



Effect of different plant spacing on growth, yield and quality parameters of radish (*Raphanus sativus* L.) cv. Japanese White

Mukesh Kumar*, S. K. Bairagi and Satyam Gangwar

Department of Horticulture, Amar Singh College, Lakhaoti, Bulandshahr 203707, Uttar Pradesh, India.

Affiliated to Choudhary Charan Singh University Meerut, Uttar Pradesh, India

ABSTRACT

The study was conducted during the *rabi* season of 2022–2023 at the Research farm of Amar Singh College, Lakhaoti, Bulandshahr District, Uttar Pradesh. The experiment used a randomized block design (RBD) and contained 9 treatment combinations with 3 replications. The following parameters were observed plant height, number of leaves per plant, leaf width, leaf area, shoot fresh weight, shoot dry weight, root length, root diameter, days to harvest, weight of whole plant, fresh root weight, dry root weight, root yield kg/plot, root yield t/ha, total soluble solid content of roots, root forking & cracking percentage, and root pithiness percentage with these treatments like T₀ (30×10 cm), T₁ (30×05 cm) T₂ (30×15 cm), T₃ (40×05 cm), T₄ (40×10 cm) T₅ (40×15 cm) T₆ (50×05 cm), T₇ (50×10 cm), T₈ (50×15 cm). The result of the study revealed that the maximum plant height (39.16 cm) and plant spacing (30×05 cm) were significantly associated, as were the largest number of leaves per plant (17.67), leaf width (11.54 cm), and leaf area (203.25 cm²). Maximum root length (22.92 cm), root diameter (3.98 cm), root fresh weight (157.38 g), and TSS (5.76°Brix) were measured at plant spacing (50×15 cm), whereas maximum root yield (38.05 t/ha) was determined at plant spacing (30×10 cm). Overall, plant spacing of 30 × 10 cm was found to be the most suitable for achieving maximum root yield, while wider spacing (50 × 15 cm) enhanced root growth, size, and TSS in Japanese White radish.

Key words: Root forking, plant spacing, Japanese white, TSS, yield.

INTRODUCTION

Radish (*Raphanus sativus* L.), a member of the *Brassicaceae* family, is native to either Europe or Asia (Thomson and Kelly, 17). It is an important and popular root vegetable crop that is grown all over the world. In India, it is farmed almost all year round. Its young, meaty roots, which can be cooked or eaten as a salad, are the reason it is grown. Cool-season crops like radish can be roughly categorized as either European (temperate) or Asiatic (tropical). In tropical and subtropical climates, Asiatic varieties provide both roots and seeds. The European type variants can grow roots in both tropical and subtropical climates, but they can only develop seeds in mountainous, temperate climates since they need cold temperatures to do so. According to Tripathi *et al.* (18), Asiatic variants are tiny, mildly pungent, mature early, and rich in quality features. India is one among the top growers of radish worldwide. Grown on over 214 thousand hectares, it produces 3,327 thousand tonnes of radishes annually in 2024-25. India's top producers of radish are West Bengal, Punjab, Haryana, Madhya Pradesh, Assam, Bihar, Uttar Pradesh, and other states (Anonymous, 1).

The yield of vegetable crops is influenced by numerous factors. The development and output of

vegetable crops, particularly root vegetables, are impacted by optimal plant density, which is one of the key factors. Because crop spacing has a significant impact on yield, it is crucial. Proper plant density reduces competition amongst plants for nutrients, light, radiation, water, and other resources, increasing potential output per unit area (Chhetri *et al.*, 3). Wider plant spacing increases the likelihood of root development through appropriate assimilation, leading to maximal root weight, girth, and length (Thamburaj and Singh, 16).

Plant spacing is obviously important for producing high-quality roots, but farmers tend to overlook these factors, which leads to the creation of low-quality roots and low yields. Producing high-quality radish roots is a very difficult process because of severe forking, splitting, cracking, and pithiness, all of which are significantly influenced by sowing timing and spacing. Selecting the appropriate timing and spacing is essential for effective radish production. (Choudhury, 4) suggested a spacing of 40×20 cm for the best plant population in Indian conditions, while (Yawalkar, 19) found that the best spacing for radish was 40×10 cm for the highest production of both top and root. In order to achieve superior growth with high yield and quality, growers frequently experiment with sowing timing and spacing. The present study was undertaken to evaluate the effect of different plant

*Corresponding author email: rajatmaurya664@gmail.com

spacings on the growth, yield, and quality parameters of radish cv. Japanese White.

