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Postharvest Quality and Shelf-Life Performance of Nineteen Carrot Genotypes

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ABSTRACT

Carrots (*Daucus carota* L.) belong to the family Apiaceae, are one of the world's most important root crops. The experiment was conducted at the Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from February-March 2024 to study performance of postharvest quality and shelf life of the nineteen carrot genotypes namely Kuroda, New Kuroda, Kuroda 35, King Kuroda, Shin Kuroda, Kuroda Improved, Shidur, Pusha Keshor, Bankim Keshor, Orange HYV, Brasilia 2007, BAU Gazor 5, Brasilia Agroflora, Prima Agroflora, Gazor lovely, Autumn King 2, Nantes 5, 16´B114-1 and 21408B. Results revealed that carrot genotypes significantly influenced all the parameters under study. The maximum dry matter content (13.39%) and TSS content (23.27% brix) were obtained from Pusha Keshor and 21408B, respectively. The minimum weight loss (14.19%) was observed in Gazor lovely while the maximum weight loss (42.25%) was recorded in 21408B. The highest disease incidence (66.67%) was recorded in Orange HYV, whereas the maximum disease severity (66.52%) was observed in 21408B, and no disease incidence was recorded in Kuroda 35. The longest shelf life (12.14 days) was observed in Kuroda 35 while the shortest (7.08 days) was observed in Orange HYV. Therefore, it can be concluded that Kuroda 35 was found to be better in respect of postharvest quality and shelf life compared to the other carrot genotypes.

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Introduction

Carrot (*Daucus carota*) is a nutritious root vegetables grown annually for edible purpose belonging to the Apiaceae (previously Umbelliferae) family, grown throughout the world. It is a famous crop in the horticultural industry with a high economic and internationally recognized value. It is one of the world's top ten most important vegetable crops in terms of market value and production regions (Sun *et al*., 2020). While carrots are often associated with the Mediterranean region, scientific evidence indicates that they originated in the area of Afghanistan and spread to the Mediterranean by the 10th to 12th centuries (Simon, 1993) and is grown in spring and summer in temperate and during winter in tropical and subtropical countries (Jaysawal *et al*., 2018). Carrots are very versatile in colors such as orange, purple, white, yellow and red, and used in a number of dishes and cultural cuisines across the globe (Sharma *et al*., 2012). Orange carrots are the richest source of β-carotene, which, when consumed, is converted into vitamin A, an essential component of eye health and immunity (Ellison *et al*., 2018; Heinonen, 1990). The carrot storage root is abundant in minerals, antioxidants, and dietary fiber in addition to being a strong source of carotenoids, vitamins, and fiber (Arscott and Tanumihardjo, 2010).

Carrot is an important winter vegetable of Bangladesh with increasing popularity among consumers and high market value for the farmers. According to the Bangladesh Bureau of Statistics (BBS), in the 2022-2023 period, Bangladesh produced 27,000 tons of carrots over 2,428 hectares, resulting in an average yield of 11.13 tons per hectare (BBS, 2024). This might be due to the lack of suitable high-yielding varieties. In addition, a significant number of carrots produced in Bangladesh are damaged due to improper handling and postharvest losses (Hassan, 2010). Major causes of postharvest losses of carrots are high perishability, microbial contamination, loss of water content, pathogen attack during storage and careless handling operations. The perishability of the carrot is associated with the increases in physiological and physico-chemical changes, such as loss of weight, respiration, transpiration, softening of pulp, sugar, and acid contents (Firmin, 1997) and these effects can vary among different carrot varieties. Therefore, the present study aimed to find out the effect of genotype on postharvest quality and shelf life performance of carrot.

Materials and Methods

Experimental material

Nineteen (19) carrot genotypes representing a range of pigmented carrot materials were grown using standard methods of cultivation at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh during the period from October 2023 to January 2024 and harvested at 90 days after planting. Carrot genotypes were Kuroda, New Kuroda, Kuroda 35, King Kuroda, Shin Kuroda, Kuroda Improved, Shidur, Pusha Keshor, Bankim Keshor, Orange HYV, Brasilia 2007, BAU Gazor 5, Brasilia Agroflora, Prima Agroflora, Gazor lovely, Autumn King 2, Nantes 5, 16´B114-1, and 21408B. After collecting the carrots, they were taken to the Postharvest Laboratory for postharvest analysis.

