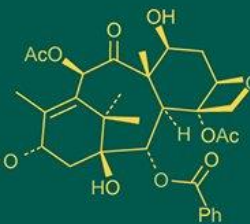
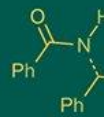
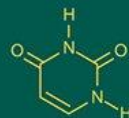


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Interactive effects of plant spacing and variety on growth, yield and quality of radish (*Raphanus sativus* L.)

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Abstract

A field experiment was conducted during the Rabi season of 2024-25 at the Horticulture Research Farm, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, to evaluate the effects of plant spacing and variety on the growth, yield and quality of radish. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising three plant spacings (20 cm × 10 cm, 20 cm × 15 cm, and 20 cm × 20 cm) and three varieties, namely Kashi Mooli-40, Kashi Hans and Kashi Shweta. The results revealed that Kashi Shweta exhibited superior performance for most growth, yield and quality parameters. Among the spacing treatments, 20 cm × 20 cm significantly enhanced plant height, number of leaves, leaf length, root length, root diameter, root weight, total soluble solids and ascorbic acid content of the leaves. However, the highest root yield (461.58 q ha⁻¹) was obtained under 20 cm × 10 cm spacing owing to the higher plant population per unit area, whereas the lowest root yield (422.43 q ha⁻¹) was recorded under 20 cm × 20 cm spacing. Among the varieties, Kashi Shweta recorded the highest average root yield (458.20 q ha⁻¹), followed by Kashi Hans (446.61 q ha⁻¹), whereas Kashi Mooli-40 produced the lowest yield (434.78 q ha⁻¹). These findings indicate that wider spacing is more suitable for producing superior root growth and quality, whereas closer spacing is more effective for maximising root yield per hectare (ha).

Keywords: Radish, plant spacing, varietal evaluation, growth, root yield and quality

Introduction

Radish (*Raphanus sativus* L.), a member of the family Brassicaceae, is one of the most important root vegetables cultivated worldwide for its edible roots and high nutritional value. It is widely grown in tropical, subtropical and temperate regions owing to its short crop duration, adaptability to diverse agro-climatic conditions and high market demand. Radish roots are an excellent source of vitamins, minerals, dietary fibre and bioactive compounds such as glucosinolates, anthocyanins and phenolic compounds, which possess antioxidant and health-promoting properties.

Among the various agronomic practices, optimum plant spacing plays a crucial role in determining the growth, yield and quality of radish. Appropriate spacing ensures efficient utilization of sunlight, water, nutrients and available growing space while minimizing competition among plants. Wider spacing generally promotes better vegetative growth, root development and quality attributes, whereas closer spacing increases plant population and may enhance the total yield per unit area despite reducing the performance of individual plants.

Varietal selection is another important factor influencing crop productivity, as different radish varieties exhibit considerable variation in their growth habits, root characteristics, yield potential, and quality traits. Therefore, the interaction between plant spacing and varietal performance may significantly influence the overall crop performance. Consequently, identifying the most suitable combination of variety and plant spacing is essential for maximising productivity and improving produce quality under specific agro-climatic conditions in the region.

Several researchers have reported the significant effects of plant spacing and varietal differences on the growth and yield of radish (Khan *et al.*, 2016; Lavanya *et al.*, 2017) [8, 11]. However, information on the combined response of different radish varieties to varying plant spacings under subtropical conditions in Uttar Pradesh remains limited. Therefore, the present study was undertaken to evaluate the performance of three radish varieties under different plant spacing regimes with respect to growth, yield and quality attributes under the agro-climatic conditions of Lucknow, Uttar Pradesh.

Materials and Methods

Experimental Site

The present investigation was conducted during the 2024-2025 Rabi season at the Horticulture Research Farm, Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India. The experimental farm is located at 26°50' N latitude and 80°56' E longitude, at an altitude of approximately 111 m above mean sea level. The region experiences a subtropical climate characterised by cool winters and warm summers, which is suitable for radish cultivation.

