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Characterization of qualitative traits among indigenous temperate and tropical region adapted accessions of carrot (*Daucus carota* L.)

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Abstract

The present investigation was carried out at the University of Horticultural Sciences, Bagalkot, Karnataka, India 2016-17, ninety-six genotypes of the carrot were subjected to 15 qualitative traits such as leaf type, root shape, root colour (Internal and external), level of cracking, branching, hairiness and tapering in the roots, etc. The minimum descriptor of carrot developed by IPGRI was used for characterization. The accessions showed greater variation for root colour. The leaf type, root shape, root texture, root hairiness, cracking which are important traits during varietal development also showed greater variations among the accessions. The present study would help carrot breeders to focus on important root qualitative parameters during varietal development program with simple selection for incorporation of multiple desired traits.

Keywords: Carrot, qualitative traits, IPGRI descriptor

Introduction

Carrot (*Daucus carota* L.), an ancient cool season root vegetable, is a member of the family Apiaceae (Peirce, 1987). It is a diploid species having a chromosome number of $2n=2x=18$, with a relatively small genome of 480 Mb (Iorizzo *et al.*, 2016) [2]. It is considered to be native of Afghanistan (Banga, 1957) [1]. Roots are used for making soups, stews, curries, pies, pickles, and for salad purposes. Carotenoid composition determines the white, yellow, orange, or red root color of the carrot (Nicolle 2004; Surles *et al.*, 2004) [4, 6]. The biennial nature of carrots makes them a challenging crop for improvement. But being a highly cross-pollinated species, with seed-producing nature and its broad genetic base makes this crop of great interest to a breeder. The study of qualitative traits such as shape, size colour is an important part of breeding activity, as these qualitative traits add characteristic features like attractiveness, indirect improvement in yield, consumer acceptance, nutritional quality etc. In the present investigation also, 96 genotypes of the carrot were subjected to 15 qualitative traits such as leaf type, root shape, root color (Internal and external), level of cracking, branching, hairiness and tapering in the roots, etc which were recorded with the help of the standard IPGRI descriptor (IPGRI, 1998) [3] developed for carrot.

Materials and Methods

The field experiment was conducted at Udyanagiri Campus of the University of Horticultural Sciences, Bagalkot, and Karnataka, India during 2016-17. Bagalkot is located in the northern region of Karnataka and positioned at $16^{\circ}12'N$, $75^{\circ}45'E$ the average elevation in this area reaches approximately 610 m. The climate is warm and dry throughout the year and rainfall is scarce with an average annual rainfall of 318 mm and belongs to a semi-arid tropical region. Ninety-six carrot (*Daucus carota* L.) germplasm lines comprising of Asiatic and European cultivated accessions. This panel represents a large diversity present in carrots, especially for the root color *viz.*, white, yellow, red, orange, Dark orange, purple and Black. The genotypes were collected from all over India, comprising open-pollinated cultivars, local varieties, modern hybrid cultivars, and released varieties. These genotypes were as nomenclature as UHSBC (University of Horticultural Sciences Bagalkot Carrot) collections. The nomenclature and the numbers are given as per the collection data. The list of 96 accessions used in the study is presented in Table 1.

The experiment was laid out in an augmented block design comprising of 3 checks (Ghataprabha Local-a local cultivar, Virgo Kuroda-western orange cultivar, and Pusa Vrishti-tropical adapted released variety) in six blocks utilized to screen the genotypes. For a healthy crop recommended cultural practices were followed throughout the crop period.

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Data were recorded for 15 qualitative traits. Qualitative characters were recorded based on plant and root morphological traits for plant growth habit, leaf type, shoot

attachment, root color, root shape, root tapering, root texture, root cracking, xylem color, phloem color, etc as depicted in Table 2.

