating the production of mRNA molecules in the cells of developing seeds. The amount and quality of the targeted product are affected by metabolic changes and other physiological processes that are regulated when GA_3 is used. There has been a report of an increase in seed quality metrics as a result of using GA_3 to improve the amount of food reserves (Ghanome *et al.*, 5). Potash plays a major role in

*Corresponding authors email: grchoudhary9116@gmail.com
[2]Department of Vegetable Science, Rani Lakshmi Bai Central Agricultural University, Jhansi (U.P.)
[3]Rajasthan Agriculture Research Institute, Durgapura, Jaipur, Rajasthan

enhancing seed structure, quality, and production. Potassium regulates the stomata's opening and closing in the plant. It is also essential for the delivery of sugar to the storage organs (Ghanome *et al*., 4). Potash applied at a rate of 80 to 100 kg per hectare improved the qualitative attributes of carrot seeds, such as the ultimate germination percentage (17% and 15%) and the vigour index of the seeds (49% and 42%, respectively, from main and secondary umbels (Noor *et al.,* 14). Similarly, in radishes, the best application of potassium fertiliser promoted healthy seed growth, increased seed weight, and nutrient build-up, all of which contributed to sufficient food reserves during seed germination (Bilekudari *et al*., 1).

Previous investigations carried out in the Jammu Division suggest that red radish can be grown in Jammu circumstances with success, though the amount of seed produced is not very substantial. Thus, the goal of the current study is to apply growth regulators and nutrients to enhance the amount and quality of seed.

MATERIALS AND METHODS

The present investigation was carried out at the Vegetable Experimental Farm –II of the Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha at an elevation of 332 m above mean sea level having geographical bearing of 32.3'' North latitude and 74.53'' East longitude during the *Rabi* seasons of 2022-2023. The 52-day-old Steckling's of SJRR-01 variety were used as plant materials. Treatment details are mentioned below in Table 1. The treatment effects were evaluated for different yield and quality traits in a Factorial Randomized Block Design (FRBD) with three replications in radish. All the recommended packages of practices and need-based plant protection measures were adopted for the Jammu region. The data were recorded from five randomly selected plants in each plot for the following parameters: days to seed harvest, number of seeds per siliqua, length of siliqua (cm), 1000 seed weight (g), seed yield per plant (g), seed yield per ha (q/ha), germination percentage (*in vitro*), and seed vigour index (*in vitro*). The data obtained were subjected to variance analysis as per the methods of Panse and Sukhamate (16).

GA_3 stock solutions of 100 ppm were prepared by dissolving 1 g of pure GA_3 in a small quantity of alcohol and then making the final volume up to 1 litre by adding distilled water. The solutions were prepared fresh at the time of each spray, the dilutions of required concentrations were made using stock solution. The GA was sprayed 30 days after sowing and 15 days after transplanting of steckling, at the time of siliqua formation, while K_2O was applied to soil at the time of field preparation.

Table 1: Treatments and their combination detail.

S. No.	Dose	Symbol
	Gibberellic acid (GA_3)	
1	0 ppm	G_1
2	100 ppm	G_2
3	200 ppm	G_3
4	300 ppm	G_4
	Potassium level	
1	40 kg/ha	K_1
2	50kg/ha	K_2
3	60kg/ha	K_3
4	70kg/ha	K_4
	Gibberellic acid × Potassium level	
	0 ppm + 40 kg K_2O	G_1 K_1
	0 ppm + 50 kg K_2O	G_1 K_2
	0 ppm + 60 kg K_2O	G_1 K_3
	0 ppm + 70 kg K_2O	G_1 K_4
	100 ppm + 40 kg K_2O	G_2 K_1
	100 ppm + 50 kg K_2O	G_2 K_2
	100 ppm + 60 kg K_2O	G_2 K_3
	100 ppm + 70 kg K_2O	G_2 K_4
	200 ppm + 40 kg K_2O	G_3 K_1
	200 ppm + 50 kg K_2O	G_3 K_2
	200 ppm + 60 kg K_2O	G_3 K_3
	200 ppm + 70 kg K_2O	G_3 K_4
	300 ppm + 40 kg K_2O	G_4 K_1
	300 ppm + 50 kg K_2O	G_4 K_2
	300 ppm + 60 kg K_2O	G_4 K_3
	300 ppm + 70 kg K_2O	G_4 K_4

RESULTS AND DISCUSSION

The results in Tables 2 and 3 indicated significant variation for all the yield and quality parameters among different treatment combinations of potassium and growth regulators screened in the Jammu region. The data analysis revealed that potassium and growth regulators (GA_3) had a significant impact on the yield parameters of red radish. Treatment GA_3 (Gibberellic Acid 200 ppm) achieved the minimum days to seed harvest of 111.79 days, exhibiting results comparable to those of GA_3 300 ppm (Table 2). The maximum number of days required for seed harvesting (133.29 days) was noted for G_1, which was notably less than for

Table 2: Effect of GA_3 and potassium yield parameter of red radish.