Design and layout of the experiment

The postharvest analysis was conducted at the Postharvest Laboratory of the Department of Horticulture, BAU during the period from January to March 2024. The single-factor experiment was carried out in Completely Randomized Design (CRD) with three replications.

Parameters measured

In the Postharvest Laboratory, representative 10 carrots were taken per each treatment for destructive and nondestructive postharvest analysis at room temperature to observe postharvest behavior. Data on various parameters such as dry matter content (%), weight loss (%), total soluble solids (% brix), disease incidence (%), disease severity (%) and shelf life (days) were measured.

Dry matter content of roots (%)

Roots were cleaned thoroughly immediately after harvest by air drying. In the laboratory, carrots were cut into small pieces and weighted accordingly. Then those were kept in the room temperature for air drying for 1 day and after that kept in the oven for around 3 days at 70-80℃. After complete drying those carrot's genotypes were again weighted and the difference between these two data are the amount of moisture that were evaporated from the carrots and the final weight were the remaining dry matter where water was excluded. The formula used here-

% Dry matter of root = {Constant dry weight of roots (g)/ Fresh weight of roots (g)} ×100

Weight loss (%)

After harvesting, representative sample of all types of carrots were kept in the postharvest laboratory for observing the weight loss characteristics. On average, 10 carrots were kept under observation. At the very first day total weight of all those carrots were measured and after that in every 2 days the weights were measured for the comparison.

% Weight loss = [{Initial weight of carrot (g) – Final weight of carrot (g)}/Initial weight of carrot (g)] ×100

Total soluble solids (%brix)

Brix is a measure of total soluble solids (TSS) in the case of pure sucrose solutions. In this experiment various genotypes were taken and measured the TSS in the harvesting day and 2,4,6,8,10 days after harvesting. Total soluble solids (TSS) content of carrot was determined from fruit juice by using a hand refractometer (Model N-1 α, Atago, Japan). Before measurement, the refractometer was calibrated with distilled water to give a zero reading. One or two drops of the filtrate were placed on the prism glass of the refractometer to obtain the %TSS reading. The reading was multiplied by dilution factor to obtain an original %TSS of the pulp tissues. Since differences in sample temperature could affect the TSS measurement, temperature corrections were made by using the methods described by (Ranganna, 1986).

Disease incidence (%)

Disease incidence means the percentage of samples infected with disease. This is measured by calculating the percentage of carrot infected in each replication. The diseases of carrot were identified symptomatically. The disease incidence was calculated as follows-

% Disease incidence = (Number of infected carrots / Total number of carrots under study) ×100

Disease severity (%)

Disease severity represents the percent diseased portion of the infected sample. The percentage of carrot diseases was recorded from the 2 days after storage. All the infected carrots were selected to determine the percent infected area of carrot. The percentage of area diseased was measured based on eye estimation.

Shelf life (days)

Shelf life of carrot was recorded on the basis of 10 carrots that were kept in the postharvest laboratory and those were observed for how many days they remained edible. Not only this, any disease infestation, fungal attack or other incidence were also observed during this time duration.

Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed using MSTAT computer program. The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by F variance test. The significance of difference between pair of means was tested by the Least Significant Difference (LSD) test at 5 and 1 % levels of probability (Gomez and Gomez, 1984).

Results and discussions

Dry matter content of carrot

In case of percent dry matter of root, there was a significant difference among different genotypes. The highest amount of dry matter was seen in the G_8 (Pusha Keshor) which is 13.39% followed by G_{18}=16´B114-1 (12.36%) and the lowest dry matter content was observed in G_{15} (Gazor Lovely) which is 8.20% (Table 1). According to Mohammadi *et al*., (2020), raw carrots contain about 10.0% dry matter, and according to Nagraj *et al*. (2020) they contain 11.3%. These discrepancies may depend on the degree of maturity of the raw material, the genotype, and the growing conditions. Genetic Traits, growing conditions, maturity duration and cultivation practices influence the Pusha Keshor genotype to bear the highest amount of dry matter content compared to other genotypes.