Experimental Design and Treatments

The experiment was laid out in a Factorial Randomised Block Design (FRBD) with three replications. The study consisted of two factors: three radish varieties, namely, V₁: Kashi Mooli-40, V₂: Kashi Hans, and V₃: Kashi Shweta and three plant spacing levels, S₁: 20 cm × 10 cm, S₂: 20 cm × 15 cm, and S₃: 20 cm × 20 cm, resulting in a total of nine treatment combinations.

Crop Management

Healthy and uniform seeds of the selected radish varieties were sown following the recommended package of practices for radish cultivation. All agronomic operations, including irrigation, weeding, nutrient management, and plant protection measures, were uniformly carried out for all treatments throughout the crop-growing period to minimise experimental variation.

Observations Recorded

Observations were recorded from five randomly selected plants in each experimental plot. Growth parameters included plant height, number of leaves per plant, and leaf length at 30 days after sowing (DAS), 45 DAS, and at harvest. yield parameters comprised root length, root diameter, root weight, root yield (q ha⁻¹), and days to harvest. quality parameters included total soluble solids (TSS, °Brix) and ascorbic acid content (mg 100 g⁻¹ fresh weight).

Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA) appropriate for a factorial randomised block design following standard statistical procedures. The significance of treatment differences was tested at the 5% probability level and the critical difference (CD) values were calculated wherever the treatment effects were significant.

Results and Discussion

Effect of Plant Spacing and Varieties on Plant Height

Plant height was significantly influenced by both plant spacing and variety throughout the crop growth period.

Among the varieties, Kashi Shweta (V₃) recorded the greatest plant height at 30 days after sowing (42.30 cm), 45 days after sowing (46.86 cm), and at harvest (49.50 cm), followed by Kashi Hans (V₂). The lowest plant height was observed in Kashi Mooli-40 (V₁), which recorded 35.73 cm, 40.28 cm, and 44.06 cm at the respective growth stages. Among the plant spacing treatments, S₃ (20 cm × 20 cm) produced significantly taller plants, recording plant heights of 42.55 cm, 46.46 cm and 50.54 cm at 30 DAS, 45 DAS and harvest, respectively. In contrast, the shortest plants were recorded under S₁ (20 cm × 10 cm), where plant height was 34.29 cm, 38.45 cm, and 41.37 cm at the corresponding growth stages. The interaction effect between variety and plant spacing was also significant. Treatment combination S₃V₃ (20 cm × 20 cm × Kashi Shweta) recorded the maximum plant height (46.32 cm, 51.14 cm, and 53.16 cm), whereas the minimum plant height (32.65 cm, 37.11 cm and 39.12 cm) was observed under S₁V₁ (20 cm × 10 cm × Kashi Mooli-40) at 30 DAS, 45 DAS, and harvest.

The superior plant height observed under wider spacing may be attributed to reduced interplant competition for light, moisture, nutrients, and growing space, resulting in enhanced vegetative growth. Furthermore, the better performance of Kashi Shweta may be associated with its superior genetic potential for vigorous growth. Similar findings have been reported by Lavanya *et al.* (2017) [11], Sharma *et al.* (2013) [19], Sahu *et al.* (2018) [17] Zucco *et al.* (2015) [21] and Smriti *et al.* (2016) [20].

