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Character association studies by correlation estimates of diverse carrot germplasm lines evaluated under tropical climate

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Abstract
Ninety six germplasm lines of carrot collected from different parts of India were evaluated on the basis of 33 phenotypic traits (18 quantitative and 15 qualitative) in an Augmented block design comprising of 3 checks (Ghataprabha Local, Vigro Kuruda and Pusa Vrishti) with 6 blocks was utilized to screen the genotypes comprising of temperate and tropical types with diverse colors at University of horticultural Sciences, Bagalkot during winter season from August-December, 2016. Correlation analysis was carried out to study the character association by Pearson's correlation coefficient analysis among root morphological and biochemical traits of carrot genotypes for the identification of appropriate selection indices. Genotypic correlation coefficient analysis revealed that root weight, root length, leaf width, petiole length, leaf length and root diameter had significant positive correlation indicating their effectiveness in selection for higher productivity in carrot.

Keywords: Carrot, correlation, root length, productivity, tropical climate

Introduction
Carrot (*Daucus carota* L.) is an important vegetable crop grown all over the world. It is grown during spring, summer and autumn in temperate climate and during winter in tropical and sub-tropical climate. It is a dicotyledonous herbaceous crop grown for its enlarged tap roots and belongs to family Apiaceae. Temperate carrots are thought to be originally native to the Asia Minor, in particular Turkey (Vavilov 1951) [7]. It is believed that it was in these areas that the carrot was domesticated from the weed "Queen Ann's Lace". Originally they were small, thin with many colours ranging from purple, orange and yellow to red as well as black to white.
Selection of one trait invariably affects number of associated traits, which evokes the need to find out the inter-relationship of various yield components both among themselves and with yield. The knowledge of the inter-relationship between different traits is important in breeding for direct and indirect selection of traits that are not easily measured and those with low heritability. The consistent associations of yield characters over environment are of immense importance and improve the breeding efficiency (Adunga and Labuschangne 2003) [1].Therefore, it is necessary to examine the magnitude of correlation between characters for achieving the higher yield. However, correlation studies do not provide the exact picture of relative importance of direct and indirect effects of each of the component character. Moreover, when more and more variables are included, the indirect association becomes more complex. Yet, such association among traits information provides a realistic basis for allocation of appropriate weight age to various yield components. Therefore an attempt was made to know variability and character association between yield and its components.
The information on Asiatic carrots (tropical type) in India and probably abroad is very scanty because tropical types has not received ample attention for its genetic improvement. Therefore in the present study 96 germplasm lines representing both tropical and temperate types were evaluated in order to compare their genotypes for various horticulture traits, along with the character association for understanding of these traits and incorporation these traits through breeding strategy.

Materials and Methods
The field experiment for germplasm evaluation for various horticultural traits was conducted at Udyanagiri Campus of University of Horticultural Sciences, Bagalkot, and Karnataka, India during 2016. Bagalkot is located in the northern region of Karnataka and positioned at 16°12′N, 75°45′E the average elevation in this area reaches approximately 610 m and

belongs to semiarid tropical region. Ninety six *Daucus carota* L. germplasm lines were used (table1), representing a large diversity present in carrot especially for the colour *viz.* white, yellow, red, orange, dark orange, purple and Black. Which were collected from all over India, comprising of open-pollinated cultivars, local varieties, and modern hybrid cultivars and released varieties. The experiment was laid out in Augmented block design comprising of 3 checks (Ghataprabha Local, Vigro Kuruda and Pusa Vrishti) with 6 blocks was utilized to screen the genotypes. For a healthy crop, recommended cultural practices were followed throughout the crop period. Data were recorded for 15 qualitative and 18 quantitative traits. Qualitative characters were recorded for both plant and root basis for plant growth habit, leaf type, shoot attachment, root colour, root shape, root tapering, root texture, and root cracking, xylem colour, phloem colour etc as depicted in table 2. Quantitative characters like leaf length (cm), leaf width (cm), petiole length (cm), root weight (gms), root length (cm), days to maturity, harvest index (%), carotenoid content (µg/100 mg), TSS (^{0}Brix), Reducing sugar (%) *etc* as depicted in 2b. Trait selection and measurement techniques were based on IPGRI descriptors by taking average measurement of six plants. Root growth measurements were taken at the time of harvest (marketable root stage). The mean for each trait over six replications was computed for each genotype and analyzed statistically as per augmented block design introduced by Federer (1956) and the software package Window stat (version 8.2) was used for the analysis in the present investigation.