Total soluble solids

It was found that total soluble solid was significantly influenced by different genotypes. The highest amount of TSS at the very first day of storage was seen in G_9 (Bankim Keshor) which was 16.4 %brix and the lowest was (12.50 %brix) observed in G_5 (Shin Kuroda). But after keeping those carrots in the postharvest laboratory for 10 days, the highest amount of TSS was in G_{19} (21408B) which was 23.27 %brix, followed by G_{18}=16´B114-1 (21.13 %brix) and the lowest TSS content was observed in G_4 (King Kuroda) which was 16.03 %brix (Table 1). There is a strong correlation between TSS and changes in sugar concentration during storage. Fruit dehydration and the conversion of starch and polysaccharides into soluble sugars were likely the causes of a rise in sugars during storage. So, the TSS were different with various genotypes of carrots. The compact growth habit of 21408B allows for efficient nutrient uptake and photosynthesis, further enhancing the accumulation of TSS. In contrast, the Kuroda Improved genotype typically exhibits lower TSS levels, as its breeding has prioritized traits such as yield and disease resistance over sweetness (Singh *et al*., 2022). The genetic makeup and environmental factors influencing the Kuroda Improved genotype may result in a dilution of sugars compared to the 21408B genotype.

Weight loss (%)

Different genotype had significant variation on weight loss of carrot root. At the beginning, the highest weight loss percentage was seen in G_{19} (21408B) which was 10.2% and the lowest weight loss was seen in G_6 (Kuroda Improved) which was 4.72%. At the last day of observation, the highest percentage of weight loss was seen in G_{19} (21408B) which was 42.25%, followed by G_{12}=BAU Gazor 5 (39.48%) and the lowest percentage was in G_{15} (Gazor lovely) which was 14.19% (Table 2). Research indicates that the robust skin structure of the genotype acts as a protective barrier, reducing moisture evaporation and minimizing desiccation (Singh *et al*., 2022). Additionally, the high sugar content and dense cellular structure contribute to its overall firmness, which helps maintain weight and texture over time. Studies have shown that proper post-harvest handling practices, combined with the inherent qualities of the Gazor Lovely genotype, lead to reduced weight loss compared to other genotypes (Singh *et al*., 2022).

Table 1. Effect of genotypes on dry matter content of root and total soluble solids (TSS) at different days after storage of carrot

Genotypes	Dry matter content (%)	Total soluble solids (TSS) at different days after storage of carrot					
		0	2	4	6	8	10
G_1	8.34	13.43	14.63	15.17	17.07	17.53	19.67
G_2	8.93	13.50	15.43	15.43	16.40	17.00	17.23
G_3	9.61	13.63	15.57	15.50	16.23	16.77	17.47
G_4	8.74	14.53	14.53	14.60	15.27	15.50	16.03
G_5	8.37	12.50	13.50	15.17	16.23	16.43	16.37
G_6	8.06	14.63	15.20	15.33	15.33	15.63	15.70
G_7	9.65	14.27	14.40	15.33	15.97	16.27	16.37
G_8	13.39	14.10	16.57	17.13	18.17	19.77	20.00
G_9	9.59	16.40	15.20	15.00	15.23	16.67	16.83
G_{10}	8.37	13.37	12.93	13.23	13.43	14.53	16.23
G_{11}	9.63	14.00	15.17	15.17	16.13	16.40	17.43
G_{12}	10.33	14.10	14.90	15.33	18.20	18.90	17.20
G_{13}	10.78	14.73	14.70	16.37	17.20	17.40	18.13
G_{14}	9.74	14.53	11.57	12.37	16.63	13.57	16.63
G_{15}	8.20	13.50	15.17	15.50	16.17	16.83	17.17
G_{16}	10.29	13.27	15.33	16.17	16.63	17.17	17.33
G_{17}	9.06	14.27	15.27	17.17	18.07	16.30	16.33
G_{18}	12.36	16.07	16.27	17.37	17.37	21.37	21.13
G_{19}	11.67	15.53	16.17	17.53	21.13	23.10	23.27
$LSD_{0.05}$	0.32	0.36	0.24	0.31	0.32	0.28	0.27
$LSD_{0.01}$	0.43	0.49	0.32	0.41	0.44	0.38	0.37
Level of significance	**	**	**	**	**	**	**