Effect of Plant Spacing and Varieties on Number of Leaves

The number of leaves per plant was significantly affected by both plant spacing and variety throughout the crop growth period. Among the varieties, Kashi Shweta (V₃) produced the highest number of leaves, recording 13.08, 13.91 and 14.57 leaves per plant at 30 days after sowing (DAS), 45 DAS and at harvest. In contrast, the lowest number of leaves was observed in Kashi Mooli-40 (V₁), which recorded 10.61, 12.32 and 12.80 leaves per plant at the corresponding growth stages. Among the plant spacing treatments, S₃ (20 cm × 20 cm) recorded the highest number of leaves per plant (13.25, 14.55 and 15.49 at 30 DAS, 45 DAS and harvest), whereas the lowest values (9.79, 11.08 and 11.96) were obtained under S₁ (20 cm × 10 cm). The interaction between variety and plant spacing also exerted a significant influence on leaf production. The highest number of leaves per plant (14.76, 15.32 and 16.72) was recorded under the treatment combination S₃V₃ (20 cm × 20 cm × Kashi Shweta), whereas the lowest values (9.32, 10.46 and 11.54) were observed in S₁V₁ (20 cm × 10 cm × Kashi Mooli-40) at 30 DAS, 45 DAS and harvest.

The increased number of leaves under wider spacing may be attributed to reduced competition among plants for essential growth resources, such as sunlight, moisture, nutrients and growing space, which promoted better vegetative development. Furthermore, the superior performance of Kashi Shweta could be associated with its inherent genetic potential for vigorous vegetative growth. These findings are in close agreement with those reported by Lavanya *et al.* (2017) [11], Pervez *et al.* (2004) [16], Sharma *et al.* (2013) [19] Shahu *et al.* (2020) [18] and Ola *et al.* (2018) [15].

Effect of Plant Spacing and Varieties on Leaf Length

Leaf length was significantly influenced by plant spacing and varietal differences throughout the crop growth period.

Among the varieties, Kashi Shweta (V_3) recorded the maximum leaf length of 25.19 cm, 28.44 cm and 30.40 cm at 30 days after sowing (DAS), 45 DAS and at harvest. In contrast, the minimum leaf length was recorded in Kashi Mooli-40 (V_1), with values of 21.27 cm, 24.21 cm, and 26.16 cm at the corresponding growth stages. Among the plant spacing treatments, S_3 (20 cm $\times$ 20 cm) produced the longest leaves, recording 24.82 cm, 27.80 cm and 29.86 cm at 30 DAS, 45 DAS and harvest. The shortest leaf length was observed under S_1 (20 cm $\times$ 10 cm), where the corresponding values were 21.76 cm, 24.06 cm, and 27.18 cm. The interaction between plant spacing and variety also had a significant effect on leaf length. The treatment combination S_3V_3 (20 cm $\times$ 20 cm $\times$ Kashi Shweta) recorded the maximum leaf length (28.13 cm, 31.11 cm, and 33.15 cm), whereas the minimum values (21.31 cm, 25.12 cm, and 27.22 cm) were observed under S_1V_1 (20 cm $\times$ 10 cm $\times$ Kashi Mooli-40) at 30 DAS, 45 DAS and harvest. The improvement in leaf length under wider spacing may be attributed to better availability of sunlight, soil moisture, nutrients and growing space, which promoted enhanced vegetative growth. Moreover, the superior performance of Kashi Shweta may be due to its greater genetic potential for vegetative development under favourable growing conditions. Similar observations have been reported by Jaisankar (2018) [6], Dulal *et al.* (2021) [5] and Aswathi *et al.* (2021) [1] who also reported significant improvements in vegetative growth under wider plant spacing in radish.

Effect of spacing and variety on yield parameters

Effect of Plant Spacing and Varieties on Root Length

Among the varieties, the highest root yield (458.20 q ha⁻¹) was recorded in V_3 (Kashi Shweta), followed by V_2 (Kashi Hans) with 446.61 q ha⁻¹, whereas the lowest root yield (434.78 q ha⁻¹) was obtained in V_1 (Kashi Mooli-40). Among the plant spacing treatments, the maximum root yield (461.58 q ha⁻¹) was recorded under S_1 (20 cm $\times$ 10 cm), followed by S_2 (20 cm $\times$ 15 cm) with 455.58 q ha⁻¹, while the minimum root yield (422.43 q ha⁻¹) was recorded under S_3 (20 cm $\times$ 20 cm). The interaction effect between varieties and plant spacing was also significant. The highest root yield (473.64 q ha⁻¹) was obtained under the treatment combination V_1S_3 (Kashi Mooli-40 $\times$ 20 cm $\times$ 20 cm), whereas the lowest root yield (413.25 q ha⁻¹) was recorded under V_3S_1 (Kashi Shweta $\times$ 20 cm $\times$ 10 cm). A higher root yield under closer spacing may be attributed to the greater plant population per unit area, which compensated for the comparatively lower individual root weight. In contrast, wider spacing promoted better growth and larger roots but resulted in a lower total yield per hectare due to the reduced plant population. Similar findings have also been reported by Sharma *et al.* (2013) [19], Lavanya *et al.* (2017) [11] and Kumar and Gupta (2018) [10].