Results and Discussion

Analysis of variance for eighteen quantitative characters namely leaf length**,** leaf width, petiole length, root length, root diameter, days to root harvest, root weight etc, revealed highly significant differences among the carrot genotypes studied. Any crop improvement strategies focus primarily on most ccomplex characteristic yield which must be related to many individually distinguishable characteristics. It is noticeable that yield is a complex character that depends upon many independent yield contributing characters, which are regarded as yield components. All changes in the components need not however, be expressed by changes in yield. This is due to varying degree of positive and negative associations between yield and its components and among components themselves. Therefore, selection should be based on these component characters after assessing their association with yield. Particularly Selection primarily based on better quality, high yield and high productivity which is mainly polygenic characters, hence, the direct improvement of these traits is cumbersome. To overcome this bottleneck, manipulation of yield contributing characters through efficient selection programs has been considered desirable. As several characters are of interest to a breeder, it is necessary to know the concurrent change that would result in the unselected economic characters when selection pressure is applied for the improvement of certain other traits. For this purpose, it is beneficial to know the inter-relationship amongst the various economically important traits.Keeping this in view, Pearson’s correlation coefficient analysis among root morphological and biochemical traits of diverse carrot genotypes estimated in the present study Table (4).

Among the plant morphological traits, five plant vegetative weight; vegetative weight/plant had a strong positive correlation with number of petioles, petiole length and plant height and the shoulder width. With respect to the economic yield such as root weight/plant and root weight/five plants, they both were influenced by almost all the plant morphological characters as depicted by their strong correlation except with shoot length, days to maturity, harvest index and biochemical parameters. There was no significant association among the biochemical traits indicating the independence of each of the character accumulation in the roots. Root width was highly influenced by shoulder width, xylem and phloem width as shown by their strong positive correlation. Interestingly, the TSS content was positively correlated with days to maturity indicating that, higher TSS will be accumulated at the later stages of root growth. Other than the negative significant correlation between number of petioles and days to maturity, there was no strong negative character association between the traits studied.

This consideration becomes still imperfective when one visualizes yield (root weight) and quality traits (biochemical traits) as a complex trait and product of the roots will tend to reduce the marketable root yield (root weight) per plot. However, Bhatia *et al.* (2002) [2] and Gupta and Verma (2007) [4] reported positive correlation between these traits. This may be attributed to the differences in the genotypes included and environmental conditions especially the soils, under which the present study was conducted. Quality traits did not show any significant correlation with root weight, root length, root diameter, phloem width or xylem width at phenotypic level, though the association of plant height with total soluble solids was positive and fairly high and it approached the significance level at genotypic level for days to maturity indicating that TSS accumulates more at the later stages of plant growth. These results are in conformity with the findings of Sukhija and Nand puri (1983) [6] and Singh *et al.* (1989) [5]. With respect to the economic yield such as root weight/plant and root weight/five plants, they both were influenced by almost all the plant morphological characters as depicted by their strong correlation except with shoot length, days to maturity, harvest index and biochemical parameters.

Selection primarily based on better quality, high yield and high productivity which is mainly polygenic characters, hence, the direct improvement of these traits is cumbersome. To overcome this bottleneck, manipulation of yield contributing characters through efficient selection programs has been considered desirable. As several characters are of interest to a breeder, it is necessary to know the concurrent change that would result in the unselected economic characters when selection pressure is applied for the improvement of certain other traits. For this purpose, it is beneficial to know the inter-relationship amongst the various economically important traits.