MATERIALS AND METHODS

This study was carried out from December 2022 to February 2023 during the rabi season. The experimental field is located on Bulandshahr-Garh Mukteshwar state route 65, 20 kilometers from Bulandshahr city. Its coordinates are 28°31'36" N longitude and 77°58'29" E latitude, with an average elevation of roughly 237.44 meters above mean sea level. The selected field was on the south-west of the farm having ample facilities of irrigation by college tubewell. The topography of the experimental field was plain and had good agricultural facilities. The climate of the region is north - west subtropical zone of the country having a temperature range of maximum 46°C and minimum 4°C in summers and winters, respectively. The months of July through September see the most rainfall in this region. Rainfall averages 875.0 mm per year. The 9 plant spacings (T_0 : 30×10 cm, T_1 : 30×05 cm, T_2 : 30×15 cm, T_3 : 40×05 cm, T_4 : 40×10 cm, T_5 : 40×15 cm, T_6 : 50×05 cm, T_7 : 50×10 cm, and T_8 : 50×15 cm) were arranged in a randomized block design with three replications. At 30, 45, and 60 days after sowing, five randomly selected and tagged plants from each plot in each replication were observed and evaluated for growth, yield, and quality parameters. The growth parameters recorded included plant height (cm), number of leaves per plant, leaf width (cm), leaf area (cm²), shoot fresh weight (g), and shoot dry weight (g). The yield parameters assessed were root length (cm), root diameter (cm), days to harvest, whole plant weight (g), fresh root weight (g), dry root weight (g), root yield (kg/plot), and root yield (t/ ha). The quality parameters evaluated

included total soluble solids (°Brix), root forking and cracking (%), and root pithiness (%). The analysis of variance approach for randomized block design, as described by Panse and Sukhatme (12), was used to statistically analyze the data collected throughout the inquiry for each character.

RESULTS AND DISCUSSION

Plant spacing had a major effect on plant height (Table 1 & Fig. 1). At 30 DAS, 45 DAS, and harvesting stage, the closest spacing treatment, T_1 (30×05 cm), recorded the highest plant height at 14.07 cm, 24.78 cm, and 39.16 cm, while the widest spacing treatment, T_8 (50×15 cm), recorded the lowest plant height at 9.97 cm, 17.96 cm, and 31.37 cm, respectively. When there is less horizontal space available for growth due to increased plant density, the plant only has vertical space, which results in taller growth. These findings agreed with those of (Layanya *et al.*, 10; Sahu *et al.*, 14). The spacing had a major effect on the number of leaves per plant (Table 1). The spacing T_8 (50×15 cm) 6.93, 10.20 and 17.67 had the most leaves per plant at 30 DAS, 45 DAS, and the harvesting stage, followed by T_5 (40×15 cm) 6.77, 9.83 and 17.36. The closer spacing T_1 (30×05 cm) had the fewest leaves per plant at 30 DAS, 45 DAS, and the harvesting stage, measuring 3.47, 6.67 and 10.93, respectively. At 30 DAS, 45 DAS, and harvesting stage, the lowest spacing T_1 (30×05 cm) had the lowest number of leaves per plant 3.47, 6.67 and 10.93 respectively. The wider spacing made available more space to plants to grow and thereby the plants got the opportunity to produce greater number of leaves. The wider spacing between plants allowed greater freedom of growth to individual plants by reducing the competition for light, nutrients and water and led

Table 1: Effect of plant spacing on plant height, number of leaves per plant, leaf width and leaf area.