Effect of Plant Spacing and Varieties on Root Diameter

Root diameter was significantly influenced by varietal differences and plant spacing. Among the varieties, Kashi Shweta (V_3) produced the maximum root diameter (40.90 mm), followed by Kashi Hans (V_2), whereas the minimum root diameter (37.55 mm) was recorded in Kashi Mooli-40 (V_1). Among the plant spacing treatments, S_3 (20 cm $\times$ 20 cm) recorded the highest root diameter (41.68 mm), while the lowest value (35.98 mm) was observed under S_1 (20 cm $\times$ 10 cm). Wider spacing provided sufficient space for root

enlargement, resulting in the development of thicker and well-expanded roots compared with closer spacing. The interaction between plant spacing and variety was also significant. Treatment combination S_3V_3 (20 cm $\times$ 20 cm $\times$ Kashi Shweta) recorded the maximum root diameter (43.66 mm), whereas the minimum value (34.21 mm) was observed under S_1V_1 (20 cm $\times$ 10 cm $\times$ Kashi Mooli-40).

The increase in root diameter under wider spacing may be attributed to reduced competition among plants for essential resources, such as nutrients, moisture, sunlight, and rooting space, which favoured better assimilate accumulation and root development. In addition, the superior performance of Kashi Shweta may be associated with its inherent genetic potential for producing larger roots under favourable growing conditions. Similar findings have been reported by Mishra *et al.*, (2024) [13].

Effect of Plant Spacing and Varieties on Days to Harvest

The number of days to harvest was significantly influenced by both varietal differences and plant spacing. Among the varieties, Kashi Shweta (V_3) required the maximum number of days to harvest (44.36 days), followed by Kashi Hans (V_2), whereas Kashi Mooli-40 (V_1) reached harvest maturity in the shortest time (42.14 days). Among the plant spacing treatments, S_3 (20 cm $\times$ 20 cm) required the fewest days to harvest (41.69 days), whereas the maximum number of days to harvest (43.86 days) was recorded for S_1 (20 cm $\times$ 10 cm). The comparatively earlier maturity observed under wider spacing may be attributed to reduced competition for light, moisture, nutrients, and growing space, which promoted better vegetative growth and faster root development. The interaction between plant spacing and variety also showed a significant effect on the number of days to harvest. The minimum number of days to harvest (41.11 days) was recorded under the treatment combination S_3V_1 (20 cm $\times$ 20 cm $\times$ Kashi Shweta), whereas the maximum (45.79 days) was observed in S_1V_1 (20 cm $\times$ 10 cm $\times$ Kashi Mooli-40).

The variation in maturity period among the treatments may be attributed to differences in varietal characteristics and the availability of growth resources under different plant-spacing levels. Wider spacing enhances resource utilisation, resulting in earlier root development and timely crop maturity. Similar findings were reported by Meena *et al.*, (2025) [12].

