Genotypic Variation for Quantitative and Qualitative Traits in Asiatic and European Carrot (*Daucus carota* L. var. *sativa*)

Asima Amin[1]*, Pradeep Kumar Singh[2] and Kouser Parveen Wani[2]
[1]*Department of Vegetable Science, Punjab Agricultural Unversity, Ludhiana-141 001, Punjab*
[2]*Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Main Campus, Srinagar-191 121, Jammu and Kashmir*

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Forty eight diverse genotypes of Asiatic and European carrots were evaluated for 17 quantitative and qualitative traits of horticultural importance. The analysis of variance was highly significant for all the traits indicating the presence of wide variability in the genotypes. High heritability estimates were recorded for plant weight, root weight, total yield, marketable yield and juice content. High estimates of genetic advance were recorded for total yield and marketable yield. The high heritability, associated with high genetic advance as percentage of mean for total yield, marketable yield, plant weight, root weight and beta carotene content, were the most reliable selection parameters. PC-50, PC-5, PC-81, IPC-122 and CT-2 were superior genotypes for yield and its components, and these can be used in further breeding programmes.

Key Words: Agronomic and biochemical traits, Carrot, *Daucus carota* L. var. *sativa*, Genetic variability

Introduction

Carrot (*Daucus carota* L.) 2n=2x=18 belongs to family Apiaceae and is native of Afghanistan (Banga, 1976). It is the most widely grown vegetable among root crops in India wherein it occupies an area of 24,000 ha with a production of 350,000 MT and an average yield of 145.83 q/ha (Anonymous, 2003). Carrots are an important source of pro-vitamin A, fiber and other dietary nutrients (Simon, 1990). According to the WHO, vitamin A deficiency partially or totally blinds nearly 350,000 children in more than 75 countries every year. Parameters of genotypic and phenotypic coefficients of variation (GCV and PCV) are useful in detecting the amount of variability present in the available germplasm. Heritability and genetic advance help in determining the influence of environment in expression of the characters and the extent to which improvement is possible after selection (Robinson *et al*., 1949). Thus, the present study aims to evaluate the available genotypes and to conduct the variability studies for different morphological and quality components of the roots in terms of yield attributes and qualitative traits like total soluble solids (TSS), dry matter, carotene content and juice yield of some Asiatic and European genotypes/cultivars selected from Punjab Agricultural University (PAU), Ludhiana; Haryana Agricultural University (HAU), Hisar; Indian Institute of Vegetable Research (IIVR), Varanasi; Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Kashmir and Indian Agricultural Research Institute (IARI), New Delhi.

Material and Methods

The experimental material included 48 entries belonging to yellow, red, black and orange colour root types. The details of genetic stocks are given in Table 1. All the genotypes were sown on ridges in a double row of 3 m length in each replication with 45 cm spacing between rows and 7.5 cm between plants, respectively. All the recommended package of practices was followed during the course of investigation for raising a good crop. The observations were recorded for yield attributing traits like top height, plant weight, root length, root weight, root girth, core girth, flesh thickness, root to top ratio, total yield and marketable yield as well as for qualitative traits like total soluble solids (TSS %), exterior root colour, core colour, forking, dry matter, carotene content and juice yield. Ten roots from each replication were selected randomly, pooled and composite samples were analyzed. Total soluble solids (TSS %) were determined using a hand refractometer. The colour of carrot roots was determined by the level of total carotenoids, accumulation of other specific pigments as well as the distribution of pigments between phloem and xylem was with the colour chart of Royal Horticultural Society, U.K. as the reference chart. Carotenoids were extracted in acetone and portioned in petroleum ether and quantified by

**Author for Correspondence: E-mail: asimaamin@rediffmail.com, pradeepsingh584@gmail.com*

Table 1. Diverse lines of carrot and their sources under study

Genotypes	Source
Amity's Carrot	SKUAST, Kashmir
CCA-05-01	IIVR, Varanasi
CT-2	IIVR, Varanasi
Early Nantes	Sutton & Sons
HC-1	HAU, Hisar
HC-100	HAU, Hisar
HC-199-1	HAU, Hisar
HCB-22-2	HAU, Hisar
HCO-4-2	HAU, Hisar
HCP-2	HAU, Hisar
HCY-183-1	HAU, Hisar
Hybrid -501	SKUAST, Kashmir
IPC-106	IARI, New Delhi
IPC-109	IARI, New Delhi
IPC-118	IARI, New Delhi
IPC-122	IARI, New Delhi
IPC-25	IARI, New Delhi
IPC-34	IARI, New Delhi
IPC-37	IARI, New Delhi
IPC-4	IARI, New Delhi
IPC-40	IARI, New Delhi
IPC-7	IARI, New Delhi
JKC	SKUAST, Kashmir
KTCTH-7	IARI, Katrain
KTCTH-8	IARI, Katrain
Nantes	IARI, New Delhi
PC-101	PAU, Ludhiana
PC-15	PAU, Ludhiana
PC-16	PAU, Ludhiana
PC-34	PAU, Ludhiana
PC-35-A	PAU, Ludhiana
PC-41	PAU, Ludhiana
PC-42	PAU, Ludhiana
PC-43	PAU, Ludhiana
PC-44	PAU, Ludhiana
PC-5	PAU, Ludhiana
PC-50	PAU, Ludhiana
PC-61	PAU, Ludhiana
PC-76	PAU, Ludhiana
PC-79	PAU, Ludhiana
PC-81	PAU, Ludhiana
PC-82	PAU, Ludhiana
PC-83	PAU, Ludhiana
PC-84	PAU, Ludhiana
PC-87	PAU, Ludhiana
PC-94	PAU, Ludhiana
PC-96	PAU, Ludhiana
PC-99	PAU, Ludhiana