Treatment Plant Spacing	Plant height (cm)			Number of leaves per plant			Leaf width (cm)			Leaf area (cm ²)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_0 (30×10 cm)	12.36	21.12	36.49	5.62	8.87	14.87	5.07	7.93	9.63	36.47	82.15	132.60
T_1 (30×05 cm)	14.07	24.78	39.16	3.47	6.67	10.93	3.17	5.73	6.80	24.26	57.16	82.23
T_2 (30×15 cm)	11.13	19.72	34.51	5.90	9.33	15.97	5.77	8.26	10.72	37.92	91.45	175.93
T_3 (40×05 cm)	13.13	23.45	37.69	5.27	7.73	13.35	4.23	7.43	8.48	33.17	72.91	109.86
T_4 (40×10 cm)	11.82	20.36	35.76	5.73	9.23	15.37	5.63	8.12	10.21	36.67	89.79	162.57
T_5 (40×15 cm)	10.27	18.03	32.02	6.77	9.83	17.36	6.20	8.56	11.35	39.20	98.34	198.13
T_6 (50×05 cm)	12.43	22.38	37.51	5.47	7.77	14.03	4.73	7.61	8.51	34.17	78.35	118.06
T_7 (50×10 cm)	10.53	18.96	33.57	6.54	9.63	16.51	5.93	8.43	11.14	38.33	97.77	192.13
T_8 (50×15 cm)	9.97	17.96	31.37	6.93	10.20	17.67	6.43	8.73	11.54	40.81	102.91	203.25
SEm±	0.78	1.03	1.37	0.44	0.48	0.91	0.30	0.54	0.72	1.33	4.91	12.45
CD at 5%	2.35	3.11	4.14	5.6	8.87	14.87	0.91	1.64	2.10	4.04	14.86	37.76

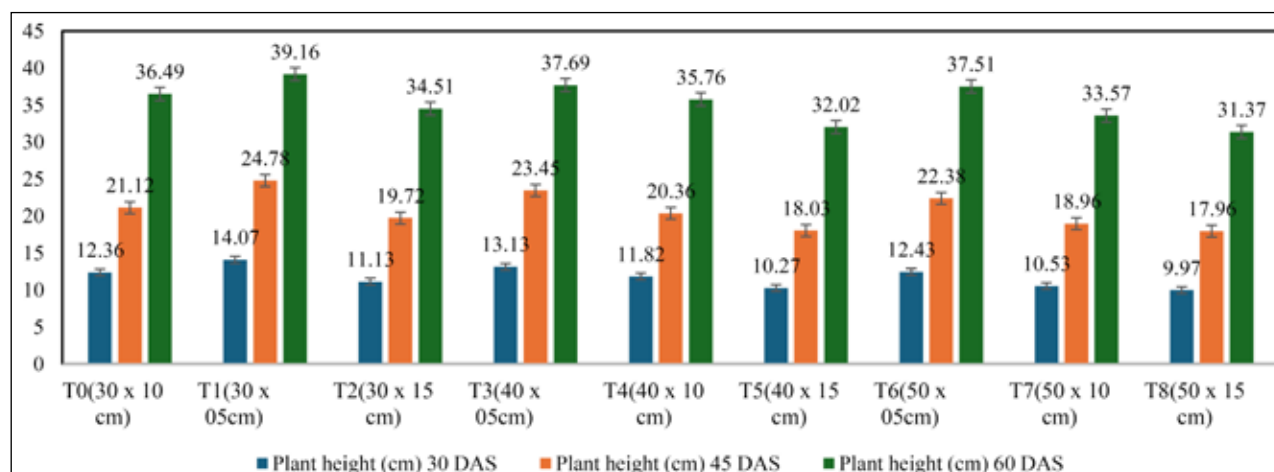


Fig. 1. Effect of plant spacing on plant height cm at 30 DAS, 45 DAS and 60 DAS after sowing.

to better growth. These findings are agreement with Asil *et al.* (2); Layanya *et al.* (10); Sahu *et al.* (14) in radish. Leaf width was significantly impacted by plant spacing (Table 2). Wider spacing T₈ (50×15 cm) showed the largest leaf width at 6.43 cm, 8.73 cm, and 11.54 cm, followed by T₅ (40×15 cm) at 6.20 cm, 8.56 cm, and 11.35 cm at 30 DAS, 45 DAS, and harvesting stage, respectively. Treatment spacing T₁ (30×05 cm) showed the smallest leaf width at 3.17 cm, 5.73 cm, and 6.80 cm at 30 DAS, 45 DAS and at harvesting stage. Increased plant spacing increased leaf width per plant due to more availability of space and nutrients. These results support the findings of Khan *et al.* (8).

