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Research Article

Effects of Variety and Organic Mulching on Growth, Yield and Quality of Carrot

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ABSTRACT

An experiment was conducted at the Horticulture Farm and Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during November 2023 to February 2024, to evaluate the effects of variety and organic mulching on the growth, yield, and quality of carrots. The two-factor experiment was laid out in a two-factor Randomized Complete Block Design with three replications. The factor A comprised of three carrot varieties *viz*. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, and V_3 = Improved Shin Kuroda, and Factor B comprised of four organic mulching treatments *viz*., M_0 = No mulching (control), M_1 = Rice straw, M_2 = Water hyacinth, and M_3 = Sawdust. Results revealed significant variations in all the parameters studied. Among the varieties, New Kuroda showed superior performance, producing the highest plant height (63.50 cm), number of leaves (8.77) at 70 DAS, maximum root length (16.40 cm), root diameter (3.30 cm), individual root weight (116.95 g), marketable yield (41.80 t/ha), minimum weight loss (37.01%), higher TSS (17.65 %brix) and shelf life (10.90 days). Among the mulching treatments, rice straw mulch produced maximum plant height (64.28 cm) at 70 DAS, root length (15.70 cm), root diameter (3.23 cm), individual root weight (116.15 g), and marketable yield (41.57 t/ha), minimum weight loss (36.68%), highest TSS (18.87 %brix) and shelf life (10.61 days). Combined effects between variety and mulching were also statistically significant at all stages. The combination of New Kuroda with rice straw mulch performed the best across most traits, producing the tallest plants (65.93 cm), longest roots (17.56 cm), widest root diameter (3.57 cm), the highest individual root weight (965.17 g), and the greatest marketable yield (29.41 t/ha), while the lowest values were recorded from the control treatment. These results suggest that the combined effect of a suitable variety and mulching practice has a synergistic impact on carrot production. Therefore, it can be concluded that the New Kuroda variety with straw mulch was found to be better in respect of growth, yield, and quality of carrot compared to other treatments.

Introduction

Carrot (*Daucus carota* L.) belongs to the family Apiaceae and is one of the most important root vegetables cultivated worldwide, prized for its nutritional value, palatability, and diverse uses in culinary practices. It is grown primarily for its storage root, which is rich in β-carotene (a precursor of vitamin A), antioxidants, dietary fiber, vitamins (especially vitamin K and vitamin C), and essential minerals (Ahmad *et al*., 2020; Arscott and Tanumihardjo, 2010). A single medium-sized carrot can provide more than 200% of the recommended daily intake of vitamin A, making it a valuable food for preventing vitamin A deficiency. Moreover, carrots contain various phytonutrients such as anthocyanins and lutein, which have antioxidant properties that help protect the body from oxidative stress and inflammation. Due to these nutritional qualities, carrot consumption has been widely recommended for improving vision, skin health, and immune function, which is a leading cause of preventable blindness in developing countries (WHO, 2009).

Nowadays, carrots are gaining popularity as a cash crop owing to their increasing demand in urban and rural markets. According to recent agricultural reports (BBS, 2024), in Bangladesh, total carrot production reached approximately 43,396 metric tons of carrots under 2776.52 hectares of land. However, despite its economic importance and increasing consumer demand, carrot production often suffers from suboptimal yield and poor quality due to various agronomic challenges. Among the factors affecting carrot production, the choice of a suitable variety and the use of proper cultural practices play a vital role in determining the overall success of the crop.

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Mulching, particularly with organic materials, is another important agronomic practice that has the potential to enhance crop performance. Organic mulching involves covering the soil surface with biodegradable materials such as straw, leaves, grass clippings, or compost, which helps to improve soil moisture retention, regulate soil temperature, suppress weed growth, and enhance microbial activity (Zhao *et al*., 2020). Recent research has highlighted the significant role of organic mulching in improving carrot growth and yield. Patel *et al*. (2021) demonstrated that application of rice straw mulch increased carrot root yield by up to 20% compared to non-mulched control plots, primarily due to better moisture conservation and temperature regulation. Similarly, Sharma *et al*. (2022) found that mulching with compost improved carrot root quality by enhancing nutrient availability in the soil. Furthermore, organic mulching has been shown to reduce weed competition, which is a common challenge in carrot production, allowing the crop to utilize nutrients more efficiently (Singh *et al*., 2020). The positive effects of mulching on carrot yield and quality have led to its recommendation as a sustainable practice in integrated crop management systems. Therefore, the present study was undertaken to evaluate the performance of different carrot varieties under various organic mulching treatments, to identify the most effective combination for enhancing growth, yield, and quality attributes of carrot.

Materials and Methods

The experiment was conducted at the Horticulture Farm and Postgraduate Laboratory at the Department of Horticulture, Bangladesh Agricultural University, Mymensingh, during the period from November 2023 to February 2024. The soil of the experimental area was sandy loam in texture, belonging to the Old Brahmaputra Floodplain Alluvial Tract (UNDP, 1988). The selected plot was highland, fertile, well-drained, with a pH of 6.7. The experiment was designed to study the effect of variety and organic mulches on the growth, yield, and quality of carrots.

A two-factor experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications, where factor A was considered for variety (V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda), which were collected from the markets of Dinajpur, Ishwardi, Pabna and Siddik Bazar, Dhaka and factor B for organic mulching (M_0 = No mulching (control), M_1 = Rice straw, M_2 = Water hyacinth, M_3 = Saw dust). Three equal blocks were created out of the entire experimental area. After that, each block was further subdivided into 12 plots, for a total of 36 (3 x 4 x 3) unit plots in the experiment. Each unit plot measured 1 m x 1 m. To allow for various intercultural procedures, a spacing of 1 m between the blocks and 0.5 m between two plots was maintained. The land was ploughed and cross-ploughed, followed by laddering, to achieve a good tilth. All weeds and stubble were removed from the field.

