



## Temperate carrot cultivars outperform tropical ones under hot and humid tropical plains

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### ABSTRACT

The suitability of leading carrot cvs. for cultivation under the hot and humid tropical plains of Kerala state was assessed. Sixteen cvs., including nine tropical varieties, two temperate varieties and five temperate hybrids, were evaluated. All tropical cvs. initiated bolting in 58.5 (Punjab Black Beauty) to 112.0 (CR29) days after sowing, whereas none of the temperate varieties bolted. Bolting per cent was low in 'Pusa Vrishti', 'Pusa Asita' and 'CR29', at 5.5, 7.5 and 8.5 %, respectively. Varieties 'Early Nantes' and 'Pusa Yamdagni' had smaller tops with 34.0 and 34.5 cm height and 5.1 and 6.2 leaves, respectively. 'Pusa Nayanjyoti', 'CR29', and Kuroda cvs. had maximum root length. In contrast, root width was highest in 'Pusa Vrishti', 'Pusa Rudhira', and Kuroda cvs. had maximum root length. In contrast, root width was highest in 'Pusa Vrishti', 'Pusa Rudhira', and 'Pusa Kesar'. In October planting, root weight was highest in 'Pusa Nayanjyoti', 'Pusa Rudhira', and 'Super Kuroda'. In contrast, in the November planting, it was highest in 'Pusa Nayanjyoti', 'Pusa Rudhira', 'Pusa Vrishti', and Kuroda cvs.. Due to extensive early bolting, root yield in 'Punjab Black Beauty' was the lowest in both seasons. Incidence of bacterial soft rot was highest in Kuroda types and 'Pusa Vrishti', and it was lowest in 'Punjab Black Beauty', 'Pusa Yamdagni', 'Pusa Nayanjyoti' and 'Pusa Asita'. Organoleptic analysis of the taste of freshly harvested roots has given the maximum score for 'Pusa Vrishti' and 'Pusa Asita' followed by 'Pusa Nayanjyoti'. This study has shown that temperate cvs. have to be chosen for cultivation in hot and humid tropical plains, and among the cvs. evaluated, 'Pusa Nayanjyoti' was the most promising.

**Key words:** *Pectobacterium carotovorum*, carrot, temperate vegetable, root length, root width.

### INTRODUCTION

Carrot (*Daucus carota* L. ssp. *sativus* (Hoffm.) Arcang., Apiaceae, 2n=2x=18) is an important temperate vegetable crop. Cultivation of this nutritious root crop is generally concentrated in the temperate and sub-tropical regions of the world. The state of Kerala in India, located between the latitudes of 8° 17' 30" N and 12° 47' 40" N, and longitudes 74° 27' 47" E and 77° 37' 12" E, primarily experiences hot and humid tropical weather. Even though carrots are an important component of the diet and dishes, cultivation on a commercial scale has not been attempted in the plains of this state. The entire requirement for this vegetable is met through supply from the hilly tracts of nearby states such as Tamil Nadu and Karnataka. Two preconceptions, which withhold the carrot cultivation were that root formation will not happen in the tropical plain of the state, and that tropical cvs. shall only be suited for the hot and humid conditions. Efforts to grow carrots on a homestead scale have been restricted to the hilly tracts (Nisha *et al.*, 13), and the available reports on screening the varieties suited for the plains have

evaluated only a limited number of varieties (Geetha and Aparna, 3; Vitthal, 16).

'Pusa Rudhira', released from the Indian Agricultural Research Institute (IARI), New Delhi, is a tropical-type carrot with small green foliage and long, red coloured self-core roots. This variety was developed for main season sowing beginning in September under north Indian conditions. Its roots are rich in total carotenoids,  $\beta$ -carotene, lycopene, iron, zinc and antioxidant superoxide dismutase activity. 'Pusa Vrishti' with self-red coloured obtriangular roots having purple pigmentation on shoulders, is the first high heat and humidity tolerant tropical carrot variety. Roots have a good number of total carotenoids, lycopene, and  $\beta$ -carotene and were released for early sowing from July under North Indian plains. 'Pusa Asita', a tropical carrot variety with long black-coloured self-core roots, is a rich source of anthocyanins, Zn, Fe and Ca. 'Pusa Nayanjyoti' is a temperate carrot hybrid suited for early sowing in hills from April to August, late sowing from November to December, and spring and summer crops in north Indian plains. Uniformly cylindrical orange roots are smooth and stumpy with a small indistinct self-coloured core. 'Pusa Yamdagni' is also a temperate carrot variety with uniformly cylindrical orange-

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coloured roots, suited for sowing from September to April (Kalia *et al.*, 7). Performance of tropical cvs. in the north Indian plains has been assessed (Singh *et al.*, 14; Kumawat *et al.*, 10; Tiwari *et al.*, 15) but the suitability of tropical and temperate cvs. to the hot and humid plains is yet to be reported.