Effect of Plant Spacing and Varieties on Root Weight

Root weight was significantly influenced by both varietal differences and plant spacing. Among the varieties, Kashi Shweta (V_3) recorded the highest root weight (119.28 g), followed by Kashi Hans (V_2), whereas the lowest root weight (107.02 g) was observed in Kashi Mooli-40 (V_1). Among the plant spacing treatments, S_3 (20 cm $\times$ 20 cm) produced the highest root weight (122.01 g), while the lowest root weight (98.71 g) was recorded under S_1 (20 cm $\times$ 10 cm). Wider spacing provided adequate growing space and reduced inter-plant competition, thereby promoting greater assimilate accumulation and better root development. The interaction between variety and plant spacing also significantly affected root weight. The treatment combination S_3V_3 (20 cm $\times$ 20 cm $\times$ Kashi Shweta) recorded the maximum root weight (126.38 g), whereas the minimum root weight (91.25 g) was observed under S_1V_1 (20 cm $\times$ 10 cm $\times$ Kashi Mooli-40).

Table 1: Interactive effects of plant spacing and variety on growth, yield and quality of radish

Treatment	Plant height			Number of leaves			Leaf Length(cm)			Yield Parameter					Quality Parameter	
DAT	30 days	45 days	Harvesting	30 days	60 days	Harvesting	30 days	60 days	Harvesting	Root Length	Root Diameter	Root Weight	Root Yield	Day To Harvest	TSS	Ascorbic Acid
Varieties (V)																
V1	35.73	40.28	44.06	10.61	12.32	12.80	21.27	24.21	26.16	20.88	37.55	107.02	434.78	42.14	4.25	20.75
V2	39.53	42.81	47.13	11.82	13.04	14.00	23.45	25.75	28.74	22.72	39.90	113.85	446.61	42.88	4.40	21.78
V3	42.30	46.86	49.50	13.08	13.91	14.57	25.19	28.44	30.4	24.19	40.90	119.28	458.20	44.36	4.57	22.99
S. Em±	0.207	0.269	0.261	0.095	0.083	0.085	0.519	0.519	0.519	0.147	0.31	0.57	0.512	0.452	0.011	0.132
CD 5%	0.627	0.814	0.788	0.289	0.251	0.256	1.569	1.569	1.569	0.445	0.95	1.724	1.549	1.366	0.034	0.400
Plants pating(S)																
S1	34.29	38.45	41.37	9.79	11.08	11.96	21.76	24.06	27.18	19.47	35.98	98.71	461.58	43.86	3.78	19.89
S2	40.73	45.04	48.79	12.48	13.64	13.92	23.33	26.54	28.26	23.67	40.69	119.44	455.58	43.82	4.68	22.64
S3	42.55	46.46	50.54	13.25	14.55	15.49	24.82	27.80	29.86	24.66	41.68	122.01	422.43	41.69	4.75	22.98
S. Em±	0.207	0.269	0.261	0.095	0.083	0.085	0.519	0.519	0.519	0.147	0.31	0.57	0.512	0.452	0.011	0.132
CD 5%	0.627	0.814	0.788	0.289	0.251	0.256	1.569	1.569	1.569	0.445	0.95	1.724	1.549	1.366	0.034	0.400
Interactions (V×S)																
V1S1	32.65	37.11	39.12	9.32	10.46	11.54	21.31	25.12	27.22	18.36	34.21	91.25	461.28	43.97	3.65	19.16
V1S2	34.84	38.12	41.16	9.48	11.32	11.86	22.68	22.95	27.85	19.62	36.54	98.36	468.29	44.68	3.73	20.01
V1S3	35.39	40.13	43.15	10.56	11.48	12.5	21.31	24.13	26.5	20.45	37.21	106.52	473.64	45.79	3.97	20.52
V2S1	36.45	41.62	45.18	10.84	12.63	12.89	20.32	23.35	25.15	21.85	38.94	112.54	441.25	42.62	4.53	21.62
V2S2	40.54	44.21	49.16	12.66	13.35	14.37	23.56	26.18	28.1	23.86	40.63	120.84	449.84	42.95	4.68	22.72
V2S3	45.21	49.31	52.19	13.95	14.95	14.51	26.12	30.1	31.55	25.31	42.51	124.96	457.21	43.32	4.85	23.60
V3S1	38.11	42.12	47.45	11.68	13.87	13.98	22.19	24.16	26.13	22.46	39.51	117.29	413.25	41.11	4.57	21.47
V3S2	43.23	46.13	51.13	13.32	14.46	15.78	24.14	28.14	30.3	24.69	41.88	122.37	421.36	41.37	4.79	22.61
V3S3	46.32	51.14	53.16	14.76	15.32	16.72	28.13	31.11	33.15	26.84	43.66	126.38	432.69	42.37	4.91	24.86
S. Em±	0.359	0.466	0.456	0.165	0.144	0.147	0.899	0.899	0.899	0.255	0.546	0.988	0.887	0.782	0.019	0.229
CD5%	1.086	1.409	1.366	0.5	0.434	0.443	2.718	2.718	2.718	0.771	NS	2.986	2.683	NS	0.059	0.693