Table 1: Details of 96 Carrot Genotypes and their description

Sl. No.	Name	UHSBC-Nomenclature	Collection site
1	Vannur Local 1	UHSBC-1	Local cultivar
2	Vannur Local 2	UHSBC-2	Local cultivar
3	Vannur Local 3	UHSBC -3	Local cultivar
4	Century Early Nantes	UHSBC-7	Ooty collections
5	Kankanakoppa Local-1	UHSBC-14	Local cultivar
6	Kankanakoppa Local-2	UHSBC-15	Local cultivar
7	Ghataprabha Local-1	UHSBC-16	Local cultivar
8	Ghataprabha Local-2	UHSBC-17	Local cultivar
9	Hangaraki Local	UHSBC-18	Local cultivar
10	Black Wonder	UHSBC-19	Online Collection
11	Bagalkot Local	UHSBC-20	Local cultivar
12	Maharashtra Local	UHSBC-21	Local cultivar
13	Jatt Local	UHSBC-22	Local cultivar
14	VRCAR-1	UHSBC-23	IIVR Collection
15	VRCAR-1	UHSBC-23-1	IIVR Collection
16	VRCAR-2	UHSBC-24	IIVR Collection
17	VRCAR-5	UHSBC-25	IIVR Collection
18	VRCAR-7	UHSBC-26	IIVR Collection
19	VRCAR-8	UHSBC-27	IIVR Collection
20	VRCAR-9	UHSBC-28	IIVR Collection
21	VRCAR-11	UHSBC-29	IIVR Collection
22	VRCAR-13	UHSBC-30	IIVR Collection
23	VRCAR-17	UHSBC-31	IIVR Collection
24	VRCAR-20	UHSBC-32	IIVR Collection
25	VRCAR-20	UHSBC-32-2	IIVR Collection
26	VRCAR-22	UHSBC-33	IIVR Collection
27	VRCAR-25	UHSBC-34	IIVR Collection
28	VRCAR-25	UHSBC-34-1	IIVR Collection
29	VRCAR-25	UHSBC-34-2	IIVR Collection
30	VRCAR-26	UHSBC-35	IIVR Collection
31	VRCAR-29	UHSBC-36	IIVR Collection
32	VRCAR-32	UHSBC-37	IIVR Collection
33	VRCAR-35	UHSBC-38	IIVR Collection
34	VRCAR-40	UHSBC-39	IIVR Collection
35	VRCAR-42	UHSBC-40	IIVR Collection
36	VRCAR-45	UHSBC-41	IIVR Collection
37	VRCAR-45	UHSBC-41-1	IIVR Collection
38	VRCAR-54-1	UHSBC-42	IIVR Collection
39	VRCAR-59	UHSBC-43	IIVR Collection
40	VRCAR-59	UHSBC-43-1	IIVR Collection
41	VRCAR-62	UHSBC-44	IIVR Collection
42	VRCAR-63	UHSBC-45	IIVR Collection
43	VRCAR-66	UHSBC-46	IIVR Collection
44	VRCAR-68	UHSBC-47	IIVR Collection
45	VRCAR-70	UHSBC-48	IIVR Collection
46	VRCAR-74	UHSBC-49	IIVR Collection
47	VRCAR-77	UHSBC-50	IIVR Collection
48	VRCAR-80	UHSBC-51	IIVR Collection

Contd...

Sl. No	Name	UHSBC-Nomenclature	Collection Site
49	VRCAR-81	UHSBC-52	IIVR Collection
50	VRCAR-85	UHSBC-53	IIVR Collection
51	VRCAR-124	UHSBC-54	IIVR Collection
52	VRCAR-153	UHSBC-55	IIVR Collection
53	VRCAR-171	UHSBC-56	IIVR Collection
54	Indam Kuroda	UHSBC-58	Temperate
55	Vaishali Seeds (Pusa Kesari)	UHSBC-59	Released Variety (IARI, New Delhi)
56	Pusa Payasa	UHSBC-63	Released Variety (IARI)
57	Pusa Rudhira	UHSBC-64	Released Variety (IARI)
58	Pusa Meghali	UHSBC-65	Released Variety (IARI)
59	Pusa Asita	UHSBC-66	Released Variety (IARI)
60	Pusa Vrishti	UHSBC-67	Released Variety (IARI)