Treatment	Days to seed harvest	Number of seed per siliqua	Length of siliqua (cm)	1000 seed weight (g)	Seed yield per plant (g)	Seed yield per hectare (q/ha)
Gibberellic acid (GA_3)						
G_1	131.83	4.29	3.68	7.78	10.05	1.33
G_2	122.80	5.22	4.82	9.32	13.91	1.69
G_3	111.79	6.25	5.90	9.55	18.09	2.19
G_4	112.88	6.17	5.83	9.44	17.86	2.18
S.Em ±	0.47	0.04	0.04	0.04	0.11	0.01
CD (P=0.05)	1.36	0.11	0.10	0.12	0.32	0.04
Potassium level						
K_1	121.32	5.28	4.89	8.83	14.52	1.78
K_2	118.66	5.55	5.13	9.12	15.16	1.88
K_3	119.35	5.54	5.11	9.04	15.09	1.86
K_4	119.97	5.54	5.11	9.10	15.14	1.87
S.Em ±	0.47	0.04	0.04	0.04	0.11	0.01
CD (P=0.05)	1.36	0.11	0.10	0.12	0.32	0.04
Gibberellic acid × Potassium level						
G_1 K_1	133.29	3.97	3.35	7.53	9.63	1.24
G_1 K_2	130.63	4.47	3.80	7.83	9.97	1.40
G_1 K_3	131.73	4.47	3.78	7.73	9.90	1.30
G_1 K_4	131.67	4.27	3.80	8.00	10.70	1.37
G_2 K_1	124.46	5.00	4.77	9.23	13.10	1.60
G_2 K_2	122.13	5.30	4.87	9.47	14.40	1.73
G_2 K_3	122.37	5.17	4.83	9.30	14.10	1.70
G_2 K_4	122.25	5.40	4.80	9.27	14.03	1.73
G_3 K_1	114.74	6.07	5.67	9.27	17.67	2.11
G_3 K_2	109.37	6.33	6.03	9.80	18.50	2.26
G_3 K_3	111.64	6.30	5.93	9.57	18.33	2.21
G_3 K_4	111.40	6.30	5.97	9.57	17.87	2.20
G_4 K_1	115.60	6.10	5.80	9.27	17.67	2.17
G_4 K_2	112.77	6.10	5.80	9.37	17.77	2.14
G_4 K_3	111.67	6.27	5.87	9.57	18.03	2.21
G_4 K_4	111.48	6.20	5.87	9.57	17.97	2.20
S.Em ±	0.94	0.07	0.07	0.08	0.22	0.03
CD (P=0.05)	2.71	0.22	0.22	0.24	0.64	0.08

any other treatment. In a similar, the days to seed harvest were significantly impacted by the potassium levels. K_2O (50 kg/ha potassium) took the minimum days to harvest seeds (118.66 days), with results comparable to those of K_3 and K_4. The maximum number of days required for seed harvesting (121.32 days) was noted in the treatment K_1, which was much longer than the duration of all other treatments.

Interaction studies depict that the combined application of 200 ppm GA_3 along with 50 kg/ha potassium (G_3K_2) recorded the minimum days to seed harvest (109.37 days), which was at par with the treatment combinations of G_3K_3, G_3K_4, G_4K_3 and GK. Maximum days to seed harvest (133.29) were recorded in a treatment combination of 0 ppm GA_3 along with 40 kg/ha potassium. The increase in yield