During final land preparation, Furadan 5G was applied at a rate of 8 kg ha^{-1} to protect young plants from insect infestation. The experimental plot was treated with the recommended doses of NPKS fertilizers. The entire amount of fertilizers was applied as a basal dose during the final land preparation. Urea was applied in three installments at 30, 45, and 60 days after sowing.

Before sowing, seeds were soaked in water for 24 hours and then enclosed in a thin cloth. To eliminate excess moisture, the soaked seeds were spread on polythene sheets for two hours, promoting rapid germination. Sowing was carried out in lines at a depth of 1.5 cm, with each plot containing four lines spaced 25 cm apart. The sowing took place on 2nd November 2023. After completion of sowing, the experimental plots were subjected to light irrigation and covered by banana leaves for seven days to provide optimum moisture and dark condition to facilitate seed germination.

Mulching materials were applied after seed germination. Three types of organic mulches-rice straw, water hyacinth, and sawdust were used along with a control (no mulch). Each mulch was spread evenly over the plot at about 5 cm thickness, leaving a small gap around seed lines to avoid harming seedlings. Materials were collected, cleaned, air-dried, and maintained throughout the growing season with periodic adjustments for uniform coverage. Standard intercultural practices, including thinning, weeding, and irrigation, were done as and when necessary. The crop was harvested 85 days after sowing of seed.

Data on various parameters were recorded at 10 days intervals starting from 40 days of seed sowing up to 70 days from five random plants under each treatment and replications on growth and yield contributing characters like plant height (cm), number of leaves per plant, root length (cm), root diameter (cm), root weight (g), branched root (%). cracked root (%), yield per hectare (t/ha), marketable yield per hectare (t/ha). After harvesting, five random roots from each treatment were selected and brought to the postgraduate laboratory for determining postharvest quality parameters like total soluble solids (TSS) (%brix), weight loss (%) and shelf life (days).
Vegetative growth of plants was recorded at 40, 50, 60 and 70 DAS (days after sowing). The plant height of each five sample plants was measured in cm by using a

meter scale and the mean was calculated. The number of leaves was recorded by counting all leaves and the mean was calculated.

At harvest, fruit length and diameter were measured using a meter scale (cm) and slide callipers (cm), respectively and the mean was calculated for each treatment. For individual root weight, five uniform roots were taken and measured by a Table Top Electric Balance and expressed in grams (g) and then the mean was calculated.

For the percentage of branched and cracked roots, the number of branched and cracked roots was counted at the time of harvest, and the branching and cracking percentage of roots per plot was calculated by the following formula:

Branched roots (%) =

$$\frac{Number\ of\ branched\ roots}{Number\ of\ total\ roots} \times 100$$

Cracked roots (%) =

$$\frac{Number\ of\ cracked\ roots}{Number\ of\ total\ roots} \times 100$$

For yield, the yield of individual plot (kg/plot) was measured by a Table Top Electric Balance and then it was converted into tons per hectare. For marketable yield of root (t/ha), the weight of carrot roots after discarding the roots damaged by cracking, rotting, and branching was taken from the total yield of roots in kilograms (kg), then it was converted into tons per hectare.

For determining TSS (total soluble solids) (%brix), TSS of roots was taken with the help of a hand refractometer for each treatment and replication at 3-day interval (0, 3, 6, 9 and 12 days during storage) and expressed in %brix. Before measurement, the refractometer was calibrated with distilled water to give a zero reading.

For determining the weight loss, weight of five roots under each treatment and replication was taken at 3-day interval (0, 3, 6, and 12 days during storage) and the percentage was calculated by following the formula:

% Weight loss of root=

$$\frac{Initial\ weight - Final\ weight\ of\ roots(g)}{Initial\ weight\ of\ roots(g)} \times 100$$

For determining the Shelf life (days), the shelf life of roots (days) was determined by visual observation depending on the edibility of roots.

Results and Discussion

Plant height

The effect of variety on plant height was found to be significant at all stages of observation. It was evaluated that the plant height increased progressively with time, irrespective of the variety, but notable varietal differences were observed throughout the growing period. Among the varieties, New Kuroda (V_2) consistently exhibited the highest plant height, attaining 23.26 cm, 48.76 cm, 58.84 cm, and 63.50 cm at 40, 50, 60 and 70 DAS, respectively, while the lowest plant height was observed in Kuroda Improved (V_1) 22.04 cm, 32.93 cm, 56.16 cm and 59.66 cm at 40, 50, 60 and 70 DAS, respectively. Plant height gradually increased with the age of the plant and showed variation due to the genetic attributes of these germplasm (Choudhary *et al*., 2023). The application of different organic mulches significantly influenced the plant height of carrots at all growth stages. It was evaluated that the plant height of carrots increased with the advancement of time and was higher in plots where rice straw mulch was applied. The highest plant height attained with rice straw mulch (M_1) was 24.29 cm, 40.29 cm, 59.81 cm and 64.28 cm at 40, 50, 60, and 70 DAS, respectively, while the lowest plant height was recorded from the control (M_0) treatment, with 21.05 cm, 37.26 cm, 55.32 cm and 59.37 cm at 40, 50, 60 and 70 DAS, respectively. This is consistent with the findings of Jahan *et al*. (2018), who observed that rice straw mulch resulted in higher plant height (30.5 cm). The interaction effect between variety and organic mulching significantly influenced the plant height of carrots at all stages of growth. It was evaluated that the plant height of carrot increased with the advancement of time and was highest when New Kuroda was grown with rice straw mulch. The maximum plant height was recorded from New Kuroda with rice straw mulch (V_2M_1), which attained 25.47 cm, 52.45 cm, 60.87 cm, and 65.93 cm at 40, 50, 60 and 70 DAS, respectively, whereas the lowest plant height was observed in Kuroda Improved with no mulch (V_3M_0), which recorded 20.49 cm, 32.23 cm, 54.43 cm, and 57.08 cm at 40, 50, 60 and 70 DAS, respectively. Similarly, in this study, rice straw mulch consistently showed better growth in all varieties, with the tallest plants observed under the rice straw treatment. The benefits of mulching may be attributed to improved soil moisture retention, temperature regulation, and weed suppression, as noted by Jahan *et al.* (2018) and Hoque *et al.* (2020).