Thus, this work was undertaken with the objective of identifying carrot cvs. suited for the plains of humid tropical regions of Kerala state by evaluating the commercially available tropical and temperate cvs. from the public and private sectors.

## MATERIALS AND METHODS

The experiment was conducted in the well-drained sandy loam soils of the Kerala Agricultural University's Experimental Farm at Tavanur, Malappuram district, Kerala state (10° 51' 5" N and 75° 59' 14" E, altitude 2 m above msl). This hot and humid tropical plain had an average temperature of 32.02 °C during the day and 21.39 °C at night, a humidity of 91.3 % during the day and 96.6 % at night, and a total rainfall of 52 cm over the October-

February period. Sixteen carrot cvs., including four tropical and two temperate varieties released from IARI, four tropical lines from the Indian Institute of Vegetable Research (IIVR) one variety from PAU and five temperate Kuroda varieties sold by different private companies, were used in the study. Breeder seeds of all public sector varieties and lines were obtained from the Division of Vegetable Science, IARI, whereas seeds of private sector varieties were purchased from the respective firms (Table 1).

The experiment was conducted using a randomized block design with three replications. Each replication had a 1 m<sup>2</sup> area, accommodating 20 plants (two rows, each having 10 plants). The crop was evaluated under two sows, the first one in October and the second one in November 2022. Seeds were sown on ridges of 20 cm height, taken at 50 cm spacing. Plant-to-plant distance was maintained at 10 cm by seedling thinning three weeks after sowing. Fertilizer application, irrigation, earthing up, and other cultural practices were done following the approved package of practices (KAU,

**Table 1.** Bolting behaviour (mean over October and November crops) of carrot cultivars under humid tropical conditions.

S. No.	Cvs.	Released from	Time of first bolting (DAS)	Per cent plants bolted (Till 120 DAS)	Seed setting (%)
I	Tropical varieties from public sector				
1	Pusa Kesar	ICAR-Indian Agricultural Research Institute, New Delhi	81.0	22.5	100
2	Pusa Rudhira		102.5	16.8	100
3	Pusa Vrishti		108.5	5.5	85.5
4	Pusa Asita		86.0	7.5	80.5
5	Agra Sel.-3	Obtained from collection of ICAR-Indian Institute of Vegetable Research, Varanasi	65.5	62.5	100
6	Agra Sel.-6		72.0	52.0	100
7	CR29		112.0	8.5	55
8	ICVT2		70.0	60.0	100
9	Punjab Black Beauty	PAU, Ludhiana	58.5	100	100
II	Temperate varieties from public sector				
10	Pusa Yamdagni	ICAR-IARI, Regional Station, Katrain	Non-bolter		
11	Pusa Nayanjyoti F <sub>1</sub>		Non-bolter		
III	Temperate varieties from private sector				
12	Early Nantes	Beejo Sheetal	Non-bolter		
13	Shin Kuroda	Century Seeds	Non-bolter		
14	Indam Kuroda	Indo-American Hybrid Seeds	Non-bolter		
15	New Kuroda	Dhaanya Seeds	Non-bolter		
16	Super Kuroda	Namdhari Seeds	Non-bolter		

9). Observations on bolting time, per cent bolting, seed setting, plant height, number of leaves, root length, width and weight, root yield, response to bacterial soft rot and taste were recorded in each cultivar. Organoleptic analysis of the taste of freshly harvested roots was done on a structured 9-point hedonic scale (1-dislike extremely, 2-dislike very much, 3-dislike, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like, 8-like very much and 9-like extremely) (Jellinek, 5). Data on each trait were analyzed using ANOVA at 5 % significance, followed by Tukey's test, using Web Agri Stat Package (WASP, <https://ccari.icar.gov.in/wasp/index.php>).