Table 1: Details of 96 Carrot Genotypes and their description

Sl. No.	UHSBC-Nomenclature	Collection site
1	UHSBC-1	Local cultivar
2	UHSBC-2	Local cultivar
3	UHSBC -3	Local cultivar
4	UHSBC-7	Ooty collections
5	UHSBC-14	Local cultivar
6	UHSBC-15	Local cultivar
7	UHSBC-16	Local cultivar
8	UHSBC-17	Local cultivar
9	UHSBC-18	Local cultivar
10	UHSBC-19	Online Collection
11	UHSBC-20	Local cultivar
12	UHSBC-21	Local cultivar
13	UHSBC-22	Local cultivar
14	UHSBC-23	IIVR Collection
15	UHSBC-23-1	IIVR Collection
16	UHSBC-24	IIVR Collection
17	UHSBC-25	IIVR Collection
18	UHSBC-26	IIVR Collection
19	UHSBC-27	IIVR Collection
20	UHSBC-28	IIVR Collection
21	UHSBC-29	IIVR Collection
22	UHSBC-30	IIVR Collection
23	UHSBC-31	IIVR Collection
24	UHSBC-32	IIVR Collection
25	UHSBC-32-2	IIVR Collection
26	UHSBC-33	IIVR Collection
27	UHSBC-34	IIVR Collection
28	UHSBC-34-1	IIVR Collection
29	UHSBC-34-2	IIVR Collection
30	UHSBC-35	IIVR Collection
31	UHSBC-36	IIVR Collection
32	UHSBC-37	IIVR Collection
33	UHSBC-38	IIVR Collection
34	UHSBC-39	IIVR Collection
35	UHSBC-40	IIVR Collection
36	UHSBC-41	IIVR Collection
37	UHSBC-41-1	IIVR Collection
38	UHSBC-42	IIVR Collection
39	UHSBC-43	IIVR Collection
40	UHSBC-43-1	IIVR Collection
41	UHSBC-44	IIVR Collection
42	UHSBC-45	IIVR Collection
43	UHSBC-46	IIVR Collection
44	UHSBC-47	IIVR Collection
45	UHSBC-48	IIVR Collection
46	UHSBC-49	IIVR Collection
47	UHSBC-50	IIVR Collection
48	UHSBC-51	IIVR Collection
49	UHSBC-52	IIVR Collection
50	UHSBC-53	IIVR Collection
51	UHSBC-54	IIVR Collection
52	UHSBC-55	IIVR Collection
53	UHSBC-56	IIVR Collection
54	UHSBC-58	Temperate
55	UHSBC-59	Released Variety (IARI, New Delhi)
56	UHSBC-63	Released Variety (IARI)
57	UHSBC-64	Released Variety (IARI)
58	UHSBC-65	Released Variety (IARI)
59	UHSBC-66	Released Variety (IARI)
60	UHSBC-67	Released Variety (IARI)
61	UHSBC-68	Bangalore Market
62	UHSBC-69	Ooty collections
63	UHSBC-71	Local cultivar
64	UHSBC-73	Local cultivar
65	UHSBC-76	Local cultivar
66	UHSBC-77	Local cultivar

67	UHSBC-78	Local cultivar
68	UHSBC-79	Tamil Nadu Collection-Temperate
69	UHSBC-85	Online collection
70	UHSBC-89	Tamil Nadu Collection-Temperate
71	UHSBC-90	Online Collections
72	UHSBC-92	Online Collections
73	UHSBC-93	Online Collections
74	UHSBC-94	Online Collections
75	UHSBC-95	Collection from Farmer (Punjab Seeds)
76	UHSBC-96	Private Sector Seeds
77	UHSBC-97	Kodaikenal
78	UHSBC-98	Ooty Market (Private Sector Hybrid)
79	UHSBC-99	Tamil Nadu Collection-Temperate
80	UHSBC-100	Ooty Market
81	UHSBC-101	Tamil Nadu Collection-Temperate
82	UHSBC-102	Ooty Collections
83	UHSBC-103	Tamil Nadu Collection-Temperate
84	UHSBC-104	Tamil Nadu Collection-Temperate
85	UHSBC-105	Tamil Nadu Collection-Temperate
86	UHSBC-106	Tamil Nadu Collection-Temperate
87	UHSBC-107	Tamil Nadu Collection-Temperate
88	UHSBC-108	Tamil Nadu Collection-Temperate
89	UHSBC-110	Online Collection
90	UHSBC-111	Tamil Nadu Collection-Temperate
91	UHSBC-112	Tamil Nadu Seeds
92	UHSBC-113	Tamil Nadu Collection-Temperate
93	UHSBC-114	Tamil Nadu Collection-Temperate
94	UHSBC-115	Tamil Nadu Collection-Temperate
95	UHSBC-116	North Indian –Temperate type
96	UHSBC-117	Local cultivar