Number of Leaves per plant

The effect of variety on number of leaves per plant was found to be significant at all stages of observation. It was evaluated that the number of leaves per plant increased with the advancement of time and was higher in plots where New Kuroda was grown. The highest number of leaves per plant was recorded from New Kuroda (V_1), which attained 4.08, 6.98, 7.74 and 8.77 at 40, 50, 60, and 70 DAS, respectively, while the lowest number of leaves per plant was observed in Kuroda Improved (V_3) 3.65, 4.83, 7.47 and 7.96 at 40, 50, 60, and 70 DAS, respectively. The variation in leaf numbers between varieties was most likely caused by the rate of leaf commencement, which could be an inherent trait of each variety (Kushwah *et al*., 2019). The application of different organic mulches significantly influenced the number of leaves per plant of carrot at all growth stages. It was evaluated that the number of leaves per plant increased with the advancement of time and was higher in plots where rice straw mulch was applied. The highest number of leaves per plant was recorded from rice straw mulch (M_1), which attained 3.98, 5.84, 8.02, and 8.73 at 40, 50, 60, and 70 DAS, respectively, while the lowest number of leaves per plant was observed in no mulch (M_0), which recorded 3.67, 5.29, 7.13, and 7.83 at 40, 50, 60, and 70 DAS, respectively. Roy *et al*., (1990) stated that straw mulch was reported to increase the leaves number per plant than other mulches. The interaction effect of variety and organic mulching significantly influenced the number of leaves per plant at all growth stages. The highest number of leaves per plant was recorded from the combination New Kuroda with rice straw mulch (V_2M_1), which attained 4.40, 7.47, 8.27, and 9.00 at 40, 50, 60 and 70 DAS, respectively, while the lowest number of leaves per plant was observed in Kuroda with no mulch (V_1M_0) which recorded 3.53, 4.67, 7.53, and 6.83 at 40, 50, 60 and 70 DAS, respectively. Straw mulch might have provided sufficient soil moisture and nutrient to increase leaf number in the variety New Kuroda compared to other treatments.

Table 1. Combined effect of variety and organic mulching on plant height and number of leaves per plant at different days after sowing (DAS) of carrot

Treatment combination	Plant height (cm) at different days after sowing				Number of leaves per plant at different days after sowing			
	40	50	60	70	40	50	60	70
V_1M_0	20.49	32.23	54.43	57.08	3.53	4.67	7.53	6.83
V_1M_1	23.60	34.07	57.87	62.25	3.73	5.00	7.60	8.53
V_1M_2	21.83	32.47	54.94	58.47	3.67	4.73	7.20	8.08
V_1M_3	22.25	32.97	57.38	60.85	3.68	4.93	7.53	8.40
V_2M_0	21.26	46.83	55.97	60.53	3.87	6.53	7.00	8.53
V_2M_1	25.47	52.45	60.87	65.93	4.40	7.47	8.27	9.00
V_2M_2	22.87	47.39	58.33	61.80	3.87	6.73	7.83	8.67
V_2M_3	23.45	48.36	60.20	65.72	4.20	7.20	7.87	8.87
V_3M_0	21.40	32.73	55.57	60.50	3.60	4.67	6.87	8.13
V_3M_1	23.79	34.34	60.70	64.67	3.80	5.07	8.20	8.67
V_3M_2	22.20	32.83	56.45	60.60	3.73	4.90	7.60	8.27
V_3M_3	22.37	33.93	57.57	62.77	3.80	4.93	7.73	8.47
$LSD_{0.05}$	0.23	0.58	0.65	0.70	0.13	0.16	0.14	0.31
$LSD_{0.01}$	0.31	0.78	0.88	0.96	0.18	0.22	0.20	0.42
Level of significance	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

Table 2. Effect of variety on yield and yield contributing characters of carrot

Variety	Root length (cm)	Root diameter (cm)	% cracked root	% branched root	Individual root weight (g)	Gross Yield (t/ha)	Marketable yield (t/ha)
V_1	13.83	4.28	7.8	8.04	619.33	21.56	19.74
V_2	16.63	4.96	2.43	7.73	965.17	30.99	29.41
V_3	15.94	4.82	2.68	9.99	872.17	29.21	27.59
$LSD_{0.05}$	0.18	0.04	0.29	1.02	31.70	0.59	0.20
$LSD_{0.01}$	0.25	0.06	0.40	1.38	43.09	0.81	0.27
Level of significance	**	**	**	**	**	**	**

** = Significant at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

Root length

Root length was found to be statistically significant due to the effects of carrot varieties. The longest root (16.63 cm) was produced by New Kuroda (V_2), whereas the shortest one (13.83 cm) was found from Kuroda Improved (V_1) (Table 3). These results are in an intimate similitude with the findings of Pervez *et al*. (2003) and Pandey and Sharma (2017) who narrated that root length varied significantly among the carrot varieties due to genetic attributes. Root length was also found to be statistically significant due to the effects of organic mulching. The longest root (16.31 cm) was produced by straw (M_1), whereas the shortest one (14.82 cm) was found from control (no mulch) (M_0) (Table 4). Akand (2003) stated that straw mulch influences the root length of the carrot. The root length was significantly influenced by the effect of carrot varieties and organic mulching. The maximum root length (17.40 cm) was obtained from New Kuroda treated with straw mulch (V_2M_1), while the minimum root length (13.27 cm) was observed from Kuroda Improved with no mulch (V_1M_0) (Table 5). The enhanced leaf area and photosynthetic activity in New Kuroda may have contributed to its superior growth performance, which is in line with Alam *et al.* (2019), who reported that New Kuroda produced larger root diameters and higher carotene content compared to other varieties.

