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Effect of growing environmental conditions and months of sowing on quality and yield of carrot (*Daucus carota* L.) cv. New Kuroda

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Abstract
The present investigation entitled "Effect of growing environmental conditions and months of sowing on quality and yield of carrot (*Daucus carota* L.) cv. New Kuroda." was carried out at Vegetable Research Station, Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Mulugu (V & M), Siddipet Dist., Telangana State. The study was conducted with six sowing times of carrot *viz*., M_1 Sept 2nd week, M_2 Oct 2nd week, M_3 Nov 2nd week, M_4 Dec 2nd week, M_5 Jan 2nd week, M_6 Feb 2nd week having two conditions *viz*., C_1 open condition, C_2 shadenet condition (35% shade). All the parameters interms of Percentage of root forking, Percentage of root cracking, Percentage of root rotting, Core thickness, Cortex to core ratio were significantly differed among the sowing times at different conditions. The lowest percentage of root forking (4.46%) was found from the crop sown in September sowing whereas minimum root cracking (3.83%), root rotting (0.28%), core thickness (1.69cm) and maximum cortex to core ratio (1.12) were recorded in the October sowing month.

Keywords: Carrot, quality, root forking, root cracking

Introduction
Carrot is a cool season crop grown under wider range of climatic conditions. It is grown during the autumn in temperate countries and winter in tropical and subtropical countries. The ideal temperature for its growth and development is 15.6 °C to 21.1°C. Higher and lower temperature reduce the rate of growth and adversely effect the quality of the roots and the best time is from mid October to mid November for its cultivation to get satisfactory yield. It is one of the most important root crops in the country, which is cultivated in an area of 82,000 ha with an annual production of 13.38 lakh MT.

Carrot (*Daucus carota* L.) a root vegetable primarily grown for its fleshy roots used as vegetable of the family Umbeliferae. It is one of the best sources of β- carotene and provides 17 per cent of the total β- carotene in human nutrition (Alasalvar *et al*., 2001) [1]. β-carotene is the principle precursor of vitamin A, which involves in vision, cell differentiation, synthesis of glycoprotein and overall growth and development of bones. Carrot also contain a wide spectrum of other antioxidants, vitamins, carbohydrates, crude fiber and nutrients like Ca, P, Fe and Mg (Sharma *et al*., 2011) [8]. Carrot intake enhances the immune system, protect against cancer, high blood pressure, osteoporosis, cataracts, atherosclerosis, heart diseases and many others (Brandt *et al*., 2004) [3].

One of the essential climatic factor for plant growth is rainfall, therefore irrigation is required throughout the growing season (Rubatzky *et al*., 1999) [7]. Water affects the physiological and metabolic functions of the plant. It is generally believed that, carrots are more tolerant to drought than other vegetable crops due to their extensive root system (Suojala, 2000a; Lada and Stiles, 2004) [9, 6]. Tindall (1968) [10] mentioned that carrots are tolerant to too little or too much irrigation. However, the availability of soil moisture throughout the growing season is one of the most vital production requirements for carrots (Rabatzky *et al*., 1999; Suojala, 2000a) [9].

Excessive or deficient soil moisture can affect the quality of the roots (Anon., 2008b) [2]. Inadequate soil moisture results in long and thin roots, while excessive soil moisture leads to short, thick and pale coloured roots (Joubert *et al*., 1994; Fritz *et al*., 1998; Rabatzky *et al*., 1999; Anon., 2008b) [5, 4, 2].

Furthermore, low soil moisture will force the plants to invest in root extension growth rather than storage root development resulting in a reduction in root yield (Lada and Stiles, 2004) [6]. According to Fritz *et al*. (1998) [4] moisture stress is reported to cause woody and poorly flavoured roots.
The quality and organoleptic parameters like cortex to core ratio, root rotting, root forking, colour, taste, appearance and overall acceptability were also recorded significantly highest sown in October month during both the years.