61	Akshay-1	UHSBC-68	Bangalore Market
62	New Kuruda	UHSBC-69	Ooty collections
63	Gaddanakeri Cross	UHSBC-71	Local cultivar
64	Belgaum Roots	UHSBC-73	Local cultivar
65	Naganur Roots	UHSBC-76	Local cultivar
66	Sangali Roots	UHSBC-77	Local cultivar
67	Bagalkot Local-2 Roots	UHSBC-78	Local cultivar
68	Golden Rod	UHSBC-79	Tamil Nadu Collection-Temperate
69	Orange Carrot	UHSBC-85	Online collection
70	Ruebli Nantaise-2	UHSBC-89	Tamil Nadu Collection-Temperate
71	Flakkeer Lang	UHSBC-90	Online Collections
72	Imperial Hybrid Dark Red	UHSBC-92	Online Collections
73	Pradham Carrot	UHSBC-93	Online Collections
74	Super Kuruda	UHSBC-94	Online Collections
75	Black Carrot	UHSBC-95	Collection from Farmer (Punjab Seeds)
76	Dhenu Seeds	UHSBC-96	Private Sector Seeds
77	Kodaikenal New Kuruda	UHSBC-97	Kodaikenal
78	F1 Eli Nantes	UHSBC-98	Ooty Market (Private Sector Hybrid)
79	Imp Kuruda	UHSBC-99	Tamil Nadu Collection-Temperate
80	Hyb Kuruda	UHSBC-100	Ooty Market
81	Sk Kuruda	UHSBC-101	Tamil Nadu Collection-Temperate
82	Ooty Kuruda	UHSBC-102	Ooty Collections
83	New Field Early	UHSBC-103	Tamil Nadu Collection-Temperate
84	Early Nantes	UHSBC-104	Tamil Nadu Collection-Temperate
85	Vigro Kuruda	UHSBC-105	Tamil Nadu Collection-Temperate
86	Unigean Kuruda	UHSBC-106	Tamil Nadu Collection-Temperate
87	Tokita Early Nantes Improved	UHSBC-107	Tamil Nadu Collection-Temperate
88	Pahaja Early	UHSBC-108	Tamil Nadu Collection-Temperate
89	Splendour Black Seeds	UHSBC-110	Online Collection
90	Splendour Kuruda Orange Seeds	UHSBC-111	Tamil Nadu Collection-Temperate
91	Splendour Desi Red Seeds	UHSBC-112	Tamil Nadu Seeds
92	Ocean Seeds Dark Red	UHSBC-113	Tamil Nadu Collection-Temperate
93	Carrot Super Kuruda	UHSBC-114	Tamil Nadu Collection-Temperate
94	Carrot Nantes	UHSBC-115	Tamil Nadu Collection-Temperate
95	Mukteshwar North	UHSBC-116	North Indian –Temperate type
96	Kularkoppa Local	UHSBC-117	Local cultivar

Table 2: List of qualitative traits recorded in 96 genotypes in carrot

S. No	Characters	Details
1	Plant growth habit (Score)	3-prostrate, 5-Semi-erect, 7-Erect
2	Root position in soil (Score)	3-Shallow, 5-Medium, 7-Deep, 9-Very deep
3	Shoot Attachment (Score)	1-Single, 2-Multiple
4	Leaf type (Score)	1-Celery, 2-Normal, 3-Fern
5	Root branching (Score)	1-Absent, 3-Sparsely, 5-Intermediate, 7-Dense
6	Root Hairiness (Score)	1-Absent, 2-Very Low, 3-Low, 4-Moderate, 5-High, 6-Very high
7	Root cracking (Score)	1-Absent, 2-Present,
8	Root tapering (Score)	1-Blunt, 2-Pointed
9	Root texture (Score)	1-Smooth, 2-Course, 3-Dimpled, 4-Ridged
10	Root shape (Score)	1-Round, 2-obovate, 3-Obstrangular, 4-oblong, 5-tapering, 6-others
11	Root colour (Score)	1-White, 2-Yellow, 3-Yellow orange, 4-Green Yellow, 5-Orange Yellow, 6-Orange/, 7-Dark Orange, 8-Light pink/Pink Yellow, 9-Pink/Purple Pink/Black Pink, 10-Dark Pink, 11-Red, 12-Purple, 13-Light purple, 14-Deep Purple, 15-Black Pink/Black/Black purple.
12	Shoulder colour (Score)	1-Absent, 2-Green, 3-Orange, 4-Dark orange, 5-Pink, 6-Red/deep/dark pink, 7-Light purple/purple pink, 8-Black/black pink/dark purple/dark pink/black green
13	Xylem colour (Score)	1-White, 2-Yellow/Light Yellow/White Yellow, 3-Dark Yellow, 4-Green, 5-Yellow Green/Light Green/Green Yellow, 6-Light Orange/Yellow Orange, 7-Dark Orange, 8-Pink, 9-Red/dark red, 10-Purple, 11-Black/Dark Purple.

Results and Discussion

The qualitative parameters scored across the 96 genotypes with the help of IPGRI descriptor was utilized for frequency distribution analysis and presented in Figure 1. The respective classes for each trait across the genotypes are given in X-Axis and the proportion of shown are in Y-axis in the bar chart. The details of the scores and classes for each parameter are mentioned in Table 2 of Material and Methods. For plant growth habits, there were mainly three classes, but more frequent in the present investigation was the semi-erect type

followed by erect. For shoot attachment to the root, the single attachment was more common than the multiple types. As the number of petioles (Top) attachment to the root increases, the metabolites will be more diverted to the petiole than for the development of the root and the quality of the root may be reduced (Figure 1).