Table 3. Effect of organic mulching on yield and yield contributing characters of carrot

Organic mulching	Root length (cm)	Root diameter (cm)	% Cracked root	% Branched root	Individual root weight (g)	Gross Yield (t/ha)	Marketable yield (t/ha)
M_0	14.82	4.54	6.66	16.5	763.78	23.82	22.02
M_1	16.31	4.86	0.86	4.47	882.22	30.48	28.95
M_2	15.09	4.62	3.31	11.39	793.56	26.37	24.69
M_3	15.64	4.74	1.32	11.31	836.00	28.34	26.66
$LSD_{0.05}$	0.21	0.05	0.34	1.18	36.61	0.69	0.23
$LSD_{0.01}$	0.29	0.07	0.46	1.60	49.76	0.93	0.31
Level of significance	**	**	**	**	**	**	**

** = Significant at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

Table 4. Combined effect of variety and organic mulching on yield and yield contributing characters of carrot

Treatment combination	Root length (cm)	Root diameter (cm)	% Cracked root	% Branched root	Individual root weight (g)	Gross Yield (t/ha)	Marketable yield (t/ha)
V_1M_0	13.27	4.18	3.23	3.87	564.33	18.35	16.37
V_1M_1	14.60	4.53	0.00	11.64	729.00	24.90	23.45
V_1M_2	13.53	4.20	2.63	5.57	585.00	19.20	18.10
V_1M_3	13.90	4.22	0.00	11.07	599.00	23.78	21.05
V_2M_0	15.80	4.79	4.07	4.27	887.67	26.83	25.33
V_2M_1	17.40	5.10	1.07	19.88	1030.33	34.03	33.17
V_2M_2	16.27	4.88	2.53	10.63	915.67	31.23	28.87
V_2M_3	17.07	5.09	2.03	11.53	1027.00	31.87	30.25
V_3M_0	15.40	4.65	12.67	4.20	839.33	26.29	24.35
V_3M_1	16.93	4.95	1.50	18.70	887.33	32.50	30.22
V_3M_2	15.47	4.79	4.77	5.73	880.00	28.68	27.11
V_3M_3	15.97	4.90	1.93	11.33	882.00	29.39	28.67
$LSD_{0.05}$	0.36	0.09	0.58	2.04	63.41	1.19	0.39
$LSD_{0.01}$	0.49	0.12	0.79	2.77	86.18	1.62	0.53
Level of significance	**	**	**	**	**	**	**

** = Significant at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

Root Diameter

Significant variation was observed in root diameter among the different carrot varieties. The maximum root diameter (4.96 cm) was recorded by New Kuroda (V_2), whereas the minimum diameter (4.28 cm) was obtained from Kuroda Improved (V_1) (Table 3). This dissimilarity might be due to genetic composition in the expression of growth potentials (Choudhary *et al*., 2023). The diameter of the root was found to be statistically significant due to the effects of organic mulching. The maximum root diameter (4.86 cm) was recorded by straw mulch, whereas the minimum (4.54 cm) was found from the control (no mulch) treatment (M_0) (Table 4). The root diameter was significantly influenced by the effect of carrot varieties and organic mulching. The maximum root diameter (5.09 cm) was obtained from New Kuroda treated with straw mulch (V_2M_1), while the minimum root length (4.18 cm) was observed from Kuroda Improved with no mulch (V_1M_0) (Table 5). The improved moisture retention and aeration provided by straw mulch to a variety New Kuroda might lead to the development of maximum root diameter.

Table 5. Combined effect of variety and organic mulches on total soluble solids (TSS) (%brix) and weight loss (%) at different days after storage of carrot

Treatment combination	TSS at different days after storage (% brix)					Weight loss at different days after storage (%)			
	0	3	6	9	12	3	6	9	12
V_1M_0	13.00	13.80	14.20	15.40	16.00	13.42	25.20	35.35	45.17
V_1M_1	14.50	15.60	16.20	16.80	18.20	10.40	19.84	29.76	39.20
V_1M_2	13.50	13.90	15.40	15.80	16.00	11.26	21.32	31.13	40.26
V_1M_3	13.50	14.50	14.80	15.90	16.80	10.67	20.51	29.92	39.47
V_2M_0	13.50	14.00	15.20	16.00	16.00	10.01	19.38	29.36	38.76
V_2M_1	15.50	15.60	17.40	18.20	19.40	9.44	17.63	26.78	35.14
V_2M_2	14.20	14.80	15.80	17.00	17.20	9.98	18.99	28.79	37.56
V_2M_3	14.50	15.20	15.80	16.50	18.00	9.72	18.87	28.13	36.57
V_3M_0	13.20	13.80	14.40	15.20	15.67	11.45	22.24	33.29	42.88
V_3M_1	14.50	15.60	16.50	18.00	19.00	9.60	18.36	27.38	35.69
V_3M_2	14.00	14.90	15.60	16.20	17.00	11.05	20.12	30.35	40.00
V_3M_3	13.80	15.00	15.20	16.20	17.80	10.47	19.81	29.79	38.81
$LSD_{0.05}$	0.44	0.25	0.27	0.39	0.45	0.20	0.24	0.37	0.34
$LSD_{0.01}$	0.60	0.34	0.37	0.52	0.61	0.28	0.33	0.50	0.46
Level of significance	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

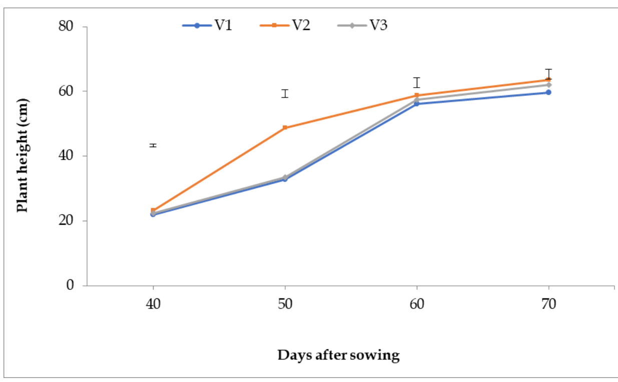

Figure 1. Effect of variety on plant height of carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