## RESULTS AND DISCUSSION

Sixteen cvs., including nine tropical and seven temperate types, were evaluated in two crops planted during October and November. During both crops, all tropical cvs. bolted, whereas the temperate ones continued with the vegetative stage (Table 1). Variety 'Punjab Black Beauty' was the earliest to bolt (58.5 DAS), and 'CR29' bolted last (112.0 DAS). 'Punjab Black Beauty' had 100 % bolting, whereas less than 10 % of plants bolted in cvs. 'Pusa Vrishti', 'Pusa Asita' and 'CR29'. Seed setting was complete in the inflorescences of 'Pusa Kesar', 'Pusa Rudhira',

'Agra Sel.-3', 'Agra Sel.-6', 'ICVT2' and 'Punjab Black Beauty'. The bolting in tropical carrots happens under supraoptimal temperatures, and a minimum of 2,200 heat units between transplanting and harvest need to be accumulated to get bolting and good-quality seeds (Nagarajan *et al.*, 12). In contrast to this, the temperate carrots require vernalization to induce flowering. The base, optimum and maximum temperatures for vernalization were found to be -1.0, 6.5 and 16.0°C, imposed for nine weeks or more on non-juvenile plants at 8-12 leaves stage (Atherton *et al.*, 1; Kahangi *et al.*, 6). Above ground height was highest in 'Pusa Kesar' (66.0 cm) and lowest in 'Pusa Yamdagni' (34.5 cm) and 'Early Nantes' (34.0 cm) (Table 2). Number of leaves was highest in 'Pusa Kesar' (29.7) and 'Agra Sel.-3' (33.5) when it was the lowest in 'Early Nantes' (5.1), 'Pusa Yamdagni' (6.2) and Kuroda types. 'Pusa Nayanjyoti', 'CR29' and Kuroda types had the longest roots (23.9-20.3 cm), whereas the roots of 'Punjab Punjab Black Beauty' were the shortest (7.8 cm). The root-to-shoot ratio was the highest in 'Early Nantes', as reported in a previous study (Dev, 2). Root tuber width was measured at a position where each had the highest width, and it was the highest in 'Pusa Vrishti', 'Pusa Rudhira' and 'Pusa Kesar' (6.07-5.32 cm), whereas

