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Research Article

Evaluation of carrot varieties for morphological traits, yield attributes and nutritional profile in Bhaktapur, Nepal

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ABSTRACT

Carrot is an important root vegetable and commonly used as a snack, part of salads, cooked in curries and used in making pickles. A research was carried out to evaluate the performance of different carrot varieties for their morphological traits, yield attributing characters and nutritional parameters from Feb 2023 to June 2023 at Thimi Municipality-2, Bhaktapur. There were five carrot varieties such as Nepa Dream, Red Champion, Sigma, SK3, and New Kuroda. The experimental design was Randomized Complete Block Design with four replications. Results showed that there were significant differences in growth parameters, morphological characters, and nutrient composition. Nepa Dream showed the greatest root length (25.24 cm), weight (100.25 g), total yield (27.48 t/ha), βcarotenoid (12.34 mg/100 g), dry matter (12.35%) and TSS (11.25 ºBrix). New Kuroda had the maximum plant length (78.17 cm). The results of the current study showed that varieties differed significantly for morphological traits, yield attributes and other nutritional aspects. Nepa Dream was found to be the appropriate variety in terms of yield, TSS, β-carotene and dry matter content for growing at Thimi, Bhaktapur, Nepal. Among other varieties, SK3 seemed to be the promising for its overall traits and so it needs to be further tested over multiple seasons and locations.

Keywords: Carrot, morphology, nutrition, yield

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INTRODUCTION

Carrot (*Daucus carota* L., 2n=18) is a popular root crop cultivated both in tropical and temperate regions. In the culinary world, it is used as a snack, part of salads, cooked in curries and used in making pickles as well. It is one of the key root vegetables full of bioactive substances like carotenoids and dietary fiber, as well as considerable amounts of other functional elements with vital health-promoting effects (Sharma *et al.*, 2012). Also, nutrients like protein, carbohydrates, fiber, vitamin A, potassium, and salt are present in large proportions (Ahmad *et al.*, 2005). Specifically, carrots are a rich source of β-carotene and contain appreciable amount of thiamine and riboflavin (da Silva Dias, 2014). Furthermore,

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the bright orange color of carrots is due to the antioxidant β-carotene. During digestion, β-carotene is absorbed in the intestines and changed into vitamin A (Singh *et al.*, 2021). Carotenoids, particularly β-carotene, are a significant dietary supply of vitamin A for many communities in underdeveloped nations (Ahmad *et al.*, 2005). Researchers have suggested that consumption of carrots might lead to reduced risk of heart diseases, stomach diseases, and several types of cancer (Zhang & Hamauzu, 2004). Specially, the carotenoids, flavonoids, polyacetylenes, vitamins, and minerals in carrots act as antioxidants, and can neutralize the effect of free radicals and inhibit mutagenesis activity thereby contributing to decrease risk of some cancers. These antioxidants are known to act as anticarcinogens, immune-enhancers, anti-diabetic, reduce cholesterol and cardiovascular disease, anti-hypertensive, hepato-protective, reno-protective, and wound healing benefits (da Silva Dias, 2014).

Carrot consumption is gradually rising not only in Nepal but throughout the world due to its reputation for being a good source of naturally occurring antioxidants with anticancer potential (Sharma *et al.*, 2012) . In some parts of Nepal, carrot production serves as a source of revenue and a potent tool for reducing poverty (Bhattarai *et al.*, 2017). It is widely cultivated and consumed as a vegetable with high nutritional and economic value. The diverse agro-climatic conditions of Nepal open up unlimited scope for seasonal and off-seasonal cultivation of carrots. Carrot is the most important crop of the Bhaktapur district, owing to its cultivation throughout the year. The cool climate of this region suits the carrot cultivation. Farmers in this area are practicing intense all year-round cultivation of carrot due to favorable soil and climate. Yield of carrot is 18.75 Mt/ha in Bhaktapur (Agriculture Statistics 2077/78). However, there is limited research regarding the choice of carrot cultivar in terms of yield, morphological features, and nutritional benefits to this particular region. Farmers are facing the problem of getting desirable varieties during planting season and selecting new hybrids that are available in the market cannot ensure the quality of consumer's choice product. Growth characters of carrots and their nutritional components are essential factors that influence consumers' perception and their purchase. Varietal development and continuous evaluation are needed for providing sufficient varietal options for the producers (Tiwari *et al.*, 2015).