Radish leaf area was strongly impacted by varying plant spacing (Table 1). The treatment T₈ (50×15 cm) recorded maximum leaf areas of 40.81 cm², 102.91 cm², and 203.25 cm² at 30 DAS, 45 DAS, and the harvesting stage, respectively. Next were T₅ (40×15 cm) 39.20 cm², 98.34 cm², and 198.13 cm² at 30 DAS, 45 DAS, and harvesting stage, respectively. Treatment T₁ (30×05 cm) had the smallest leaf area at 30 DAS, 45 DAS, and the harvesting stage, measuring 24.26 cm², 57.16 cm², and 82.23 cm², respectively. The wider plant spacing produced greater leaf area due to very less crop competition and more availability of space and nutrients. These findings are in conformity with those of (Layanya *et al.* (10); Sharma *et al.* (15). Plant spacing had significant effects on fresh shoot weight (Table 2). The fresh shoot weight of T₈ (50×15 cm), which had the largest spacing, was the highest (122.06 g), followed by T₅ (40×15 cm) (119.95 g). The fresh shoot weight (45.16 g) was the lowest at the narrowest spacing T₁ (30×05 cm). These findings in radish are consistent with those of Chhetri *et al.* (3); Sharma

et al. (15). Radish dry shoot weight was significantly impacted by plant spacing (Table 2). The highest dry shoot weight (13.71 g) was measured in the wider spacing T₈ (50×15 cm), followed by T₅ (40×15 cm) (12.67 g). The lowest dry shoot weight (4.61 g) was obtained with closer plant spacing T₁ (30×05 cm). These results are comparable to those of Khan *et al.* (8). Plant spacing had a considerable impact on radish root length (Table 2). At the harvesting stage, the spacing T₈ (50×15 cm) had the longest roots (22.92 cm). This was closely followed by T₅ (40×15 cm) 21.45 cm of root length. The shortest roots (9.96 cm) were registered in plots with the closest spacing of T₁ (30×05 cm). These findings are conformity with Chhetri *et al.* (3); Jat *et al.* (5); Kabir *et al.* (6) in radish. The spacing has a major effect on the radish root diameter (Table 2). The greatest root diameter was measured at the harvest stage using a greater spacing of T₈ (50×15 cm) 3.98 cm and T₅ (40×15 cm) 3.68 cm. There may be more room available for each plant as a result of the thicker roots with wider spacing. The minimum root diameter with the least spacing, T₁ (30×05 cm), was 1.79 cm. Radish root diameter increased because there was less crop competition for light, water, air, and nutrient uptake due to the wider spacing. These results are in conformity with Asil *et al.* (2); Khan *et al.* (8); Chhetri *et al.* (3) in radish.

The number of days needed to harvest radish roots early was significantly impacted by plant spacing (Table 2). comparatively greater number of days was needed for the roots to reach harvesting stage with closer spacing T₁ (30×05 cm) 67.38 DAS. While, the plants planted with wider spacing T₈ (50×15 cm) 59.45 DAS took comparatively lesser number of days to reach harvesting stage. More

Table 2: Effect of plant spacing on fresh shoot weight, dry shoot weight, root length, root diameter, days to harvesting, whole plant weight, fresh root weight, dry root weight and root yield (t/ha).

Treatment plant spacing	Fresh shoot weight (g) at 60 DAS	Dry shoot weight (g) at 60 DAS	Root length (cm) at 60 DAS	Root diameter (cm) at 60 DAS	Days to harvesting	Whole plant weight (g)	Fresh root weight (g)	Dry root weight (g)	Root yield (t/ ha)
T ₀ (30×10 cm)	99.42	10.26	18.53	2.71	63.82	205.47	134.15	10.58	38.05
T ₁ (30×05 cm)	45.16	4.61	9.96	1.79	67.38	111.38	85.83	7.18	17.56
T ₂ (30×15 cm)	102.22	11.79	20.02	3.55	61.15	212.58	140.36	12.69	34.64
T ₃ (40×05 cm)	68.83	7.78	14.85	2.40	65.94	141.72	102.89	8.42	26.44
T ₄ (40×10 cm)	101.39	11.76	19.76	3.48	62.28	209.28	137.88	11.54	36.97
T ₅ (40×15 cm)	119.95	12.67	21.45	3.68	59.97	245.15	145.16	13.91	27.86
T ₆ (50×05 cm)	83.17	10.13	16.91	3.51	64.60	171.37	108.20	9.81	25.28
T ₇ (50×10 cm)	108.80	12.47	20.44	3.58	60.25	221.40	140.59	13.36	30.52
T ₈ (50×15 cm)	122.06	13.71	22.92	3.98	59.45	249.45	157.38	14.35	19.98
SEm±	6.68	0.85	1.24	0.21	0.78	14.52	7.66	0.81	2.12
CD at 5%	20.76	2.59	3.75	0.64	2.38	43.91	23.16	2.45	5.63