The increased root weight under wider spacing may be attributed to the improved availability of sunlight, nutrients, moisture and rooting space, which enhanced photosynthetic activity and facilitated greater translocation of photosynthates to the storage roots. Furthermore, the superior performance of Kashi Shweta may be associated with its higher genetic potential for biomass accumulation and root development. Similar findings have also been reported by Sharma *et al.* (2013) [19], Khan *et al.* (2016) [8], Smriti *et al.* (2016) [20] and Chhetri *et al.* (2019) [2].

Effect of Plant Spacing and Varieties on Root Yield

Root yield was significantly influenced by varietal differences and plant spacing. Among the varieties, Kashi Shweta (V₃) recorded the highest root yield (458.20 q ha⁻¹), followed by Kashi Hans (V₂) (446.61 q ha⁻¹), whereas the lowest root yield (434.78 q ha⁻¹) was obtained in Kashi Mooli-40 (V₁). Among the plant spacing treatments, the highest root yield (461.58 q ha⁻¹) was recorded under S₁ (20 cm × 10 cm), followed by S₂ (20 cm × 15 cm) (455.58 q ha⁻¹), while the lowest root yield (422.43 q ha⁻¹) was obtained under S₃ (20 cm × 20 cm). Although wider spacing promoted better growth and larger root size, closer spacing resulted in a higher plant population per unit area, thereby producing a greater total root yield. The interaction effect between variety and plant spacing was significant. The maximum root yield (473.64 q ha⁻¹) was recorded under the treatment combination S₁V₁ (20 cm × 10 cm × Kashi Mooli-40), whereas the minimum root yield (413.25 q ha⁻¹) was observed under S₃V₁ (20 cm × 20 cm × Kashi Shweta).

The higher root yield recorded under closer spacing may be attributed to the greater plant population per unit area, which compensated for the comparatively lower yield of individual plants. Conversely, wider spacing favoured the development of larger roots but resulted in a reduced plant population, thereby decreasing the overall yield per hectare. Similar

findings have been reported by Khatri *et al.*, (2019) [9] and Ola *et al.*, (2018) [15].

Effect of spacing and variety on quality parameters:

Effect of Plant Spacing and Varieties on Ascorbic Acid Content

Ascorbic acid content was significantly influenced by varietal differences and plant spacing. Among the varieties, Kashi Shweta (V₃) recorded the highest ascorbic acid content, followed by Kashi Hans (V₂), whereas the lowest value was observed in Kashi Mooli-40 (V₁). Among the plant spacing treatments, S₃ (20 cm × 20 cm) recorded the highest ascorbic acid content, whereas the lowest value was observed under S₁ (20 cm × 10 cm). The higher ascorbic acid content under wider spacing may be attributed to improved light interception, better nutrient uptake, and reduced interplant competition, which enhanced photosynthetic efficiency and the biosynthesis of vitamin C. The interaction effect between variety and plant spacing was also significant. Treatment combination S₃V₃ (20 cm × 20 cm × Kashi Shweta) recorded the highest ascorbic acid content, whereas the lowest value was observed under S₁V₁ (20 cm × 10 cm × Kashi Mooli-40).