The effectiveness of agricultural inputs primarily depends on seed, which in turn determines agricultural productivity. A vital element in producing good quality carrots is choosing the appropriate varieties of seed. Hence, the study on varietal trial of carrot in Bhaktapur is multifaceted and holds significant promise for local farmers. This experiment may help to increase agricultural yields and nutritional quality, two factors crucial to ensuring food security and raising the standard of living for local farmers. The objective of this study is to evaluate the morphological traits, yield attributes and nutritional aspects of different carrot varieties under the unique agro-climatic circumstances of Bhaktapur. The finding of this study will provide valuable information for carrot growers in this region to make more informed decision regarding the selection of a variety.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted to evaluate different carrot cultivars for their morphological, yield and nutritional characters. The study was carried out during Feb to June

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2023. The field study was conducted at Thimi Municipality, Ward No. 2, Bhaktapur (27.68º N latitude and 85.36º E longitude). The site was purposively selected as it is in region of *Manohara Corridor*, which has carrot production throughout the year. During the research period, the site experienced maximum temperature of 33º C in May-June and minimum temperature of 7º C in March (DHM, 2023). The region received an average annual precipitation of 1559 mm most of which was during the months of June-July.

Experimental Design and Treatment Details

The experiment was conducted in Randomized Complete Block Design (RCBD) with five treatments and four replications. Treatments (T) included five carrot varieties namely; T1 (Nepa Dream), T2 (Red Champion), T3 (Sigma), T4 (SK3) and T5 (New Kuroda). The individual plot size was 1.05 m^2 (1.5 m × 0.7 m). The total experimental area was 44.55 m^2. Spacing of 0.5 m was kept between the treatments and 0.7 m between the replications. There was a total of 20 plots, each plot had 7 rows and 5 columns. A single plot consisted of 35 carrot plants sown at a spacing of 10 cm between plants and 30 cm between rows.

Cultural Practices

The field was prepared by tilling four times to make the soil loose and ensure less interference in carrot root development. Sowing was done on March 1st, 2023 into raised beds. A row to row spacing of 30 cm and plant to plant spacing of 10 cm was maintained as recommended by Agriculture Diary (2079). Since carrot is a heavy feeder, the field was supplied with farm yard manure (FYM) at 1500 kg/ropani (equivalent to 29.5 t/ha) and Urea-Diammonium phosphate (DAP)-Muriate of Potash (MOP) at 5 kg/ropani (equivalent to 100 kg/ha) each as recommended by (Agriculture Diary 2079). The plants were thinned to maintain the optimum plant stand at seedling stage i.e., 30 days of sowing (DAS). Weeding was done manually at 15 DAS, 30 DAS, 45 DAS, and 60 DAS throughout the plots. The field was irrigated periodically throughout the experiment. Finally, harvesting was done manually on June 10.

Data Collection

Data pertaining to yield attributes and morphological traits were taken immediately after harvest. On the other hand, data related to nutritional profile of carrots were taken 2 days after harvest. Analysis of nutritional parameters were performed in laboratory of National Horticulture Research Division, NARC, Khumaltar.

Morphological Traits

Total of 10 sample plants were selected from each plot. Plant and root length were measured in centimeter (cm) from shoot to root tip and from shoulder to root tip respectively by using measuring tape. Similarly, root girth was measured in mm at shoulder of the carrot by using Vernier Caliper. On the other hand, root weight was measured in grams using weighing scale and the number of leaves per carrot plant was manually recorded.

Yield Attributes

The yield of carrots immediately after the harvest was recorded from each plot as total yield in kg. The total weight of marketable roots (carrots without any splits, cavities and deformities) from each plot was recorded. Roots which were not marketable due to growth defects (roots with splits, cavities and other deformities) gave total unmarketable yield. First,

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yield data were taken in kg/plot and later converted to t/ha.

Nutritional Parameters

Dry matter content of carrot was determined by using Oven Dry method.
To calculate the dry matter content, below formula was used:

$$\text{Dry Matter Content (\%)} = \frac{\text{Weight of oven dry carrots}}{\text{Weight of fresh carrot samples}} \quad \ldots\ldots\ldots\ldots\ldots\ (1)$$

Total soluble solids (TSS) was determined using digital Acid-Brix meter (Manufactured by ATAGO Company). Carrots were randomly selected from each treatment, peeled and then juice was extracted with a blender. Carrot juice was dropped onto the prism of refractometer and Total Soluble Solids as ^{0}Brix displayed by the instrument was recorded. The ascorbic acid content of the carrot was measured by volumetric method as per Sadasivam and Manickam (1992).