** = Significant at 1% level of probability. G_1=Kuroda, G_2=New Kuroda, G_3=Kuroda 35, G_4=King Kuroda, G_5=Shin Kuroda, G_6=Kuroda improved, G_7=Shidur, G_8=Pusha keshor, G_9=Bankim keshor, G_{10}=Orange HYV, G_{11}=Brasilia 2007, G_{12}=BAU Gazor 5, G_{13}=Brasilia Agroflora, G_{14}=Prima Agroflora, G_{15}=Gazor lovely, G_{16}=Autumn King 2, G_{17}= Nantes 5, G_{18}=16'B114-1, G_{19}=21408B)

Table 2. Effect of genotypes on percent weight loss at different days after storage of carrot

Genotypes	Weight loss (%) at different days after storage				
	2	**4**	**6**	**8**	**10**
G_1	6.07	11.25	16.49	19.87	24.14
G_2	6.11	11.55	16.39	20.32	27.50
G_3	5.72	10.29	14.58	17.70	21.78
G_4	5.61	10.48	14.77	18.21	22.64
G_5	5.78	10.77	15.52	18.82	23.20
G_6	4.72	8.78	12.65	15.43	19.77
G_7	5.98	11.21	16.17	19.84	23.86
G_8	6.81	12.08	16.65	20.66	24.53
G_9	6.41	11.61	16.06	19.58	24.59
G_{10}	4.97	9.33	14.07	17.02	20.42
G_{11}	9.20	17.56	22.18	29.76	34.12
G_{12}	8.29	16.21	23.01	27.74	39.48
G_{13}	5.45	10.25	16.78	23.25	26.27
G_{14}	8.51	15.96	19.90	27.48	33.79
G_{15}	3.55	6.90	10.60	11.99	14.19
G_{16}	8.16	16.28	20.82	23.75	28.06
G_{17}	6.33	12.04	16.65	20.22	24.53
G_{18}	8.67	15.82	20.71	25.61	34.63
G_{19}	10.20	18.95	25.91	33.63	42.25
$LSD_{0.05}$	3.18	5.77	8.34	9.90	11.83
$LSD_{0.01}$	4.26	7.80	11.27	13.39	16.00
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability. G_1=Kuroda, G_2=New Kuroda, G_3=Kuroda 35, G_4=King Kuroda, G_5=Shin Kuroda, G_6=Kuroda improved, G_7=Shidur, G_8=Pusha keshor, G_9=Bankim keshor, G_{10}=Orange HYV, G_{11}=Brasilia 2007, G_{12}=BAU Gazor 5, G_{13}=Brasilia Agroflora, G_{14}=Prima Agroflora, G_{15}=Gazor lovely, G_{16}=Autumn King 2, G_{17}= Nantes 5, G_{18}=16'B114-1, G_{19}=21408B)

Disease incidence (%)

The first 6 days of storage, no disease was observed in the carrot sample. But after 8 days, G_{15} (Gazor lovely) and G_{18} (16´B114-1) showed diseases in only one carrot from each genotype. On the last day of observation, the highest disease infestation was observed in G_{19}=21408B (53.33%), followed by G_{15}=Gazor lovely (20%), G_2=New Kuroda (13.33%), G_6=Kuroda improved (13.33%) and G_{10}=Orange HYV (13.33), whereas G_3= Kuroda 35 was observed with no disease (Figure 1).