Material and Methods

The present investigation entitled "Studies on the effect of growing conditions, sowing months on growth and yield of carrot (*Daucus carota* L.) cv. New Kuroda" was carried out during *Rabi* and Summer (2017-18 and 2018-19), at Vegetable Research Station, Rajendranagar, Hyderabad. The experimental site comes under sub-tropical zone and is situated at latitude of 17^0 19^1 N and longitude of 79^0 23^1 E. The altitude of the place is 542.3 m above the mean sea level. The soil was black sandy loam with good drainage and moderate water holding capacity with a pH value of 8.00. Soil samples were collected randomly to a depth upto 30cm of experimental plot and analysis were done and showed Available Nitrogen 450 kg ha^{-1}, Available Phosphorus 51 kg ha^{-1}, Available Potassium 575 kg ha^{-1}, Organic Carbon 0.34% and Electrical conductivity 0.69 dS m^{-1}.
New Kuroda variety of carrot was used for the experiment, the seeds of this variety were collected from local market. The experiment was conducted to study the effect of six levels of sowing times and two levels of conditions. Different levels of two factors were as follows,

Factor 1: Growing condition, carrot seeds were sown at two different growing conditions denoted as,
C_1: Open condition
C_2: Shade net

Factor 2: Carrot seeds were sown at six different sowing times denoted as,
M_1: September 2nd week
M_2: October 2nd week
M_3: November 2nd week
M_4: December 2nd week
M_5: January 2nd week
M_6: February 2nd week

The two factors experiment was laid out in a FRBD with three replications. The whole experimental area was 90×90m, which was divided into three blocks. Each block was again divided into 12 plots and hence there were 36 (12*3) unit plots. The treatments were assigned randomly in each block separately. The size of unit plot was 2.5×2.5m. The distance between two adjacent blocks and plots were 1.0m and 0.5m respectively. Land preparation, manuring and intercultural operations were done properly.

1. Per cent of root forking (%)

At harvest, the number of forked roots of carrot was counted and the forking percentage of roots per plot was calculated by the following formula:

$$\text{Root forking percentage} = \frac{\text{Number of forked roots per plot}}{\text{Number of total roots per plot}} \times 100$$

2. Per cent of root cracking (%)

At harvest, the number of cracked roots was counted and the cracking percentage of roots per plot was calculated by the following formula.

$$\text{Root cracking percentage} = \frac{\text{Number of cracked roots per plot}}{\text{Number of total roots per plot}} \times 100$$

3. Per cent of root rotting (%)

At harvest, the number of rotten roots was counted and rotting percentage of roots per plot was calculated by the following formula

$$\text{Root rotting percentage} = \frac{\text{Number of rotten roots per plot}}{\text{Number of total roots per plot}} \times 100$$

4. Cortex to core ratio (%)

Using meter scale the root and core diameter of five roots selected randomly from each treatments was recorded separately at crown portion, and based on five samples, the average root and core diameter was worked out in centimeter. Using average radius, the root and core surface area was calculated discretely, and the area of cortex segment was calculated by subtracting the area of core from the area of whole surface at crown. The cortex to core ratio was calculated by dividing the average cortex area of root crown with the average area of root core.

$$\text{Cortex to Core ratio} = \frac{\text{Diameter of cortex (cm)}}{\text{Diameter of core (cm)}}$$

Growth parameters were recorded at the time of harvest. The recorded data on different growth and yield parameters were calculated for statistical analysis. Analysis of variances (ANOVA) for most of the characters under consideration were performed with the help of MSTAT program. Treatment means were separated by Duncane's Multiple Range Test (DMRT) at 5% level of significance for interpretation of the results.