**Table 2.** Growth and yield traits (Mean±SD) of carrot cultivars under humid tropical conditions\*.

S. No.	Cvs.	Plant height (cm)	Number of leaves	Root length	Maximum root width	Mean root weight (g)		Root yield (kg m <sup>-2</sup> )	
						October	November	October	November
I Tropical varieties from public sector									
1	Pusa Kesar	66.0±5.1a	29.7±3.3a	20.6±2.9ab	5.32±0.6ab	116.1±12.7b	108.1±13.1b	1.79±0.85e	1.68±0.67cd
2	Pusa Rudhira	42.8±7.3d	13.9±1.8c	19.3±3.1b	5.93±0.8a	123.7±13.3a	116.7±10.8a	2.07±67d	1.91±0.56c
3	Pusa Vrishti	50.2±3.8c	11.2±1.6c	17.3±2.0bc	6.07±0.5a	113.4±7.8c	115.5±12.4ab	1.92±0.87de	2.00±0.55bc
4	Pusa Asita	52.5±4.6bc	10.1±0.9cd	15.9±5.2c	3.75±0.9d	62.6±19.5f	86.8±14.1c	1.15±0.79f	1.59±0.65d
5	Agra Sel.-3	55.0±4.9b	33.5±4.7a	18.1±3.7b	4.25±0.8c	84.3±21.6e	93.9±16.8c	0.68±0.38g	0.74±0.39e
6	Agra Sel.-6	50.0±6.1c	12.1±1.8c	17.7±3.6b	2.35±1.0e	43.9±26.7f	68.0±22.2d	0.42±0.34gh	0.62±0.55e
7	CR29	57.5±5.2b	23.3±3.0b	23.6±3.0a	4.85±0.6b	118.2±14.38b	110.4±13.5b	2.07±1.06d	1.88±0.65c
8	ICVT2	53.8±4.7b	18.0±2.0b	18.8±3.3b	3.79±0.8d	71.3±22.4f	95.6±24.9bc	0.57±0.11g	0.83±0.39e
9	Punjab Black Beauty	55.0±5.9b	13.7±0.9c	7.8±4.1d	2.05±1.1e	18.6±12.5g	27.1±16.5e	0.37±0.12h	0.31±0.20f
II Temperate varieties from public sector									
10	Pusa Yamdagni	34.5±4.0e	6.2±0.8de	18.1±2.0b	4.93±0.6b	83.5±24.1e	86.3±16.1c	1.91±0.83d	2.02±0.46b
11	Pusa Nayanjyoti F <sub>1</sub>	59.3±6.1b	8.0±0.8d	23.9±2.7a	4.88±0.5b	127.7±15.0a	122.7±13.2a	2.73±0.30a	2.61±0.27a
III Temperate varieties from private sector									
12	Early Nantes	34.0±5.0e	5.1±1.1e	19.1±2.6b	4.11±0.7c	88.5±10.7e	103.7±11.2b	2.03±0.55d	1.97±0.68c
13	Shin Kuroda	42.3±3.9d	7.3±0.9de	22.3±3.4a	4.05±0.5c	116.8±9.6b	120.9±12.0a	2.38±0.34bc	2.51±0.18a
14	Indam Kuroda	55.5±4.4b	8.7±1.2d	21.6±2.8a	4.32±0.4c	103.7±8.8d	118.5±9.3a	2.11±0.27cd	2.41±0.45a
15	New Kuroda	52.6±5.6bc	7.2±1.1de	20.3±1.9ab	3.98±0.6cd	112.3±12.6c	115.6±10.1ab	2.27±0.28c	2.33±0.31ab
16	Super Kuroda	42.5±4.9d	9.8±1.3cd	22.1±2.2a	4.65±1.1b	121.3±14.7ab	118.2±12.9a	2.58±0.33ab	2.60±0.41a

\*at 5% significance, number of replications-3, number of plants per replication-20

it was the lowest in 'Agra Sel.-6' and 'Punjab Black Beauty' (2.35-2.05 cm).

In the October crop, the maximum root weight was observed in 'Pusa Nayanjyoti', 'Pusa Rudhira' and 'Super Kuroda' (127.7-121.3 g), whereas the tropical bolting cvs. 'ICVT2', 'Pusa Asita', 'Agra Sel.-6' and 'Punjab Black Beauty' had the minimum root weight (71.3-18.6 g). In the November crop, 'Pusa Nayanjyoti', all Kuroda types, 'Pusa Rudhira' and 'Pusa Vrishti' had the maximum root weight (122.7-115.5 g), and the tropical cvs. 'Agra Sel.-6' and 'Punjab Black Beauty' had the minimum root weight (68.0-27.1 g). The results have shown that the bolting in the tropical cvs. leads to a considerable reduction in root weight. The reduction was more pronounced in the early bolting cvs., 'Punjab Black Beauty', 'Agra Sel.-3', 'ICVT2', 'Agra Sel.-6', 'Pusa Kesar' and 'Pusa Asita'. All the non-bolting temperate cvs., and late bolting tropical cvs. such as 'Pusa Rudhira' and 'Pusa Vrishti' have given good root tuber size.

Root yield in October crop was the highest in 'Pusa Nayanjyoti' and Kuroda types (2.73-2.11 kg m<sup>-2</sup>) and it was the lowest in 'Punjab Black Beauty', 'Agra Sel.-6', 'ICVT2' and 'Agra Sel.-3' (0.37-0.68 kg m<sup>-2</sup>). In November crop, root yield was the highest in 'Pusa Nayanjyoti', Kuroda types and 'Pusa Yamdagni' (2.61-2.02 kg m<sup>-2</sup>). All temperate cvs. recorded a distinctly higher yield compared to the tropical types. However, the yield realized in this study was lower than the potential yields reported for these cvs. (Kalia *et al.*, 7). Per cent bolting in cvs. was proportional to the earliness in bolting, and early bolters recorded the minimum root yield. Bacterial soft rot caused by *Pectobacterium carotovorum* is the major disease of carrots, especially in acidic soils under hot and humid environments (He *et al.*, 4). The occurrence of soft rot was the highest in Kuroda types and 'Pusa Vrishti' (44.5-26.0%, Table 3). Soft rot incidence was significantly lower in tropical carrots, which might be attributed to the less fleshy nature of the roots. Among the temperate cvs., 'Pusa Yamdagni', 'Pusa Nayanjyoti' and 'Early Nantes' had a low incidence of 5.0-14.5%.