land area available to the plants with wider spacing caused better vegetative growth of the plants which, consequently may have led to better and quicker root development hence, earliness. These findings were consistent with Mengistu and Yamoha (11). The results showed that plant spacing had a substantial impact on radish entire plant weight (root plus top leaves) (Table 2). The maximum whole plant weight was observed with the widest spacing T₈ (50×15 cm) 249.45 g, followed by T₅ (40×15 cm) 245.15 g. While, the minimum whole plant weight was recorded with the narrowest spacing T₁ (30×05 cm) (111.38 g) in radish. Plant spacing had a significant impact on radish fresh root weight (Table 2). At harvesting stage, the maximum fresh root weight was recorded with spacing T₈ (50×15 cm) at 157.38 g, followed by T₅ (40×15 cm) at 145.16 g. The narrowest spacing T₁ (30×05 cm) yielded the lowest root weight (85.83 g). These results are consistent with those found in radish by Kabir *et al.* (6); Tripathi *et al.* (18); Chhetri *et al.* (3); Parajuli *et al.* (13) Plant spacing T₈ (50×15 cm) had the highest dry root weight (14.35 g), while closest spacing T₁ (30×05 cm) had the lowest dry root weight (7.18 g) (Table 2). These results are in corroboration with that of Kabir *et al.* (6). Varying plant spacing exerted significant effect on root yield t/ha (Table 2 & Fig. 2). Plant spacing T₀ (30×10 cm) had the maximum root yield per hectare (38.05 t/ha). T₄ (40×10 cm) 36.97 t/ha came next. On the other hand, the narrow plant spacing T₁ (30×05 cm) yielded the lowest root yield per hectare (17.56 t/ha). The number of plants per unit area and the

performance of individual plants are the two key factors that determine radish output. In the current experiment, a general tendency was shown that increasing plant spacing from the narrowest to the broadest improved individual plant performance in nearly every character examined; T₈ (50×15 cm) was found to be the best treatment overall. However, under spacing T₀ (30×10 cm), the greatest root output was noted. This could be explained by the fact that T₀ (30×10 cm) had a higher root output than T₈ (50×15 cm) due to both the above-average individual plant performance and the significantly higher number of plants per unit area. These findings are in conformity Kharsan *et al.* (9); Layanya *et al.* (10); Kadam *et al.* (7); Sahu *et al.* (14). The plant spacing indicated significant effect on TSS content in radish (Table 3). The plant spacing T₈ (50×15 cm) (5.76 °Brix) had observed the highest TSS contents, while the least TSS content was recorded with spacing T₁ (30×05 cm) 3.61 °Brix in radish. The higher TSS content recorded with wider spacing could have been due to more availability major and micro nutrients, and other resources including sunlight and the favorable conditions with wider spacings. This was against the lower TSS content with closer spacings due to heavy competition for water and recourses. These results are agreement with Tripathi *et al.* (18); Jat *et al.* (5) in radish.

Different plant spacing exerted significant effect on root disorders like forking & cracking (Table 3). The maximum incidence of root forking & cracking was found with the closest plant spacing T₁ (30×05 cm) 9.27 %, while the least percentage of the above