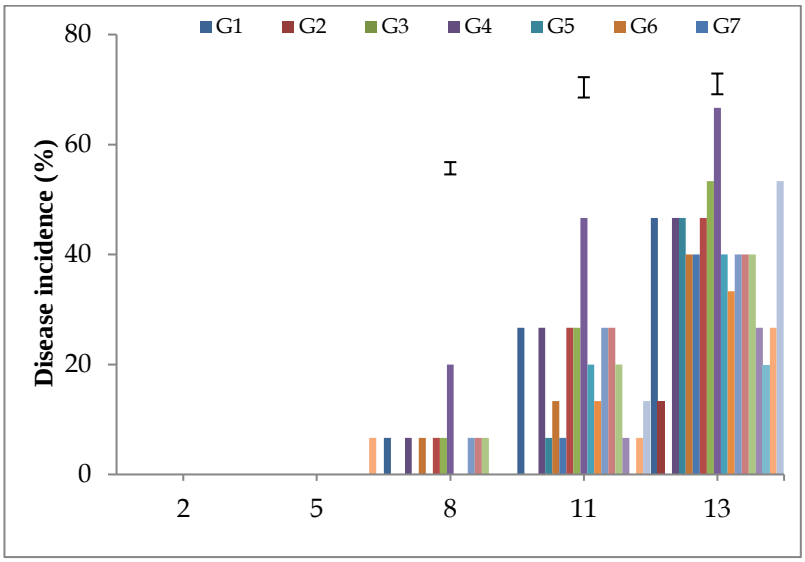


Figure 1. Effect of genotypes on disease incidence of carrot. Vertical bars represent LSD at 5% level of probability

G_1=Kuroda, G_2=New Kuroda, G_3=Kuroda 35, G_4=King Kuroda, G_5=Shin Kuroda, G_6=Kuroda improved, G_7=Shidur, G_8=Pusha keshor, G_9=Bankim keshor, G_{10}=Orange HYV, G_{11}=Brasilia 2007, G_{12}=BAU Gazor 5, G_{13}=Brasilia Agroflora, G_{14}=Prima Agroflora, G_{15}=Gazor lovely, G_{16}=Autumn King 2, G_{17}= Nantes 5, G_{18}=16'B114-1, G_{19}=21408B

Disease severity (%)

It was observed that different genotypes of carrot showed significant variation on disease severity under the present investigation. The highest disease severity (66.52%) was observed in 21408B genotype and no disease was found in Kuroda 35 genotype (Figure 2).

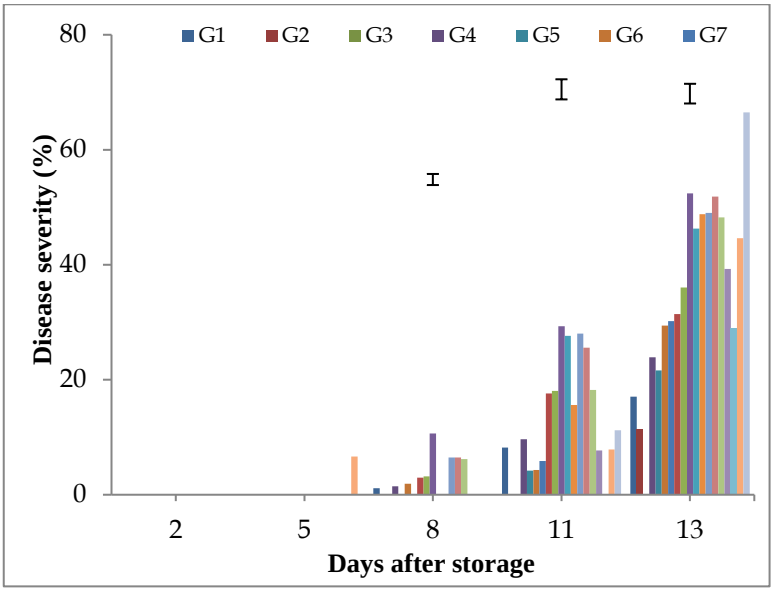


Figure 2. Effect of genotypes on disease severity of carrot. Vertical bars represent LSD at 5% level of probability