The superior performance of Kashi Shweta under wider spacing may be attributed to its greater genetic potential and favourable growing conditions, which enhanced carbohydrate synthesis and the accumulation of ascorbic acid in the storage roots. Similar observations have been reported by Sahu *et al.* (2018) [17] and Chhetri *et al.* (2019) [2], who also reported significant improvements in vitamin C content under optimum plant spacing.

Effect of Plant Spacing and Varieties on Total Soluble Solids (TSS)

Total soluble solids (TSS) content was significantly influenced by varietal differences and plant spacing. Among

the varieties, Kashi Shweta (V_3) recorded the highest TSS content, followed by Kashi Hans (V_2), whereas the lowest TSS value was observed in Kashi Mooli-40 (V_1). Among the plant spacing treatments, S_3 (20 cm $\times$ 20 cm) recorded the highest TSS content, whereas the lowest value was observed under S_1 (20 cm $\times$ 10 cm). The increase in TSS under wider spacing may be attributed to the improved availability of sunlight, moisture, nutrients, and growing space, which enhanced photosynthetic activity and promoted the accumulation of soluble sugars in the storage roots. The interaction between plant spacing and variety was also significant. Treatment combination S_3V_3 (20 cm $\times$ 20 cm $\times$ Kashi Shweta) recorded the highest TSS content, whereas the lowest value was observed under S_1V_1 (20 cm $\times$ 10 cm $\times$ Kashi Mooli-40).

The higher TSS content observed under wider spacing may be associated with better translocation and accumulation of photosynthates in the roots due to reduced interplant competition. Furthermore, the superior performance of Kashi Shweta may be attributed to its inherent genetic potential for higher sugar accumulation under favourable growing conditions. Similar findings have been reported by Sharma *et al.* (2013)^[19], and Chhetri *et al.* (2019)^[2].

Conclusion

The present investigation demonstrated that both plant spacing and varietal selection significantly influenced the growth, yield, and quality of radish under the agro-climatic conditions of Lucknow, Uttar Pradesh. Among the varieties, Kashi Shweta consistently performed better than Kashi Hans and Kashi Mooli-40 in terms of plant growth, root development, root weight, total soluble solids, ascorbic acid content and average root yield. The wider spacing of 20 cm $\times$ 20 cm was the most effective for improving vegetative growth and root quality by reducing inter-plant competition and enhancing resource availability. In contrast, the highest root yield per hectare (461.58 q ha⁻¹) was obtained under the closer spacing of 20 cm $\times$ 10 cm because of the higher plant population per unit area of land. Therefore, Kashi Shweta is recommended for the production of high-quality radish roots, whereas a spacing of 20 cm $\times$ 10 cm is recommended when the primary objective is to maximise root yield per hectare. The findings of this study provide valuable information for selecting suitable varieties and plant spacings to enhance radish productivity under subtropical conditions.