Results and Discussion

Percentage of root forking

The percentage of root forking was varied significantly among the different sowing time. The lowest percentage of root forking (4.46%) was found from the crop sown in September sowing which was on par with October sowing (4.60%) whereas the highest percentage of root forking was recorded in January month sowing (6.15%). This might be caused by adverse environmental conditions like temperature, humidity, light and rainfall. Between different growing conditions significantly minimum percentage of root forking (5.15%) was observed under openfield conditions.
The interaction effect between sowing times and growing conditions was found to be significant. Significantly the lowest root forking (4.24%) was observed with treatment combination of September sowing and openfield condition which was on par with the October sowing in open field conditions (4.38%) whereas the highest percentage of root forking (6.75%) was recorded in the February sowing in open field condition.

Percentage of root cracking

The percentage of root cracking was found significantly among the six sowing times. The minimum percentage of root cracking was observed from the crop sown in the October month (3.83%), which was on par with December month sowing (3.85%) whereas the maximum percentage of root cracking was recorded in February month sowing (4.97%). The mean value of the cracking percentage with the treatment of two growing conditions varied significantly. The minimum percentage (3.80%) of root cracking was observed under the shadenet condition.

The combined effect of different sowing times and growing conditions was highly significant among the treatments. The minimum percentage of root cracking (3.43%) was observed in the treatment combination of December sowing and shadenet conditions whereas the maximum percentage of root cracking (6.11%) was found in the treatment combination in February sowing and openfield condition.

Percentage of root rotting

Among the different sowing times there is a significant differences in respect of percentage of root rotting. The minimum percentage of root rotting (0.28%) was observed from the October sowing month and followed with the September sowing (0.50%) whereas the maximum percentage of root rotting was recorded in February month sowing (2.20%). Between different growing conditions significantly minimum percentage of root rotting (0.95%) was observed in shadenet condition. The interaction effect between sowing times and growing conditions was found to be significant. The minimum percentage of root rotting (0.26%) was found in the treatment combinations of October sowing under shadenet condition which was on par with October sowing under openfield condition (0.31%) while maximum percentage of root rotting (2.28%) was found in January sowing in open field condition.

Core thickness (cm)

Significant differences was observed among the different sowing times in respect of core thickness. The minimum core thickness (1.69cm) was recorded in the October sowing month which was on par with the November sowing (1.86cm) whereas the maximum core thickness was recorded in February sowing (2.09cm) month. Between different growing conditions significantly minimum core thickness (1.93cm) was observed in shadenet condition. The interaction effect between sowing times and growing conditions was found to be significant. The minimum core thickness (1.65cm) was found in the treatment combinations of October sowing under openfield condition which was on par with October sowing under shadenet condition (1.73cm) while maximum core thickness (2.18cm) was found in January sowing in shadenet condition.

Cortex to core ratio

There was a significant differences was observed. Among the different sowing times in respect of cortex to core ratio. The maximum cortex to core ratio (1.12) was recorded in the October sowing month and the minimum cortex to core ratio was recorded in February (0.19) month. Between different growing conditions significantly maximum cortex to core ratio (0.68) was observed in openfield condition. The interaction effect between sowing times and growing conditions was found to be significant. The maximum cortex to core ratio (1.46) was found in the treatment combinations of October sowing under openfield condition while minimum cortex to core ratio (0.09) was found in February sowing in open field condition.

Root forking and cracking gradually increased from early sowing months to late sowing months, recorded highest in February sowing month. Root cracking and forking were more under open field condition than under shade net condition. Root forking is a secondary elongation of roots and splitting is due to cell wall rupture forcing radial longitudinal fracture in the phloem parenchyma tissues. Gracie (2002) demonstrated that, the major implications for splitting to be rapid growth of the inner phloem tissue, as a result of high turgor and cell wall synthesis.

Root yield per hectare (t)

Root yield per hectare was significantly affected by different dates of sowing considering the month of October sowing gave the highest root yield per hectare (28.26t/ha). The lowest root yield per hectare (13.61t/ha) was obtained from the February sowing. Between different growing conditions the significant difference was observed. The maximum root yield/ha (21.81t/ha) was observed from the crop sown under open field conditions (Table 2). The interaction effect of different sowing times and growing conditions was found to be significant. The treatment combination of October sowing and under open field conditions recorded highest root yield/ha (31.09t/ha) which was on par with September sowing (27.47 t/ha) in open field condition whereas the lowest root yield/ha (11.63t/ha) was recorded from crop sown in February sowing in open field condition.