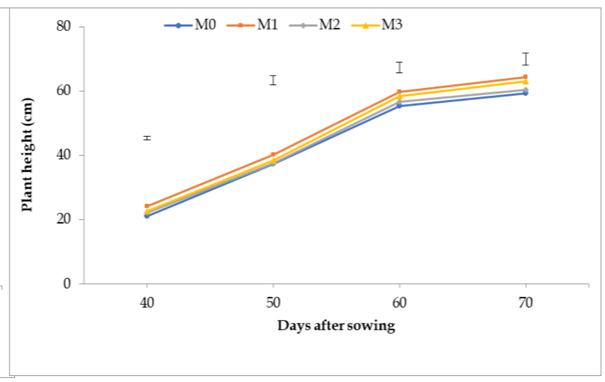

Figure 2. Effect of organic mulching on plant height of carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

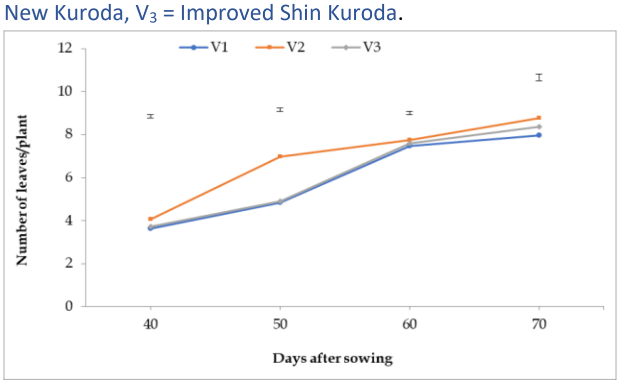

Figure 3. Effect of variety on number of leaves per plant of carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

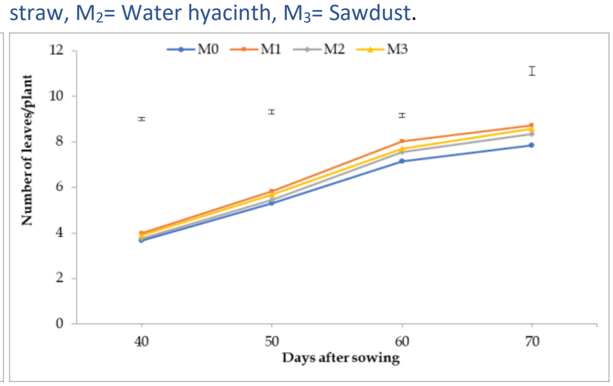

Figure 4. Effect of organic mulching on number of leaves per plant of carrot at different days after sowing. Vertical bars indicate LSD at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

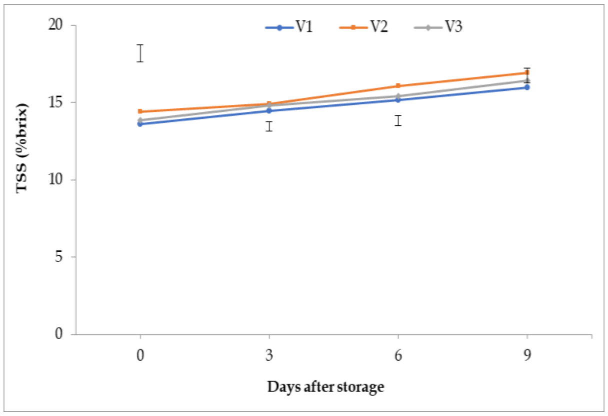

Figure 5. Effect of variety on total soluble solids at different days after storage. Vertical bars indicate LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

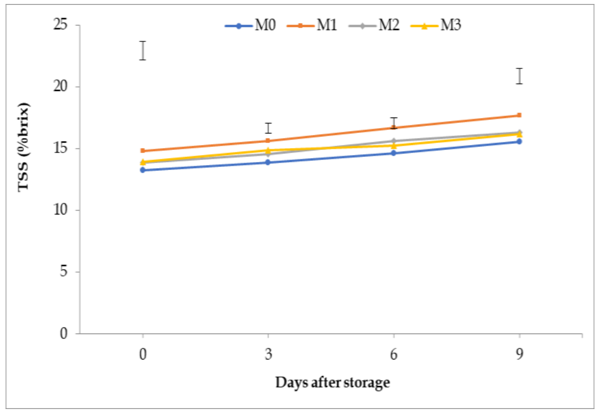

Figure 6. Effect of organic mulching on on total soluble solids at different days after storage. Vertical bars indicate LSD at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

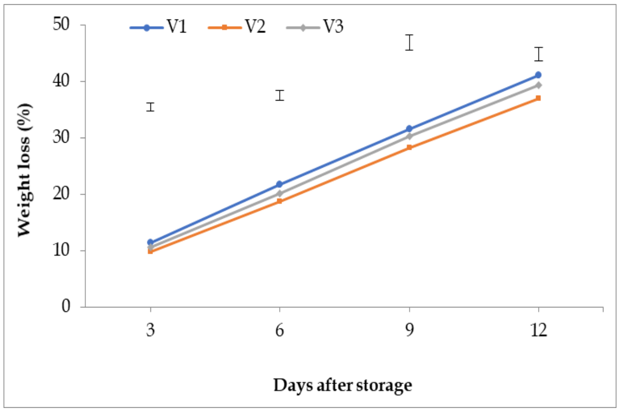

Figure 7. Effect of variety on weight loss at different days after storage. Vertical bars indicate LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

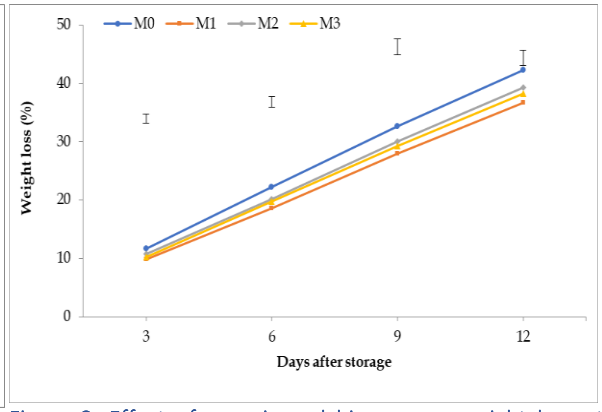

Figure 8. Effect of organic mulching on on weight loss at different days after storage. Vertical bars indicate LSD at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