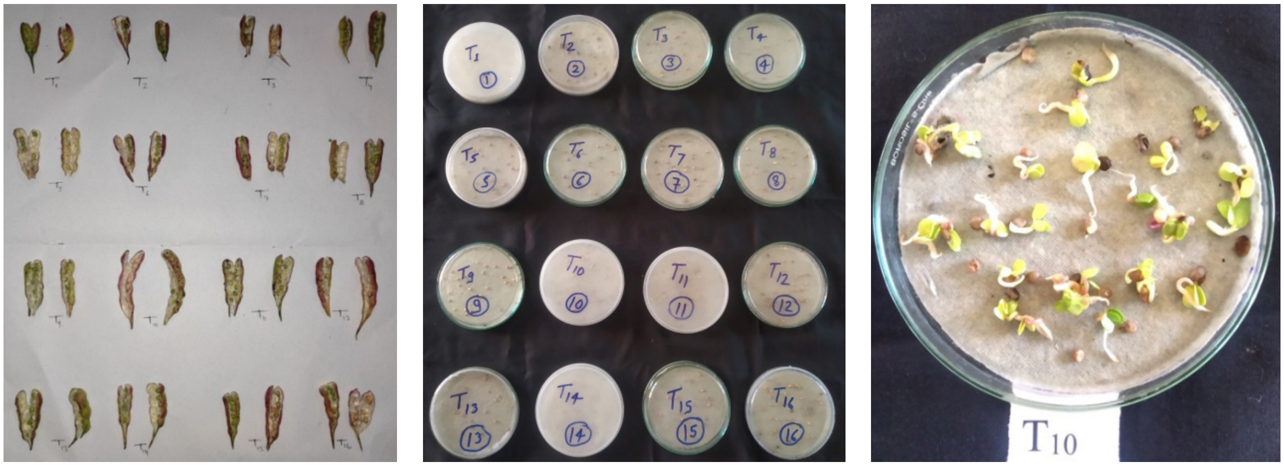
Table 3: Effect of GA_3 and potassium level on seed germination and seed vigour index in red radish.

Treatment	Germination percentage	Seed vigour index
Gibberellic acid (GA_3)		
G_1	72.02	92.74
G_2	83.54	198.58
G_3	93.13	249.06
G_4	91.79	246.77
S.Em ±	0.53	1.01
CD (P=0.05)	1.53	2.91
Potassium level		
K_1	83.04	188.99
K_2	86.00	200.12
K_3	85.75	199.30
K_4	85.69	198.73
S.Em ±	0.53	1.01
CD (P=0.05)	1.53	2.91
Gibberellic acid × Potassium level		
$G_1 K_1$	69.00	92.83
$G_1 K_2$	71.67	93.73
$G_1 K_3$	71.67	92.03
$G_1 K_4$	75.75	92.37
$G_2 K_1$	82.50	190.00
$G_2 K_2$	86.67	202.20
$G_2 K_3$	83.33	200.63
$G_2 K_4$	81.67	201.47
$G_3 K_1$	90.67	236.07
$G_3 K_2$	95.00	255.33
$G_3 K_3$	94.00	254.13
$G_3 K_4$	92.83	250.70
$G_4 K_1$	90.00	237.07
$G_4 K_2$	90.67	249.20
$G_4 K_3$	94.00	250.40
$G_4 K_4$	92.50	250.40
S.Em ±	1.06	2.02
CD (P=0.05)	3.06	5.83

parameters might be due to the application of 200 ppm GA_3 along with 50 kg/ha potassium, which might have regulated cell elongation, tissue swelling, cell division, and differentiation in certain plant tissues and participated in many developmental processes like senescence, photosynthesis, flower formation, and photosynthate partitioning. Similarly, early flowering and seed harvest are due to potassium application because it plays a crucial role in various physiological processes, including flowering. Adequate potassium levels promote early flowering and seed harvest. Similar findings were also confirmed by reports (Shruthi *et al.*, 4; Bilekudari *et al.*, 1; Waghmode *et al.*, 20; Mishra and Nagaich, 12; Chetri *et al.*, 3).

The number of seeds per siliqua of red radish was significantly affected by potassium and growth regulators (GA_3), as shown in table 2. The maximum number of seeds per siliqua (6.25), length of siliqua (5.90 cm) and 1000 seed weight (9.55 g) were obtained in the application of 200 ppm GA_3, which exhibited at -par results with 300 ppm gibberellic acid. GA_3 0 ppm had the lowest number of seeds per siliqua (4.29), length of siliqua (3.68 cm) and 1000 seed weight (7.78 g), which was significantly lower than in every other treatment. Similarly, the number of seeds per siliqua was significantly affected by potassium levels. The application of 50 kg/ha potassium produced the maximum number of seeds per siliqua (5.55), length of siliqua (5.13 cm) and 1000 seed weight (9.12 g), which was statistically at par with K_3 and K_4. The minimum number of seeds per siliqua (5.28), length of siliqua (4.89 cm) and 1000 seed weight (8.83 g) were noticed in the K_1 (40 kg/ha potassium) treatment, which was significantly lower than all of the treatments.