Yield is the end product of various physiological processes, starting from germination to root development. The greatest accumulation of carbohydrates in the plants helps in giving highest yields. From the results it can be concluded that the highest root yield was obtained from October sowing month and the lowest yield was recorded in February sown month under open condition. increase in plant height, number of leaves and dry matter have attributed in increasing the root weight during October sowing, which might be due to favorable environmental conditions during that period. These results are in conformity with Rubatzky *et al*. (1999) [7] in carrot.

Table 1: Effect of growing environmental condition and months of sowing on quality and yield of carrot

	Percentage of root forking			Percentage of root cracking			Percentage of root rotting		
Treatments	**C1**	**C2**	**Mean**	**C1**	**C2**	**Mean**	**C1**	**C2**	**Mean**
T1	4.24	4.69	4.46	4.06	4.04	4.05	0.51	0.50	0.50
T2	4.38	4.82	4.60	3.78	3.89	3.83	0.31	0.26	0.28
T3	4.63	5.27	4.95	4.21	3.84	4.02	0.57	0.53	0.55
T4	5.68	5.10	5.39	4.27	3.43	3.85	1.09	1.03	1.06
T5	6.26	6.05	6.15	5.68	3.78	4.73	2.28	1.60	1.94
T6	6.75	6.27	6.01	6.11	3.83	4.97	2.61	1.80	2.20
Mean	5.15	5.36		4.68	3.80		1.22	0.95	
Factors	SE (m)+_		C.D. at 5%	SE (m)+_		C.D. at 5%	SE (m)+_		C.D. at 5%

Sowing month (S)	0.04		0.41	0.04		0.13	0.05		0.15
Growing condition (G)	0.08		NS	0.04		0.13	0.02		0.08
S X G	0.19		0.58	0.06		0.19	0.07		0.21

Table 2: The interaction effect of different sowing times and growing conditions was found to be significant.

	Core thickness (cm)			Cortex to core ratio			Root yield per hectare (t)		
Treatments	**C1**	**C2**	**Mean**	**C1**	**C2**	**Mean**	**C1**	**C2**	**Mean**
T1	1.92	1.87	1.89	0.88	0.66	0.77	27.47	23.90	25.68
T2	1.65	1.73	1.69	1.46	0.78	1.12	31.09	25.44	28.26
T3	1.88	1.84	1.86	0.90	0.68	0.79	25.80	24.17	24.98
T4	2.09	1.96	2.02	0.46	0.75	0.60	21.16	24.31	22.73
T5	1.95	2.18	2.06	0.29	0.43	0.36	13.76	17.05	15.40
T6	2.10	2.09	2.09	0.09	0.29	0.19	11.63	15.60	13.61
Mean	1.93	1.94		0.68	0.59		21.81	21.74	
Factors	SE (m)+_		C.D. at 5%	SE (m)+_		C.D. at 5%	SE (m)+_		C.D. at 5%
Sowing month (S)	0.02		0.05	0.03		0.09	0.99		2.91
Growing condition (G)	0.01		NS	0.02		0.06	0.57		NS
S X G	0.02		0.07	0.05		0.09	1.40		4.12

Conclusion

From this investigation, it can be concluded that the lowest root forking (4.24%) was observed with treatment combination of September sowing and openfield condition. The minimum percentage of root cracking (3.43%) was observed in the treatment combination of December sowing and shadenet conditions. The minimum percentage of root rotting (0.26%) was found in the treatment combinations of October sowing under shadenet condition. The minimum core thickness (1.65cm) was found in the treatment combinations of October sowing under openfield condition. The maximum cortex to core ratio (1.46) was found in the treatment combinations of October sowing under openfield condition. The highest root yield per hectare (31.09t/ha) was recorded in the treatment combination of October sowing under open field conditions.

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