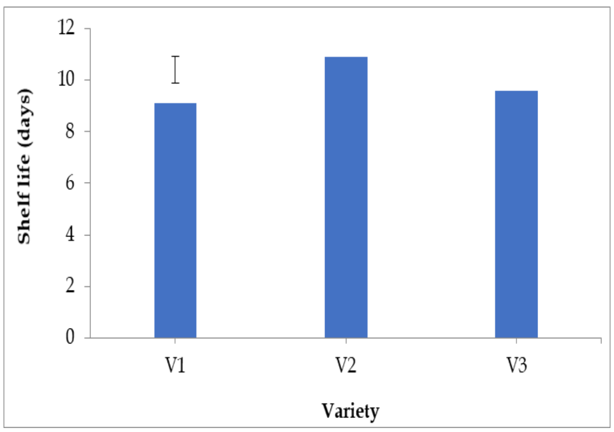

Figure 9. Effect of variety on shelf life of carrot. Vertical bar indicates LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda.

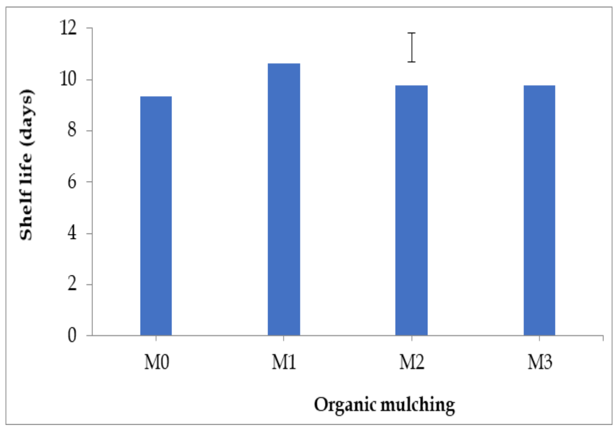

Figure 10. Effect of organic mulching on shelf life of carrot. Vertical bar indicates LSD at 1% level of probability. M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

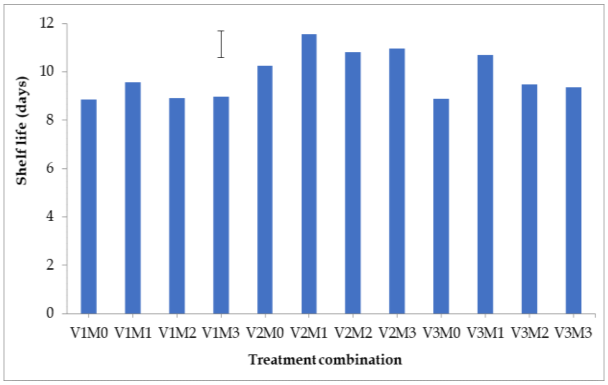

Figure 11. Combined effect of variety and organic mulching on shelf life of carrot. Vertical bar indicates LSD at 1% level of probability. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

Cracked and branched root percentage

Different varieties had significant variations in percentages of cracked and branched roots. New Kuroda (V_2) showed the lowest percentage of cracked roots (2.43%) and branched roots (7.73%), while the highest cracked (7.8%) and branched (9.99%) were recorded from Kuroda Improved (V_1) and Improved Shin Kuroda (V_3), respectively. Organic mulching also had significant effect on the percentage of cracked and branched roots. Rice straw mulch recorded the lowest percentage of cracked roots (0.86%) and branched roots (4.47%). Interaction between varieties and organic mulching had a significant effect on cracked and branched root. Lowest cracked root (0.00%) were recorded from Kuroda Improved treated with rice straw (V_1M_1) and Kuroda Improved treated with saw dust (V_1M_3) respectively and branched root (3.87 %) from Kuroda Improved with no mulch (V_1M_0), and the highest cracked root (12.67%) was obtained from Improved Shin Kuroda with no mulch (V_3M_0) and branched root (19.88 %) from New Kuroda treated with rice straw (V_2M_1). Environmental and management variables altered by the organic mulches might affect the genetic make-up of respective varieties to produce branched and cracked roots (Hartz *et al*., 2004).