G_1=Kuroda, G_2=New Kuroda, G_3=Kuroda 35, G_4=King Kuroda, G_5=Shin Kuroda, G_6=Kuroda improved, G_7=Shidur, G_8=Pusha keshor, G_9=Bankim keshor, G_{10}=Orange HYV, G_{11}=Brasilia 2007, G_{12}=BAU Gazor 5, G_{13}=Brasilia Agroflora, G_{14}=Prima Agroflora, G_{15}=Gazor lovely, G_{16}=Autumn King 2, G_{17}= Nantes 5, G_{18}=16'B114-1, G_{19}=21408B

Shelf life (days)

The variation due to the effect of different genotypes in respect of shelf life was highly significant. Shelf life of carrot was recorded on the basis of 5 carrots that were kept in the Postharvest Laboratory and those were observed for how many days they remained edible. The highest days for shelf life was seen in the G_3 (Kuroda 35) genotype which is 12.14 days followed by G_2=New Kuroda (11.45 days) and the lowest days for shelf life was seen in G_{10} (Orange HYV) which is 7.08 days (Figure 3). Carrots undergo a number of chemical changes while being stored, including the release of flavors and changes to their texture, color, and sensory properties as they reduce sugars from sucrose and become simple sugars from polysaccharides (Ademosun *et al*., 2024). Because of these properties, the shelf life differs from one genotype to another. Kuroda 35 might possess a high concentration of antioxidants, which help maintain quality and prevent degradation during storage. Effective postharvest handling practices, such as optimal temperature and humidity control, further enhance the shelf life of this genotype by slowing down metabolic processes (Hassan, 2010).

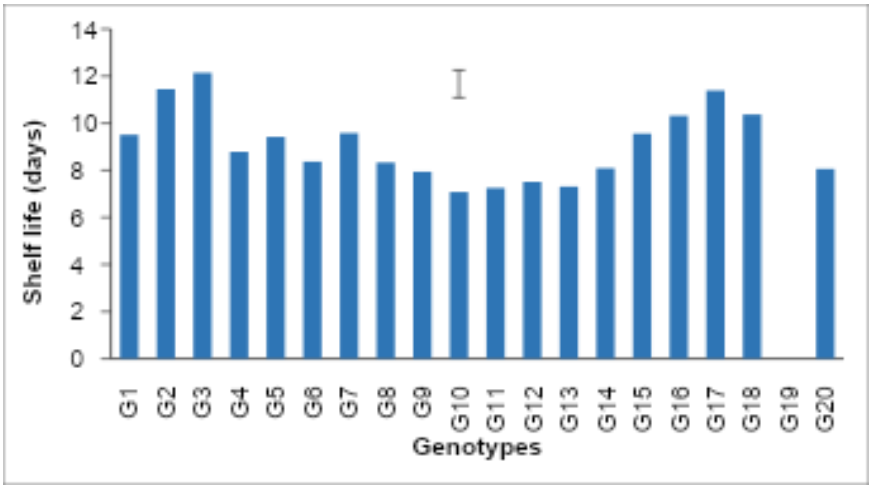


Figure 3. Effect of genotypes on shelf life of carrot. Vertical bar represents LSD at 5% level of probability

G_1=Kuroda, G_2=New Kuroda, G_3=Kuroda 35, G_4=King Kuroda, G_5=Shin Kuroda, G_6=Kuroda improved, G_7=Shidur, G_8=Pusha keshor, G_9=Bankim keshor, G_{10}=Orange HYV, G_{11}=Brasilia 2007, G_{12}=BAU Gazor 5, G_{13}=Brasilia Agroflora, G_{14}=Prima Agroflora, G_{15}=Gazor lovely, G_{16}=Autumn King 2, G_{17}= Nantes 5, G_{18}=16'B114-1, G_{19}=21408B