measuring the absorbance at 452 nm in a UV-visible double beam spectrophotometer as per the standard procedure (Ranganna, 1986). The specific absorbance values (specific extinction coefficient) tabulated by Davies (1976), were used for the calculation of carotene. Total carotene was expressed as mg/100 g fresh weight of carrot. Analysis of variance was calculated as suggested by Panse and Sukhatme (1985). The phenotypic and genotypic coefficients of variation (PCV and GCV) were estimated (Burton, 1953). Heritability in the broad sense suggested by Allard (1960) and genetic advance (in terms of percentage of mean) were computed according to Johnson *et al*. (1955).

Results and Discussion

Range, mean and analysis of variance for different quantitative and qualitative traits are presented in Table 2. The mean sums of squares were highly significant for all traits, indicating the presence of wide variability in the genotypes studied. Top height ranged from 50.48 cm (Nantes) to 71.21 cm (CT-2), with a mean value of 63.44 cm. There was considerable variability with respect to plant height which ranged from 181.67 g (PC-94) to 390.00 g (PC-15). Maximum root length and root weight were reported in PC-5 (24.92 cm) and PC-50 (182.00 g) and minimum were recorded in IPC-25 (19.57 cm) and HC-199-1 (101.33g), respectively. Maximum root girth (3.21 cm) was recorded in PC-42 and minimum (2.58 cm) in HC-100, whereas maximum (1.32 cm) and minimum (0.77 cm) core girth were recorded in HC-1 and PC-44, respectively.

Maximum flesh thickness (2.34 cm) was recorded in PC-42 and minimum (1.52 cm) in HC-100, whereas maximum root to top ratio (1.67) and minimum (0.66) were recorded in PC-35-A and KTCTH-8, respectively. The total yield exhibited by the genotypes, under study, varied from 3.15 kg/plot (IPC-37) to 7.92 kg/plot (PC-50) with average yield being 4.59 kg/plot. Marketable yield varied from 2.60-6.85 kg/plot with Amity's carrot registering the lowest and PC-50 the highest. PC-83 exhibited maximum TSS (8.78%) whereas a minimum was exhibited by IPC-34 (6.25%). Maximum dry matter (8.78%) was recorded in PC-83 and minimum (6.77%) in PC-94. There was a wide range (2.31- 6.96 mg/100g) for average carotene content with the minimum and maximum being recorded in genotypes PC- 61 and Hybrid-501, respectively. Juice yield varied between 415.83-581.67 ml/kg of roots with maximum being in PC-5 and minimum in Early Nantes, respectively.

Table 2. Range, mean and analysis of variance for different characters in carrot as per pooled data analysis

Character	Range	Min.	Max.	Mean	CD at 5%
Top height (cm)	50.48 -71.21	Nantes	CT-2	63.44	5.34
Plant weight (g)	181.67-390.00	PC-94	PC-15	260.34	18.78
Root length (cm)	19.57 -24.92	IPC-25	PC-5	21.89	1.26
Root weight (g)	101.33 -182.00	HC-199-1	PC-50	132.96	17.08
Root girth (cm)	2.58– 3.21	HC-100	PC-42	2.91	0.42
Core girth (cm)	0.77-1.32	PC-44	HC-1	0.98	0.26
Flesh thickness (cm)	1.52-2.34	HC-100	PC-42	1.87	0.41
Root to top ratio	0.66- 1.67	KTCTH-8	PC-35-A	1.49	0.26
Total yield (kg/plot)	3.15-7.92	IPC-37	PC-50	4.59	0.65
Marketable yield (kg/plot)	2.60- 6.85	Amity's carrot	PC-50	3.64	0.85
Total soluble solids (%)	6.25- 8.78	IPC-34	PC-83	7.47	5.67
Dry matter (%)	6.77- 8.78	PC-94	PC-83	7.72	4.01
Carotene content (mg/100g)	2.31-6.96	PC-61	Hybrid-501	3.07	0.53
Juice yield (ml/kg)	455.83 -581.67	Early Nantes	PC-5	507.28	12.13

The pooled data is also represented in the form of a dendrogram (Fig. 1). Software package NTSYS PC version 2.02e (Rohlf, 1998) was used for estimation of genetic similarities among the lines using SIMQUAL mode of NTSYS. The similarity matrix value based on coefficient of similarity (Jaccard, 1909) was used to generate dendrogram. Clustering was done by UPGMA using SHAN module of NTSYS PC version 2.02e.