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

S. No	Characters	Details
1	Days to maturity	No of days to harvest from the date of sowing
2	No of petioles	Petioles Counted
3	Shoot length (cm)	Measuring scale
4	Plant height	Measuring scale
5	Root length (cm)	Measuring scale
6	Petiole length (cm)	Measuring scale
7	Root width (mm)	Digital Vernier Caliper-converted to cm
8	Shoulder width (mm)	Digital Vernier Caliper- converted to cm
9	Vegetative weight/plant (GMS)	Weighing Balance
10	Five Plants Vegetative weight	Weighing Balance
11	Xylem width (cm)	Measuring scale
12	Phloem width (cm)	Measuring scale
13	Harvest index (%)	Economic yield/biological yield
14	Total Soluble Solids (^{0}Brix)	Digital Refractometer
15	Reducing Sugars (%)	Dinitro Salicylic Acid (DNS) method
16	Beta Carotene Content (µg/100 mg)	Acetone Extraction Method
17	Root yield (gms)/plant	Weighing Balance
18	Five plants root weight	Weighing Balance

Table 3: Pearson's correlation coefficient analysis among root morphological and biochemical traits of carrot genotypes

Traits	**DM**	**NP**	**SL**	**PH**	**RL**	**PL**	**RWD**	**SWD**	**VW**	**FPVW**	**XW**	**PW**	**HI**	**TSS**	**RS**	**β**	**RW**	**FPRW**
DM	1.000																	
NP	-0.170*	1.000																
SL	0.018	0.055	1.000															
PH	-0.137	0.282**	0.058	1.000														
RL	-0.107	0.165*	0.182*	0.273**	1.000													
PL	-0.072	0.000	-0.039	0.527**	0.063	1.000												
RWD	0.221**	0.000	-0.091	0.193*	0.042	0.254**	1.000											
SWD	0.082	0.084	0.049	0.691**	0.069	0.507**	0.558**	1.000										
VW	-0.203*	0.726**	-0.009	0.699**	0.135	0.312**	0.174*	0.481**	1.000									
FPVW	-0.216	0.743**	0.061	0.670**	0.137	0.235**	0.135	0.464**	0.910**	1.000								
XW	0.019	0.124	0.106	0.692**	0.097	0.432**	0.433**	0.869**	0.440**	0.448**	1.000							
PW	0.153	-0.178	-0.115	0.056	-0.059	0.200*	0.440**	0.450**	-0.166*	-0.092	0.387**	1.000						
HI	-0.126	-0.056	0.015	-0.210	-0.038	-0.117	-0.109	-0.204*	-0.145	-0.057	-0.167*	0.039	1.000					
TSS	0.237**	-0.043	-0.053	0.290**	-0.020	0.209*	0.155	0.252**	0.030	0.104	0.260**	0.119	-0.114	1.000				
RS	0.089	-0.049	-0.048	0.059	0.030	-0.012	-0.043	0.040	-0.030	-0.057	0.005	0.124	-0.107	0.079	1.000			
β-carotenoid	0.073	-0.124	0.068	-0.114	0.096	0.115	0.110	-0.021	-0.187*	-0.174	0.040	0.088	0.004	0.141	-0.084	1.000		
RW	0.109	0.289**	0.096	0.637**	0.255**	0.448**	0.675**	0.784**	0.538**	0.547**	0.726**	0.342**	-0.136	0.297**	0.054	0.105	1.000	
FPRW	0.082	0.272**	0.080	0.577**	0.246**	0.396**	0.670**	0.779**	0.459**	0.552**	0.722**	0.430**	-0.089	0.328**	0.005	0.129	0.894**	1.000

*significance at 5%, ** significance at 1% level of probability

Conclusion

Yield is considered to be a complex, polygenic and highly variable character determined by cumulative effects of its component characters. Therefore, direct selection for yield may not be very effective and precise. Thus, it becomes necessary to find out the direction and degree of association between two characters at phenotypic and genotypic levels. At genotypic levels, aassociation studies revealed positive and significant correlations with respect to the economic yield such as root weight/plant and root weight/five plants. Which were influenced by almost all the plant morphological characters as depicted by their strong correlation except with shoot length, days to maturity, harvest index and biochemical parameters.Thus the analysis of association of different characters with yield will help to select the yield contributing characters in breeding process.

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