When the taste was evaluated on a hedonic scale, cvs. 'Pusa Vrishti' and 'Pusa Asita' received the maximum score of 9.0, followed by 'Pusa Nayanjyoti' (8.8), 'Pusa Rudhira' and 'Early Nantes' (8.6) (Table 3). All the temperate types have scored above 8.0, suggesting that the temperate cvs., when grown under tropical conditions, do not lose their root quality. In tropical cvs. 'CR29', 'Agra Sel.-6', 'Agra Sel.-3', and 'ICVT2', scores ranged from 4.8 to 6.2, suggesting that bolting reduces the root quality considerably. In a similar study, it was reported that the diameter of the root tubers of tropical carrots

**Table 3.** Response of carrot cultivars to bacterial soft rot\* and the scores of organoleptic analyses on the taste of freshly harvested roots\*\*.

S. No.	Cvs.	Bacterial soft rot (%)	Organoleptic score
I	Tropical varieties from public sector		
1	Pusa Kesar	18.6±3.1 <sup>c</sup>	7.0
2	Pusa Rudhira	16.5±1.2 <sup>c</sup>	8.6
3	Pusa Vrishti	28.5±4.7 <sup>b</sup>	9.0
4	Pusa Asita	8.5±1.1 <sup>d</sup>	9.0
5	Agra Sel.-3	12.4±1.8 <sup>cd</sup>	5.4
6	Agra Sel.-6	15.5±2.0 <sup>c</sup>	5.0
7	CR29	16.0±1.3 <sup>c</sup>	4.8
8	ICVT2	12.0±2.7 <sup>cd</sup>	6.2
9	Punjab Black Beauty	4.0±0.6 <sup>e</sup>	7.8
II	Temperate varieties from public sector		
10	Pusa Yamdagni	5.0±1.3 <sup>e</sup>	8.0
11	Pusa Nayanjyoti F <sub>1</sub>	8.5±1.0 <sup>d</sup>	8.8
III	Temperate varieties from private sector		
12	Early Nantes	14.5±2.2 <sup>c</sup>	8.6
13	Shin Kuroda	32.8±5.1 <sup>b</sup>	8.2
14	Indam Kuroda	26.0±1.4 <sup>b</sup>	8.0
15	New Kuroda	28.5±3.7 <sup>b</sup>	8.0
16	Super Kuroda	44.5±5.8 <sup>a</sup>	8.4

\*at 5% significance, mean over October and November crops, \*\*mean over five evaluators

reduces significantly at higher soil temperatures, and those grown above 28 °C day temperature develop bitter, sour, bland tastes (Manosa, 11). In India, IARI, Punjab Agricultural University, and IIVR have developed eight, four, and two varieties of tropical carrots. Additionally, the Indian Institute of Horticultural Research, Chaudhary Charan Singh Haryana Agricultural University, and Dr Yashwant Singh Parmar University of Horticulture and Forestry have released one variety each. Most of these are bred for growing in the plains during *Rabi* season or in the hills during summer (Kalia *et al.*, 8). The performance of these cvs. under hot and humid plains has yet to be reported so far. This study has shown that under the mean day- and night temperatures of 32.02 °C and 21.39 °C, tropical cvs. bolt, leading to poor root yields, whereas temperate cvs. remain in the vegetative stage, resulting in quality roots. Thus, it is concluded that since temperate cvs. produce a higher yield of roots with acceptable size and taste, they may be chosen for cultivation in the hot and humid plains. Among the cvs. screened, 'Pusa

Nayanjyoti' hybrid was found best with larger root tubers, higher yield, lower soft rot incidence and acceptable taste.

### AUTHORS' CONTRIBUTION

Conceptualization of research, designing of the experiments; execution of field experiments, data collection, analysis of data and interpretation, and preparation of the manuscript (DM).

### DECLARATION

The author declares that he has no conflict of interest with anyone associated with this work.

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