5 mL of the working standard was pipette out into a 100 mL conical flask. 10 mL of 4 % oxalic acid was added and titration was done against the dye (V1 mL). The amount of the dye consumed till end point as represented by the appearance of pink coloration was equivalent to the amount of ascorbic acid. 2 mL sample carrot juice was dissolved in 10 mL of 4 % oxalic acid and was centrifuged. 5 mL of this supernatant was pipette out to which 10 mL of 4 % oxalic acid was added and titration was done against the dye (V2 mL).
The titration was done using 2, 6-dichlorophenol indophenol. Then, below formula was used to calculate the ascorbic acid content.

$$\text{Amount of ascorbic acid (mg/100g sample)} = \frac{0.5\ \text{mg} \times V2 \times 100\ \text{mL} \times 100}{V1\ \text{mL} \times 5\ \text{mL} \times \text{weight of the sample}} \quad \ldots\ldots\ldots\ldots..2)$$

Where, V_1= amount of dye consumed during the titration
V_2= amount of dye consumed when the supernatant was titrated with 4% oxalic acid

B-Carotene content was determined as per Ranganna (1986*)*. The method is based upon the separation of the biologically active carotenoid pigments from the total carotenoid pigments in an extract by using an adsorbent having varying affinities for the different pigments.

I. Preparation of Extract
5 g of sample was taken and 62.5 mL of acetone was added into the sample. It was then blended for 5 minutes, followed by filtration using a filter paper. The residue was washed with acetone until the filtrate became colorless.

II. Preparation of Methanolic KOH
20 g of KOH was dissolved in 100 mL methanol in a volumetric flask (exothermic reaction).

III. Preparation of 10% Sodium sulphate
10 g of sodium sulphate was dissolved in 100 mL distilled water.

IV. Separation
The obtained colorless filtrate from Step (I) was transferred into a separating funnel. 25 mL

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Petroleum ether was added to the filtrate, followed by 10 mL of 10% Sodium sulphate (Na_2SO_4). Then the separating funnel was well shaken and lower phase (i.e. lower layer) was drawn into the second separating funnel. (Note: Upper phase contained β-carotene and lower phase contained residual amount of β-carotene). After that, 25 mL petroleum ether was added to the second funnel. It was well shaken and lower phase was drawn. The upper layer was pooled with ether extract in the second separating funnel. 12.5 mL of acetone was added to it. It was again well shaken and lower phase was finally discarded. Then, 12.5 mL of methanolic KOH was added and well shaken. Again, the lower phase was discarded and 80 mL of distilled water was added to it. Lower layer was discarded after shaking the funnel well. Finally, the extract was filtered through Whatman filter paper and volume was made up to 100 mL in a volumetric flask with Petroleum ether. Thus, obtained final extract was well shaken and the absorbance of sample was measured at 450 nm against β-carotene standard.

V. Preparation of Standard β-carotene

25 g of β-carotene was taken and then dissolved in 2.5 mL of chloroform. The volume was then made up to 250 mL by petroleum ether.

This gave standard concentration of = 0.0001 g/mL = 0.1 mg/mL = 100 µg/mL

Blank = 3 mL acetone in 97 mL Petroleum ether

Standard solution of 5 µg/mL was prepared by mixing 0.5 mL of Standard β-carotene solution (concentration of 100 µg/mL) and 9.5 mL of Petroleum ether.

Similarly, other standard solutions of 10 µg/mL, 15 µg/mL, 20 µg/mL, 25 µg/mL, 30 µg/mL, 35 µg/mL, 40 µg/mL, 45 µg/mL and 50 µg/mL were prepared.

The intensity of color was measured at 450 nm using 3% acetone in petroleum ether as blank by placing the sample in a cuvette inside spectrophotometer.

Following formula was used to determine β-carotene content:

µg of carotene per 100 g=

$$(\text{conc. of carotene in solution as read from standard curve } (\mu g/mL) \times \text{Final Volume} \times \text{Dilution } \times 100)/(\text{weight of the sample})$$

Statistical Analysis

The data obtained from the experimental plots on various parameters mentioned above were statistically analyzed to find out the effects of treatments. The recorded data was tabulated in Microsoft Excel and further analyzed by using R-Studio (version 4.0.2). Significance was determined at $P \leq 0.05$ and Duncan's Multiple Range Test (DMRT) was employed to find out the significant differences between the mean values.