Knowledge of genetic diversity among population and its quantitative assessment usually helps a plant breeder in choosing desirable parents for a breeding programme. Genotypic diversity which has been generally considered as a criterion for the measure of genetic diversity in crop plants, very often fails to convey information about the genetic divergence.

In general, the phenotypic variance and phenotypic coefficient of variation were higher than the respective genotypic variance and genotypic coefficient of variation for all the traits (Table 3) indicating considerable influence of environment on their expression. Marketable yield had highest coefficient of variation at the genotypic and phenotypic level followed by total yield. Singh *et al.* (2004) also studied the coefficient of variation at the genotypic and phenotypic level, which was highest for average fresh weight of roots and root weight with leaves. Sizable coefficient of variation at genotypic and phenotypic (3-17%) levels was observed for carotene content, TSS, core girth and root length indicating high level of variability in these characters and ample scope for their effective improvement. Genotypic coefficient of variation would be more useful for assessing the variability.

Table 3. Coefficient of variation, heritability and genetic advance as % of mean for different qualitative and quantitative traits

Characters	GCV	PCV	Heritability (broad sense)	Genetic advance as % of mean
Top height (cm)	7.04	8.94	62.00	11.43
Plant weight(g)	22.61	23.05	96.30	45.71
Root length (cm)	3.83	10.59	13.10	2.83
Root weight (g)	21.72	23.19	87.70	41.91
Root girth (cm)	1.09	9.40	1.30	0.34
Core girth (cm)	4.40	23.38	3.50	2.04
Flesh thickness (cm)	4.63	12.48	13.80	0.53
Root to top ratio	2.11	14.69	2.10	4.70
Total yield (kg/plot)	33.06	34.35	92.60	65.58
Marketable yield (kg/plot)	37.21	39.91	86.90	71.43
Total soluble solids (%)	8.5	10.22	69.20	14.59
Dry matter (%)	5.25	6.61	63.10	8.55
Carotene content (mg/100g)	13.65	17.21	62.90	22.47
Juice yield (ml/kg)	3.93	4.20	87.70	7.58

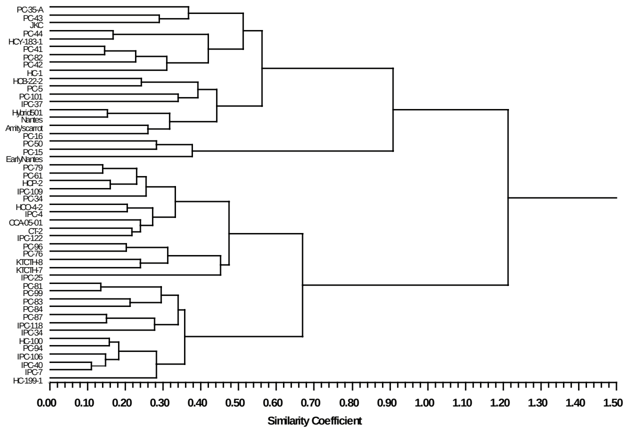

Fig. 1. Dendrogram on the basis of morphological studies using Jaccard's similarity coefficient

Burton (1953) has suggested that genotypic coefficient of variation together with heritability estimate would give the best option expected for selection. Heritability estimates were high in plant weight (96.30), total yield (92.60), root weight (87.70), juice yield (87.70) and marketable yield (86.90). High heritability for the characters controlled by polygene might be useful to plant breeder for making effective selection. Selection is always favored when a major proportion of a large amount of phenotypic variability is due to heritable variation. Heritability is a measure of genetic relationship between parent and progeny and has been widely used in determining the degree to which a character may be transmitted from parents to offspring. Knowledge of the degree of heritability for the character permits a rational choice of breeding methods to be followed for its improvement and helps to estimate the genetic gains from selection. Johnson *et al.* (1955) reported that the heritability estimates along with genetic advance are more useful than the heritability alone in predicting the resultant effect for selecting the best genotype as it suggests the presence of additive gene effect (Panse, 1957). High estimates of genetic advance as percentage of mean were recorded for marketable yield (71.43) and total yield (65.58). Similar results were also reported by Singh *et al*. (2004) and Tewatia *et al.* (1990). The high heritability was associated with high genetic advance as percent of mean for marketable yield, total yield, plant weight and root weight. The parallelism between the magnitude of heritability and degree of genetic gain has been due to the additive genes playing a predominant role. Presence of high and moderate heritability with low genetic gain suggested that high heritability did not necessarily lead to increased genetic gain unless sufficient genetic variability existed in the genotypes.

Occurrence of sufficient genetic variability for yield *per se* and its contributing traits, in the present set of genotypes can be exploited for carrot improvement. Marketable yield, total yield, plant weight, root weight and juice yield were the most reliable selection parameters. On the basis of above finding, PC-5, PC-15, PC-50, PC-42, PC-44, PC-35-A and Hybrid-501 were recorded to be superior genotypes for yield *per se* and its components traits, which can be used in future breeding programmes.

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