Interaction studies depict that the maximum number of seeds per siliqua (6.33), length of siliqua (6.03 cm) and 1000 seed weight (9.80 g) were recorded in the treatment combination of 200 ppm gibberellic acid along with 50 kg/ha potassium, which was at par with the treatment combinations of G_3K_3, G_3K_4, G_4K_3 and G_4K_4. The lowest number of seeds per siliqua (3.97), length of siliqua (3.35 cm) and 1000 seed weight (7.53 g) were noticed in a treatment combination of 0 ppm GA_3 along with 40 kg/ha potassium, which was significantly lower than all of the treatment combinations. The possible interpretation of these results could be attributed to the stimulating effect of GA_3 on the complete growth of the plant, which resulted in the formation of larger quantities of synthesized products, allowing assimilates to be distributed to the pods. Potassium is important for seed development and helps ensure proper cell expansion and division during seed formation. The results were consistent with the findings of Krishnkant *et al.* (9); Marie *et al.* (11); Bilekudari *et al.* (1); Khan *et al.* (8). This could be because GA made the cell wall more permeable, which let more water and dissolved substances into the cell. This, in turn, led to an increase in the seed's weight, as demonstrated by the 1000-seed weight. Additionally, potassium promotes cell division and enlargement, leading to larger and



(a) Pod of different treatments (b) Seeds under different treatments (c) Seed germination

Fig. 1. Effect of different treatments on pod characteristics, seed quality, and germination in radish.

heavier seeds. It also enhances the transport and accumulation of carbohydrates in developing seeds, which contributes to the 1000-seed weight Haque *et al*. (6); Noor *et al*. (14) and Singh (7) also observed similar results with the use of GA_3 and potassium. The results indicated that varying levels of GA_3 and potassium significantly influenced radish seed yield (Table 2). The highest seed yield (18.09 g/plant; 2.19 q/ha) was recorded with GA_3 @ 200 ppm (G_3), which was at par with G_4, while the lowest yield (10.05 g/plant; 1.33 q/ha) was observed in G_1. Similarly, potassium application had a significant effect, with the highest yield obtained at K_2 (15.16 g/plant; 1.88 q/ha), comparable to K_3 and K_4, whereas K_1 recorded the lowest yield. Interaction effects revealed that GA_3 200 ppm combined with 50 kg K/ha (G_3K_2) produced the maximum seed yield (18.50 g/plant; 2.26 q/ha), which was at par with G_3K_3, G_3K_4, G_4K_3, and G_4K_4. The lowest yield was recorded in G_1K_1 (9.63 g/plant; 1.24 q/ha). The enhanced yield may be attributed to GA_3-induced stimulation of photosynthesis, assimilate accumulation, and nucleic acid synthesis, along with potassium-mediated enzyme activation, improved reproductive processes, and efficient seed set. These findings are in agreement with Waghmode *et al.* (20) and Noor *et al*. (14).

The germination percentage and seed vigour index of red radish were significantly influenced by potassium and GA_3 (Table 3). The highest germination (93.13%) and seed vigour index (249.06) were recorded under G_3 (GA_3 @ 200 ppm), which was at par with G_4, while the lowest values (72.02% and 92.76) were observed in G_1 (Fig. 1). Similarly, potassium levels significantly affected germination, with K_2 recording the highest germination (86%) and vigour index (200.12), comparable to K_3 and K_4, whereas K_1 showed the lowest values. Interaction effects revealed that GA_3 @ 200 ppm combined with 50 kg K/ha (G_3K_2) resulted in the highest germination (95%) and seed vigour index (255.33), which was at par with G_3K_3, G_3K_4, G_4K_3, and G_4K_4. The lowest values were recorded in G_1K_1 (69% and 92.83). The improvement may be attributed to GA_3-induced metabolic activity and hydrolytic enzyme synthesis, enhancing germination and seedling vigour, along with potassium-mediated enzyme activation, cell division, and protein synthesis, leading to better seedling establishment. These findings are in agreement with Bilekudari *et al*. (1); Ghanome *et al.* (5); Baloch *et al.* (2).

Based on the investigation, it can be concluded that the application of 200 ppm GA_3 at three stages (15 days after seed sowing, 30 days after steckling planting and at the time of siliqua formation) in combination with 50 kg potassium/ha resulted seed yield. This treatment combination significantly improved the seed yield and other seed quality parameters.

AUTHOR'S CONTRIBUTION

Conceptualization, data gathering, analysis (GR); Designing experiment (SC, SS); Data interpretation, manuscript preparation (GR, ALO, VP).

DECLARATION

The authors declare no conflict of interest.

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