G1: Kuroda

G2: New Kuroda

G3: Kuroda 35

G4: King Kuroda

G5: Shin Kuroda

G6: Kuroda Improved

G7: Shidur

G8: Pusha Keshor

G9: Bankim Keshor

G10: Orange HYV

G11: Brasilia 2007

G12: BAU Gazor 5

G13: Brasilia Agroflora

G14: Prima Agroflora

G15: Gazor Lovely

G16: Autumn King 2

G17: Nantes 5

G18: 16´B114-1

G19: 21408B

Plate 1. Pictorial view of the carrot in the storage at 2 days

G_1: Kuroda

G_2: King Kuroda

G_3: Kuroda 35

G_4: King Kuroda

G_5: Shin Kuroda

G_6: Kuroda Improved

G_7: Shidur

G_8: Pusha Keshor

G_9: Bankim Keshor

G_{10}: Orange HYV

G_{11}: Brasilia 2007

G_{12}: BAU Gazor 5

G_{13}: Brasilia Agroflora

G_{14}: Prima Agroflora

G_{15}: Gazor Lovely

G_{16}: Autumn King 2

G_{17}: Nantes 5

G_{18}: 16´B114-1

G_{19}: 21408B

Plate 2. Pictorial view of the carrot in the storage at 5 days

G_1: Kuroda

G_2: King Kuroda

G_3: Kuroda 35

G_4: King Kuroda

G_5: Shin Kuroda

G_6: Kuroda Improved

G_7: Shidur

G_8: Pusha Keshor

G_9: Bankim Keshor

G_{10}: Orange HYV

G_{11}: Brasilia 2007

G_{12}: BAU Gazor 5

G_{13}: Brasilia Agroflora

G_{14}: Prima Agroflora

G_{15}: Gazor Lovely

G_{16}: Autumn King 2

G_{17}: Nantes 5

G_{18}: 16´B114-1

G_{19}: 21408B

Plate 3. Pictorial view of the carrot in the storage at 8 days

G1: Kuroda

G2: King Kuroda

G3: Kuroda 35

G4: King Kuroda

G5: Shin Kuroda

G6: Kuroda Improved

G7: Shidur

G8: Pusha Keshor

G9: Bankim Keshor

G10: Orange HYV

G11: Brasilia 2007

G12: BAU Gazor 5

G13: Brasilia Agroflora

G14: Prima Agroflora

G15: Gazor Lovely

G16: Autumn King 2

G17: Nantes 5

G18: 16´B114-1

G19: 21408B

Plate 4. Pictorial view of the carrot in the storage at 11 days

G_1: Kuroda

G_2: New Kuroda

G_3: Kuroda 35

G_4: King Kuroda

G_5: Shin Kuroda

G_6: Kuroda Improved

G_7: Shidur

G_8: Pusha Keshor

G_9: Bankim Keshor

G_{10}: Orange HYV

G_{11}: Brasilia 2007

G_{12}: BAU Gazor 5

G_{13}: Brasilia Agroflora

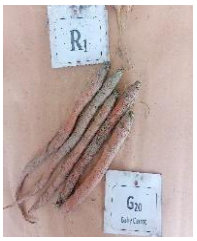
G_{14}: Prima Agroflora

G_{15}: Gazor Lovely

G_{16}: Autumn King 2

G_{17}: Nantes 5

G_{18}: 16´B114-1



G_{19}: 21408B

Plate 5. Pictorial view of the carrot in the storage at 13 days

Conclusion

The experiment was conducted at the Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from January-March 2024 to study the performance of postharvest quality and shelf life of nineteen carrot genotypes. Experimental results revealed that, TSS content was the highest in 21408B and the lowest was in Kuroda improved but it varies among the Orange HYV, Prima Agroflora. The highest weight loss was observed in 21408B and the lowest was in Gazor lovely. It was found that the longest shelf life was in Kuroda 35 and Orange HYV was the fastest genotype to deteriorate. Therefore, it can be concluded that Kuroda 35 was found to be better in respect of postharvest quality and for shelf-life performance compared to other genotypes.

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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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