Normal carrot type of leaf was more common in the present population; however, celery type and fern type of leaves were also present in the present study, especially in the western background cultivars. Among the root color parameters

(External and internal), orange root color was more common, although greater variation in color was seen such as yellow, dark orange, pink, purple, and black. There are mainly five colours are most frequently described for carrots in the descriptor, such as white, yellow, orange, red and purple/black. However in the study, greater variation was seen for colour range (Both internal and external), hence, the range of colours are presented in the study. For the internal root colour, xylem and cambium showed more yellowish colour but in phloem colour, the frequency of dark orange was more. These colour variations may have a greater influence on nutritional composition especially carotenoid; hence there is a need to evaluate these accessions for carotenoid content. Root color (External and internal) is the most important qualitative parameter of carrot and most of the breeding efforts are mainly concentrated to improve the colour of the carrot for its orange colour. In the present investigation, maximum number of genotypes showed external colour as Orange, however the internal colour (Xylem and cambium) mostly showed yellow colour more frequently than orange or red or pink etc. The phloem colour was mainly dark orange with few genotypes showing yellow, red, orange or pink (Figure 1).

With respect to shoulder colour, since most of the genotypes did not show any shoulders especially in the temperate varieties, however in either local varieties or tropical germplasm collections, either green or pink or orange coloured shoulder was seen mostly which was in comparison

with the carrot root colour. Tapering types of carrot root shapes and coarse textured roots were more common in the population. Among the nature of plant habit, semi-erect types were more frequent than erect type or prostrate type. Among the leaf type, normal carrot type of leaves were more common in the population, however, fern and celery type of leaves were also observed in the present study mainly in the European type of collections. Most of the Asiatic type collections were (Temperate) were of either normal leaf or celery. The texture of the root is most important trait for the consumer acceptance and generally European types which grow under temperate condition have smooth texture than Asiatic types mainly grown under tropical or sub-tropical conditions. In the present study, course textured genotypes were more frequent than smooth or ridged or dimpled texture. The root texture although is a genetic trait, but highly influenced soil conditions and the climate in which the carrots are grown. Hence, both genetic and environmental factors must be considered while selecting for root texture.

Moderate to a higher percentage of hairiness, cracking, and tapering was also observed in the present investigation as shown by the frequency distribution in the carrot germplasm panel. In most of the genotypes of the selected population, pointed roots were seen than more blunt types, and cracking was more often than non-cracking due to the hardy soil of the experimental site. Medium to deep positions of root was seen in many of the genotypes.

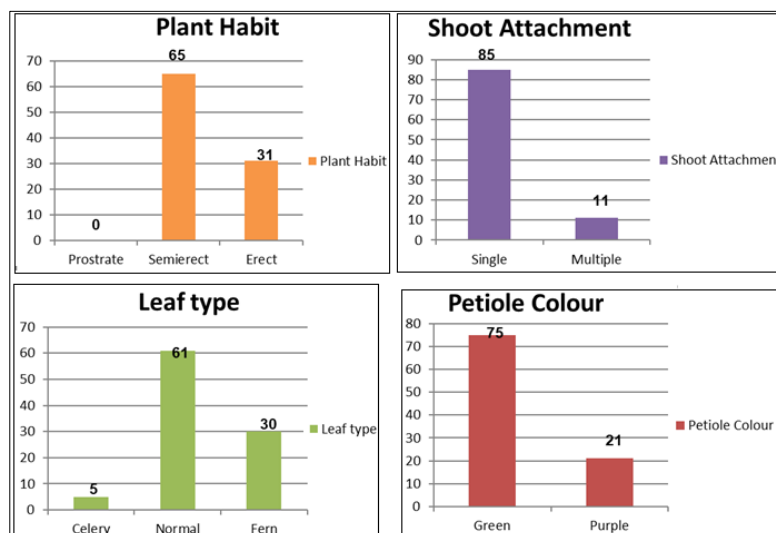


Fig 1: Frequency Distribution for qualitative characters recorded for 96 genotypes in carrot