Plate 1. Application of organic mulches on the experimental plots

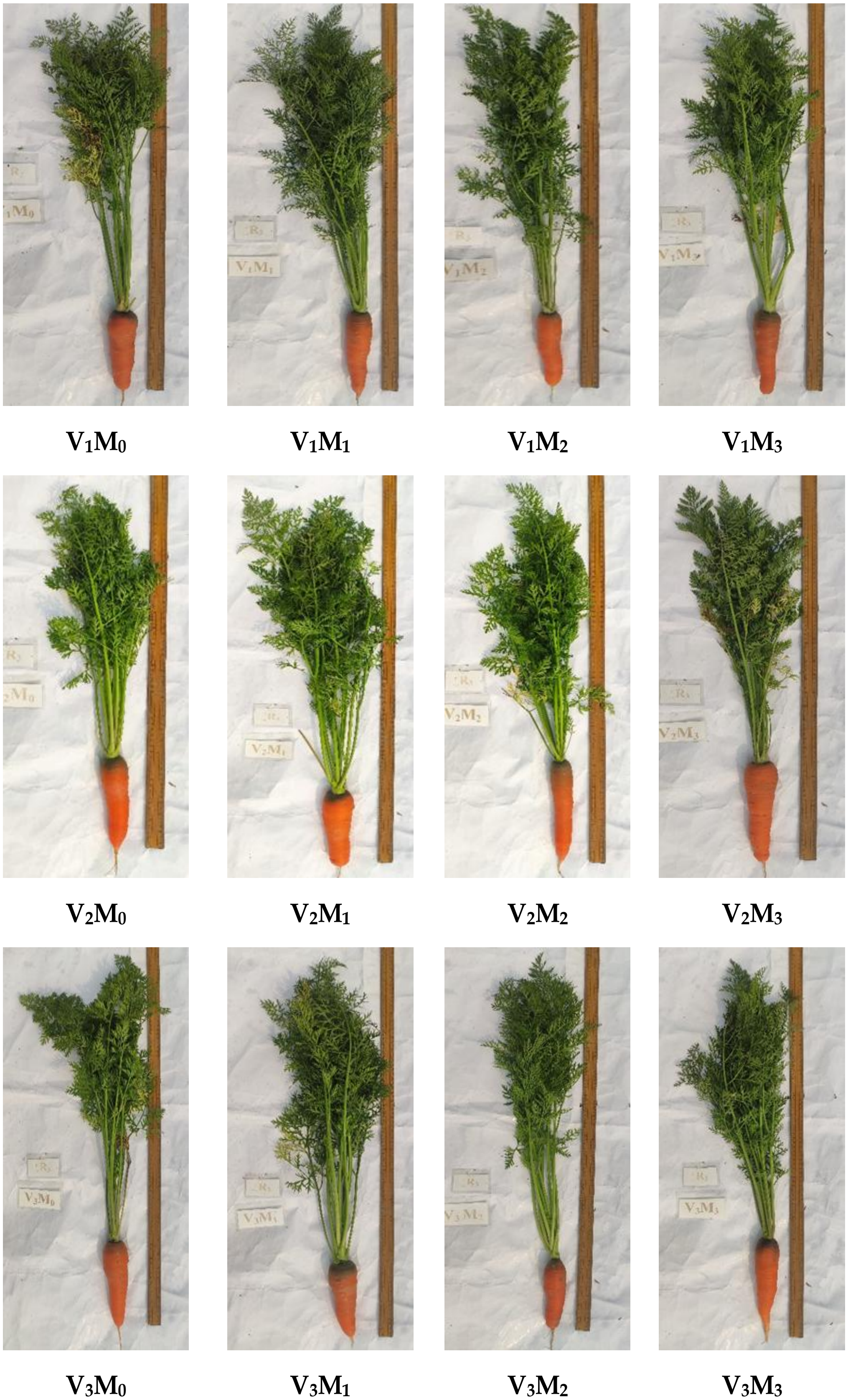

Plate 2. Effects of variety and organic mulching on carrot roots. V_1 = Kuroda Improved (Tokita), V_2 = New Kuroda, V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1=Rice straw, M_2= Water hyacinth, M_3= Sawdust.

Plate 3. Postharvest observation of carrots at 0 days after storage; where V_1 = Kuroda Improved; V_2 = New Kuroda; V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1= Straw, M_2 = Water hyacinth, M_3 = Sawdust.

V_1M_0

V_1M_1

V_1M_2

V_1M_3

V_2M_0

V_2M_1

V_2M_2

V_2M_3

V_3M_0

V_3M_1

V_3M_2

V_3M_3

Plate 4. Postharvest observation of carrots at 3 days after storage; where V_1 = Kuroda Improved; V_2 = New Kuroda; V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1= Straw, M_2 = Water hyacinth, M_3 = Sawdust.

Plate 5. Postharvest observation of carrots at 6 days after storage; where V_1 = Kuroda Improved; V_2 = New Kuroda; V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1= Straw, M_2 = Water hyacinth, M_3 = Sawdust.

Plate 6. Postharvest observation of carrots at 9 days after storage; where V_1 = Kuroda Improved; V_2 = New Kuroda; V_3 = Improved Shin Kuroda; M_0= No mulching (Control), M_1= Straw, M_2 = Water hyacinth, M_3 = Sawdust

Individual root weight

Root weight was found to be statistically significant due to the effects of carrot varieties. New Kuroda (V_2) recorded the highest weight of the individual roots (965.17 g), while the lowest root weight (619.33 g) was form Kuroda Improved (V_1). The maximum diameter of root might have resulted in the largest fresh weight of root New Kuroda (V_2). The individual root weight was found to be statistically significant due to the effects of organic mulching. Rice straw mulch (M_1) was recorded with the highest root weight (882.22 g), and the lowest root weight (763.78 g) was found from control (M_0).

Interaction between varieties and organic mulching had a significant effect on the individual root weight of carrot. Resende *et al*. (2005) reported that mulch materials were technically and economically viable for carrot cultivation. The highest root weight (1030.33 g) was observed from New Kuroda treated with straw mulch (V_2M_1), while the lowest root weight (564.33 g) was obtained from Kuroda Improved with no mulch (V_1M_0). Similarly, Rahman *et al.* (2015) observed that Kuroda Improved had better root length and diameter compared to local varieties, further supporting the higher yield and growth potential of these varieties.

Yield per hectare

Varieties had a significant effect on the yield of carrot roots. Kuroda (V_2) also recorded the highest yield (30.99 t/ha), whereas Kuroda Improved (V_1) produced the lowest yield (21.56 t/ha). Significant variation was also found due to the effects of organic mulching. Rice straw mulch (M_1) recorded for highest yield (30.48 t/ha), while the lowest yield (23.82 t/ha) was found from control (M_0). Yield per hectare was also found to be significant due to the interaction between varieties and organic mulching. New Kuroda treated with straw mulch (V_2M_1) produced the highest yield (34.03 t/ha), while Kuroda Improved with no mulch treatment (V_1M_0) recorded for the lowest yield (18.35 t/ha). This result supports the findings of Hasan *et al*. (2018), who reported that the performance of carrot varieties varied across different mulching treatments.