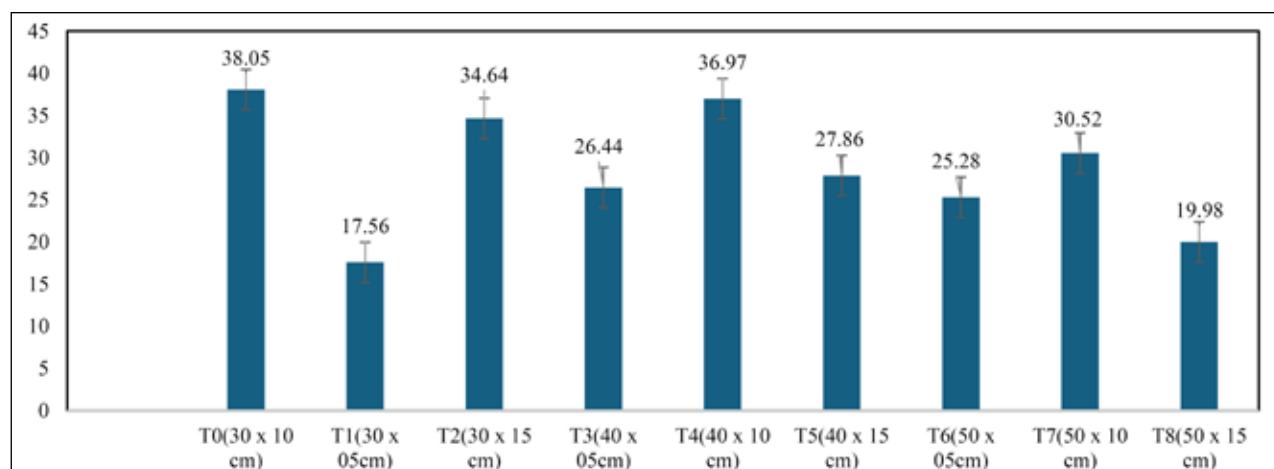


Fig. 2. Effect of plant spacing on root yield t/ha.

Table 3: Effect of plant spacing on TSS content, forking and cracking (%) and root pithiness (%).

Treatment plant spacing	TSS (°Brix) content	Forking & cracking (%)	Root pithiness (%)
T ₀ (30×10 cm)	4.90	6.43	1.83
T ₁ (30×05 cm)	3.61	9.27	2.80
T ₂ (30×15 cm)	5.15	5.92	1.32
T ₃ (40×05 cm)	4.22	8.08	2.05
T ₄ (40×10 cm)	4.92	6.39	1.53
T ₅ (40×15 cm)	5.28	4.90	1.13
T ₆ (50×05 cm)	4.77	6.58	1.85
T ₇ (50×10 cm)	5.24	5.10	1.17
T ₈ (50×15 cm)	5.76	4.13	0.86
SEm±	0.21	0.48	0.18
CD at 5%	0.63	1.47	0.56

root disorders was recorded with the widest spacing T₈ (50×15 cm) 4.13 %. These findings are consistent with those of Kabir *et al.* (6). Significant variations were seen in the impact of plant spacing on root pithiness (Table 3). The treatment T₁ (30×05 cm) observed the highest percentage 2.8 % of roots affected by pithiness, followed by T₃ (2.05 %) and T₆ 1.85 % root pithiness. On the other hand, the least percentage (0.86 %) of root pithiness was recorded in the farthest plant spacing T₈ (50×15 cm). These results are conformity with Kabir *et al.* (6). Plant spacing influenced the growth, yield and quality attributes of radish cv. Japanese White. The wider spacing of T₈ (50×15 cm) produced superior individual plant growth and root attributes, recording the highest number of leaves per plant, leaf width,

leaf area, fresh and dry shoot weight, root length, root diameter, fresh and dry root weight, and total soluble solids, while also reducing the incidence of root forking, cracking and pithiness. However, the highest root yield (38.05 t/ha) was obtained with T₀ (30×10 cm) spacing, indicating the advantage of a higher plant population per unit area for maximizing yield. Therefore, under the agro-climatic conditions of Bulandshahr, Uttar Pradesh, a spacing of 30×10 cm may be considered suitable for higher root yield, whereas T₈ (50×15 cm) may be preferred where superior individual root size and quality are the primary objectives.

The present study demonstrated that plant spacing significantly influenced the growth, yield, and quality parameters of radish cv. Japanese White. Closer spacing proved beneficial for maximizing root yield per hectare, while wider spacing enhanced individual root growth, size, and total soluble solids content. Among the treatments evaluated, the spacing of 30 × 10 cm was found to be the most suitable for achieving maximum root yield under the agro-climatic conditions of the study area. However, since the findings are based on a single season and location, further research is recommended across multiple seasons, locations, and varying agro-climatic conditions to validate these results and develop location-specific spacing recommendations for sustainable radish production.

AUTHOR'S CONTRIBUTION

Conduct of experiments (MK); Field work and data collection (MK, SG); Analysis of data and interpretation (MK); Preparation of manuscript (MK); Supervision (SKB); Manuscript review and editing (SKB, MK).

DECLARATION

The authors confirm that they do not have any conflicts of interest.

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