References

- Aswathi P, Prasad VM, Bahadur V, Deepanshu. Integrated nutrient management in radish (*Raphanus sativus* L.) cv. Scarlet Red Globe. The Pharma Innovation Journal. 2021;10(10):1582-1584.
- Chhetri RK, Panta P, Shrestha RK. Effect of spacing and potassium application on growth and yield of radish (*Raphanus sativus* L.) cv. Mino Early. International Journal of Biological Research. 2019;2(1):176-180.
- Dongarwar LN, Kashiwar SR, Ghawade SM, Dongarwar UR. Performance of different radish (*Raphanus sativus* L.) varieties in black soils of Vidarbha, Maharashtra. International Journal of Plant and Soil Science. 2017;20(5):1-9.
- Dongarwar LN, Kashiwar SR, Ghawade SM, Dongarwar UR. Varietal performance of radish (*Raphanus sativus* L.) varieties in black soils of Vidarbha, Maharashtra, India. International Journal of Current Microbiology and Applied Sciences. 2018;7(1):2319-7706.
- Dulal D, Baral D, Poudel A, Kafle K, Shrestha B. Effect of different doses of vermicompost on growth, yield and quality of radish (*Raphanus sativus* L.) cv. Mino Early. Archives of Agriculture and Environmental Science. 2021;6(3):354-359.
- Jaisankar P. Effect of integrated nutrient management on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki. International Journal of Current Microbiology and Applied Sciences. 2018;7(11):2319-2326.
- Jat PK, Singh SP, Devi S, Mahala P, Rolaniya MK. Performance of organic manures, inorganic fertilizers and plant density on the yield and quality of radish. International Journal of Agricultural Science and Research. 2017;7(2):261-266.
- Khan MA, *et al.* Effect of spacing on radish growth and yield. Vegetable Science. 2016;43:45-49.
- Khatri KB, Ojha RB, Pande KR, Khanal BR. Effects of different sources of organic manures on growth and yield of radish (*Raphanus sativus* L.). International Journal of Applied Sciences and Biotechnology. 2019;7(1):39-42.
- Kumar A, Gupta R. The effects of vermicompost on growth and yield parameters of vegetable crop radish (*Raphanus sativus* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(2):589-592.
- Lavanya AVN, Sudhavani V, Reddy PS, Chaitanya K. Effect of sowing dates and spacing on growth and root yield of radish cv. Pusa Chetki. Plant Archives. 2017;14(1):619-623.
- Meena DK, Lata R, Kumar S, Meena ML, Verma RS, Mitra DS, *et al.* Effect of integrated nutrient management on yield and quality attributes of radish (*Raphanus sativus* L.) cv. Japanese White. Plant Archives. 2025;25(2):1945-1951.
- Misra S, Semwal P, Pandey DD, Mishra SK, Chauhan PS. Siderophore-producing *Spinacia oleracea* bacterial endophytes enhance nutrient status and vegetative growth under iron-deficit conditions. Journal of Plant Growth Regulation. 2024;43(5):1317-1330.
- Naruka IS, Dhaka RS. Effect of row spacing and nitrogen fertilisation on growth, yield and composition of bulb in garlic (*Allium sativum* L.) cultivars. Journal of Spices and Aromatic Crops. 2001;10(2):111-117.
- Ola AL, Rana DK, Jhajhra MR. Evaluation of radish (*Raphanus sativus* L.) varieties under the valley condition of the Garhwal hills. Journal of Pharmacognosy and Phytochemistry. 2018;7(1):2740-2743.
- Pervez MA, Ayub CM, Saleem BA, Virk NA, Nasir M. Effect of nitrogen levels and spacing on growth and yield of radish (*Raphanus sativus* L.). International Journal of Agriculture and Biology. 2004;6(3):504-506.
- Sahu G, Singh VK, Singh T. Effect of sowing dates and plant spacing on growth and yield of radish (*Raphanus sativus* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7:546-548.
- Shahu DK, Bhardwaj LP, Khiromani, Nag, Rajput JS. To investigate the effect of integrated nutrient management on growth and yield of radish (*Raphanus*

- sativus* L.). International Journal of Chemical Studies. 2018;4:110-113.
19. Sharma UG, Vihol NJ, Chavda JC. Influence of plant density and nutrient management on growth, yield and quality of radish (*Raphanus sativus* L.) cv. Pusa Chetki. Asian Journal of Horticulture. 2013;8(2):671-676.
 20. Smriti S, Sanjay K, Verma VK, Kumar PV, Sutanu M. Effect of different levels of sulphur on growth, yield and quality of some radish varieties. International Journal of Agricultural Sciences. 2016;8(51):2189-2191.
 21. Zucco MA, Walters SA, Chong SK, Klubek BP, Masabni JG. Effect of soil type and vermicompost applications on tomato growth. International Journal of Recycling of Organic Waste in Agriculture. 2015;4:135-141.