Marketable yield per hectare

Varieties had a significant effect on the marketable yield of carrot roots. Kuroda (V_2) recorded the maximum marketable yield (29.41 t/ha), whereas Kuroda Improved (V1) produced the lowest yields (gross yield of 21.56 t/ha and marketable yield of 19.74 t/ha). Marketable yield was also found to be significant due to the effects of organic mulches. Rice straw mulch (M_1) recorded for highest marketable yield (28.95 t/ha), whereas the lowest marketable yield (22.02 t/ha) from control (M_0). The combined effect of varieties and organic mulching had significant effect on the marketable yield of the root. New Kuroda with straw mulch (V_2M_1) produced the highest values for marketable yield (33.17 t/ha), while Kuroda Improved with no mulch (V_1M_0) was recorded for the lowest marketable yield (16.37 t/ha). These findings are supported by Ahmed *et al*. (2020), who highlighted that organic mulching reduces mechanical damage and improves the visual appeal of roots, which is crucial for marketability.

Total Soluble Solids (TSS)

Total soluble solids (TSS) content of carrot roots was significantly influenced by variety at all storage intervals. At harvest (0 day), New Kuroda (V_2) exhibited the highest TSS (14.43%). As storage progressed, TSS increased steadily in all varieties, with New Kuroda (V_2) maintaining significantly higher TSS values throughout the 12 days, reaching 17.65% at the end of storage. The lowest TSS at all intervals was recorded in Kuroda Improved (V_1), which reached only 16.75% by day 12. According to Crop Services International (2014), the higher the Brix reading, the better the health and expression of the plant's genetic potential. Total soluble solids (% brix) differ in carrot varieties because of the distinction in their genetic composition. It is consistent with the findings of Kushwah *et al*. (2019) and Singh *et al*. (2020). Organic mulching had a significant effect on the TSS content of carrots at all stages of storage. At harvest (0 day), straw mulch (M_1) showed the highest TSS (14.83%), which consistently increased and peaked at 18.87% by the 12th day of storage, significantly higher than all other treatments. In contrast, the control (M_0) recorded the lowest TSS at each interval, starting at 13.23% and reaching only 15.89% by day 12. Mulching with water hyacinth (M_2) and sawdust (M_3) resulted in intermediate TSS values, with sawdust (M_3) slightly outperforming water hyacinth (M_2) at the end of storage. The interaction between variety and organic mulching significantly influenced TSS content of carrot roots at all storage intervals. The treatment New Kuroda with straw mulch (V_2M_1) exhibited the highest TSS values consistently across all days, starting from 15.50% at harvest and reaching a peak of 19.40% at 12 days. In contrast, control treatments (M_0) under each variety V_1M_0, V_2M_0 and V_3M_0 showed the lowest TSS values throughout storage, with V_3M_0 being the lowest (15.67% at 12 days). Straw mulch might influence the genetic attributes of New Kuroda to enhance sugar retention and accumulation under this combination.

Weight loss

The percent weight loss of carrot roots during storage varied significantly among the varieties at all recorded intervals (3, 6, 9, and 12 days after storage). The variety New Kuroda (V_2) consistently exhibited the lowest weight loss percentages across all storage durations, with values of 9.79%, 18.72%, 28.26%, and 37.01% at 3, 6, 9, and 12 days, respectively. Improved Shin Kuroda (V_3) showed intermediate values but still exhibited significantly higher weight loss than V_2 at all stages. In contrast, Kuroda Improved (V_1) recorded the highest weight loss percentages, reaching 41.03% by the 12th day of storage. Sudimac *et al*. (2012) apprised that the percentage weight loss ranged from 15% to 35% depending on varieties. Organic mulching had a significant influence on the percent weight loss of carrots during storage at all observed intervals. The lowest weight loss percentages were recorded under straw mulching (M_1), with 9.81%, 18.61%, 27.97%, and 36.68% at 3, 6, 9 and 12 days after storage, respectively, while no mulching (M0) resulted in the highest weight loss, reaching 42.27% by the 12th day. The interaction between variety and organic mulching had a significant effect on the percent weight loss of carrots at 3, 6, 9 and 12 days after storage. Among all treatment combinations, the lowest weight loss was recorded in New Kuroda with straw mulch (V_2M_1), with only 9.44%, 17.63%, 26.78%, and 35.14% at 3, 6, 9, and 12 days after storage, respectively. In contrast, the highest weight loss was observed in Kuroda Improved with no mulch (V_1M_0), reaching 45.17% by day 12. This might be due to low rate of respiration and CO_2 evolution during storage under straw mulch than control (Das and Dutta 2018).

The results of this study underscore the importance of both varietal selection and mulching practices in optimizing the growth, yield, and quality of carrots. New Kuroda was the most productive variety, with superior plant height, number of leaves, and root yield. The use of organic mulches, particularly rice straw, significantly improved plant growth, yield, and quality. The interaction between variety and mulching practices was significant, and combining the right variety with the appropriate mulching technique holds great potential for enhancing carrot production in Bangladesh. The findings of this study provide valuable insights for farmers and agricultural researchers in selecting appropriate varieties and mulching practices for sustainable and high-quality carrot production.

Shelf life

The shelf life of carrot roots varied significantly among the three varieties studied. The variety New Kuroda (V_2) exhibited the longest shelf life of 10.90 days, while Kuroda Improved (V_1) had the shortest shelf life of 9.09 days. The shelf life of carrot roots was significantly affected by different organic mulching treatments. Among the treatments, straw mulching resulted in the longest shelf life of 10.61 days, which was significantly higher than all other treatments. The shelf life under sawdust and water hyacinth mulching was 9.76 and 9.75 days, respectively, showing intermediate effects. The shortest shelf life was recorded in the control treatment with 9.33 days. The interaction between variety and organic mulching had a significant influence on the shelf life of carrot roots. Among all treatment combinations, the longest shelf life of 11.56 days was recorded in New Kuroda with straw mulching (V_2M_1), in contrast, the shortest shelf life was observed in Kuroda Improved without mulching (V_1M_1), with only 8.86 days.

Conclusion

The study was undertaken to study the effect of variety and organic mulches on the growth, yield and quality of carrots. Therefore, based on all results, it can be concluded that New Kuroda with straw mulching (V_2M_1) was found to be better in respect of growth, yield and quality compared to other treatments.

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Conflict of interest:

The authors did this research and wrote the article and there is no conflict of interest with other people.

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