RESULTS

Morphological traits

Morphological traits like plant length, root length, root girth, root weight and number of leaves were recorded. The result of analysis of all these parameters is presented in Table 1. The effect of varieties on plant length was found significantly different ($P< 0.001$). Maximum plant length was observed in New Kuroda (78.17 cm). The result showed significant varietal effect on root length, root girth and root weight (Table 1). Nepa Dream was found to have the maximum root length of 25.24 cm among all the varieties. All other varieties recorded similar

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root length. The maximum root girth was recorded in Nepa Dream (37.85 mm) and New Kuroda (37.80 mm) with only numerical differences between them. Alternatively, Sigma (30.61 mm) had smallest root girth. Nepa Dream was found to have the maximum root weight (100.25 g). The varietal effect on number of leaves was not significant.

Table 1: Morphological traits of carrot influenced by varieties at Thimi, Bhaktapur, 2023

Treatments	Plant length(cm)	Root length (cm)	Root Girth (mm)	Root weight (g)	No. of leaves/plant
Nepa Dream	74.48^{b}	25.24^{a}	37.85^{a}	100.25^{a}	9.75
Red Champion	76.68^{ab}	21.38^{b}	32.89^{bc}	66.63^{b}	11.63
Sigma	64.86^{c}	21.90^{b}	30.61^{c}	82.13^{b}	9.13
SK3	76.51^{ab}	21.75^{b}	35.77^{ab}	80.38^{b}	12.18
New Kuroda	78.17^{a}	22.49^{b}	37.80^{a}	66.25^{b}	13.40
Grand Mean	74.14	22.55	34.98	79.13	11.22
LSD(0.05)	3.15	1.85	3.34	15.86	
SE_m(±)	0.46	0.27	0.48	2.30	
Significance	***	**	**	**	ns
CV %	2.76	5.33	6.19	13.01	

CV: Coefficient of Variation: *, ** and *** represents significance at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively; ns: Not Significant; SEm: Standard error of mean; LSD: Least Significant Difference at 5% level of significance. Means (±standard error) in columns not sharing the same letters are significantly different according to LSD test ($p = 0.05$).

Yield Attributes

The effect of varieties on yield attributes i.e., total yield and marketable yield was found to be significantly different (P<0.05). Unmarketable yield was found to be insignificant. Highest yield was recorded highest in Nepa Dream, followed by Sigma and SK3 (Table 2). The lowest yield was recorded in Red champion and New Kuroda.

Table 2: Yield Attributes of carrot influenced by varieties at Thimi, Bhaktapur, 2023

Treatments	Total yield (t/ha)	Marketable yield (t/ha)	Unmarketable yield (t/ha)
Nepa Dream	27.48^{a}	25.71^{a}	1.76
Red Champion	20.92^{b}	16.63^{b}	4.28
Sigma	22.58^{ab}	20.88^{ab}	1.70
SK3	22.18^{ab}	20.40^{ab}	1.77
New Kuroda	18.38^{b}	16.51^{b}	1.87
Grand Mean	22.31	20.03	2.27
LSD(0.05)	5.59	5.98	
SE_m(±)	0.81	0.87	
Significance	*	*	Ns
CV %	16.27	19.38	

CV: Coefficient of Variation: *, ** and *** represents significance at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively; ns: Not Significant; SEm: Standard error of mean; LSD: Least Significant Difference at 5% level of significance. Means (±standard error) in columns not sharing the same letters are significantly different according to LSD test ($p = 0.05$).

Nutritional Parameters

The effect of varieties on TSS was found to be significantly different (P<0.05). Maximum

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TSS was found in Nepa Dream (11.25 ºBrix) and SK3 (11.13 ºBrix). The lowest TSS was recorded in Sigma (9.9 ºBrix) and New Kuroda (9.93 ºBrix). The varieties had no impact on ascorbic acid Content ($p<0.05$) (Table 3).The β-carotene content was significantly different among carrot varieties ($P<0.001$). Highest β-Carotene content was found in Nepa Dream (12.34 mg/100 g sample) which was significantly par with SK3 (10.61 mg/100 g sample). Variety Red Champion had the lowest amount of beta carotene (7.31 g/100 g).

The effect of varieties on dry matter was found to be significant ($P<0.01$). Maximum dry matter content was found in variety Nepa Dream (12.35%), followed by SK3 (12.02%) and Sigma (10.56). The least dry matter was recorded in variety New Kuroda (9.37%) and Red Champion (9.51%).