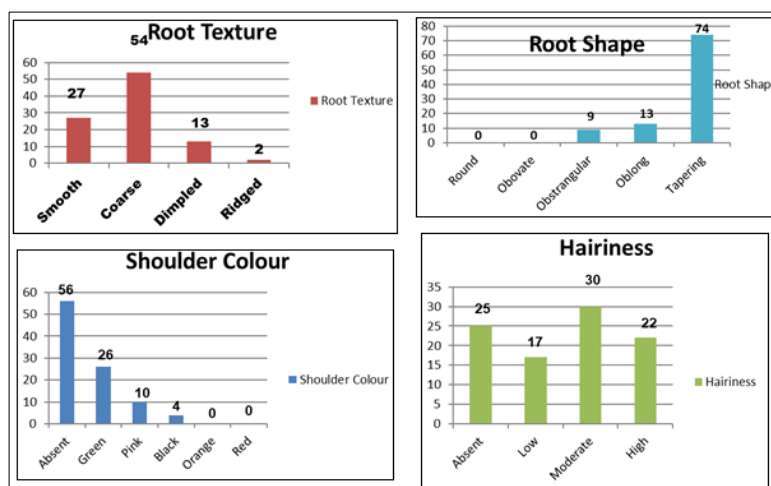


Fig 2: Frequency Distribution for qualitative characters recorded for 96 genotypes in carrot

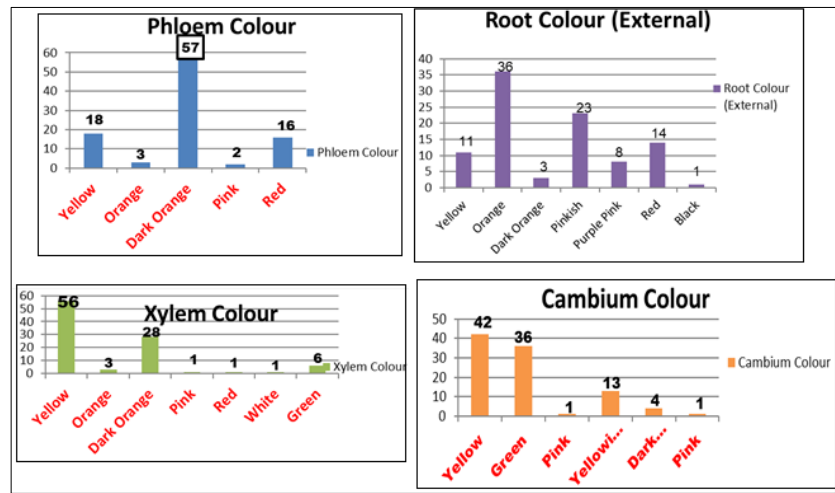


Fig 3: Frequency Distribution for qualitative characters recorded for 96 genotypes in carrot

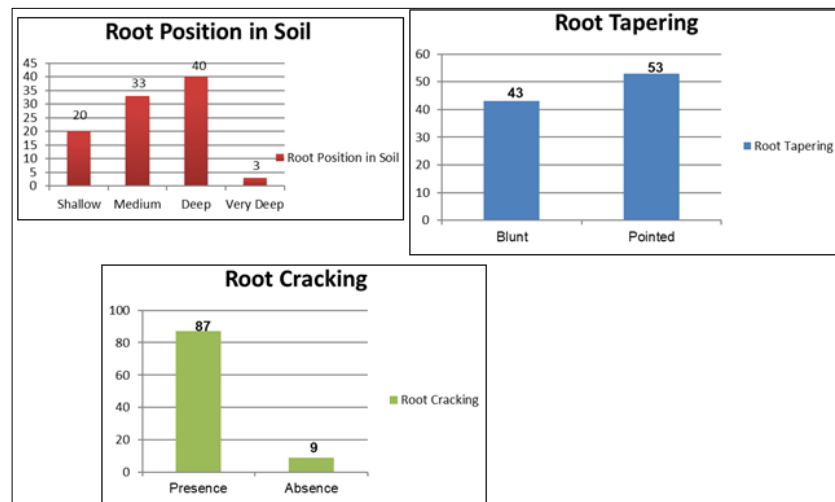


Fig 4: Frequency Distribution for qualitative characters recorded for 96 genotypes in carrot

Conclusion

In the present investigation, a large number of genotypes were characterized for qualitative traits. Among the external color, orange, was more frequent however, the internal color (Xylem and cambium) mostly showed yellow color more frequently than orange or red or pink or purple. The phloem color was mainly dark orange with a few genotypes showing yellow, red, orange, or pink. In most of the genotypes of the selected population, pointed roots were seen more than blunt types, and cracking was more often than non-cracking due to the hardy soil of the experimental site representing the tropical region. The present study help breeders to understand the genetic variation present in the qualitative traits of carrot especially the root shape, color, etc to plan the breeding strategy to incorporate these simply inherited multiple desired characters during varietal development.

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