Table 3: Nutritional characters of carrot influenced by varieties at Thimi, Bhaktapur, 2023

Treatments	TSS (ºBrix)	Ascorbic Acid (mg/100g)	Beta Carotene (mg/100g)	Dry Matter (%)
Nepa Dream	11.25^{a}	5.21	12.34^{a}	12.35^{a}
Red Champion	10.53^{ab}	2.72	7.31^{d}	9.51^{c}
Sigma	9.9^{b}	3.85	9.26^{bc}	10.56^{bc}
SK3	11.13^{a}	4.99	10.61^{b}	12.02^{ab}
New Kuroda	9.93^{b}	5.44	9.17^{c}	9.37^{c}
Grand Mean	10.55	4.44	9.74	10.76
LSD(0.05)	1.07		1.37	1.77
$SE_m(\pm)$	0.15		0.20	0.25
Significance	*	ns	***	**
CV,%	6.61		9.15	10.41

CV: Coefficient of Variation: *, ** and *** represents significance at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively; ns: Not Significant; SEm: Standard error of mean; LSD: Least Significant Difference at 5% level of significance. Means (±standard error) in columns not sharing the same letters are significantly different according to LSD test ($p = 0.05$).

DISCUSSION

Carrots are an important crop produced in Bhaktapur region, Nepal. However, there is a research gap in the performance of current available varieties to growers. The results of the current study showed that varieties significantly affect morphological traits. The maximum root weight, girth and length was noted in Nepa Dream Variety in our study. On the other hand, Nepa Dream recorded maximum plant length in their study, which contradicts with the current study as plant height was maximum in New Kuroda. Additionally, similar results to that of the current study in terms of the number of leaves (11.53) and the mean root girth (3.3 cm) was found in the research done by Biratu *et al.* (2022). When it came to yield attributes, Nepa Dream also had higher yield (Table 2). The genetic composition of the variety could have attributed this yield difference. Genetic diversity plays major role for a species' adaptation to different agroecology. For our study, its plausible that Nepa Dream exhibited better adaptation to the environment of Bhaktapur, Nepal. In contrast, Varietal difference didn't have a significant effect on the yield attributes in the study done by Merlin *et al.* (2020). The result showed that there was significant influence of varieties on different nutritional parameters. Nepa Dream and SK3 had the highest TSS, followed by Red Champion, New Kuroda and Sigma. Carrot quality is influenced by both biotic and abiotic elements throughout the whole production cycle, from seed to the final product. Certainly, the sugar content is a

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partial determinant of carrot root quality, contributing to their appealing flavor (Merlin *et al.*, 2020). On the other hand, maximum ascorbic acid content was seen in the variety New Kuroda (5.44 mg/100 g) and Nepa Dream (5.21 mg/100 g). Ascorbic acid content in carrot was found to be 4.7 mg/100 g sample as per Howard *et al.* (1999) which is similar to the ascorbic acid content seen in the current research.

Total β-carotenoid found (7.31-12.34 mg/100g) in our research were similar to those reported by Karnjanawipagul *et al.* (2010), that was in the range of 6.19-14.59 mg/100 g. Similarly, the current study had a carotenoid content between 7.31 to 12.34 mg/100 g. The variations observed in the biochemical composition of carrot varieties may be attributed to their genetic makeup, as genetically distinct genotypes often exhibit different characteristics. The crop genotypes affect the amount of bioactive components and that key gene differences primarily control quality-related features like sugars and vitamins. Maximum dry matter content was found in variety Nepa Dream followed by SK3 and Sigma. In conclusion, Nepa Dream variety was found to have superior qualities in terms of yield, TSS, beta carotene and dry matter content while SK3 with higher TSS content and decent marketable yield along with other nutritional aspects is noteworthy and could use further research for its suitability in other regions of Nepal. The finding of the current study can give necessary information to the growers in order to choose the best variety.

CONCLUSION

Carrots have a great potential to thrive in Bhaktapur's agro-climatic regime. This study helped to form basis for the recommendation of ideal carrot variety. Among the five varieties, Nepa Dream is the best variety in terms of yield and also has the best nutritional profile, namely Beta-Carotene, highest TSS and dry matter percent among all.

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Authors' Contributions

P. Paudel arranged the research concept, data analysis and wrote the manuscript. A. Subedi had contributed in designing of the research and provided guidance in writing the manuscript.

Conflict of Interest

The authors of the paper declare that there is no conflict of interest for the publication of this manuscript.

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