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Genetic variability in carrot (*Daucus carota* L.) under different environments

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ABSTRACT

Present investigation was aimed to explain genetic variability under four different environments with 24 diverse lines of carrot. A wide phenotypic range was observed for most of the traits including weight of root and total biomass in environment E-II indicating environment E-II to be the most favorable for expression of maximum genetic variability present in the genotypes. The estimates for parameters GCV (%) and PCV (%) displayed relatively higher amount of genetic variability for petiole length, β-carotene content and total soluble sugar over the environments. High heritability accompanied with high genetic advance was observed for weight of root per plant, core size, harvest index, root index, β-carotene content and total soluble sugar in environment E-II. Root weight per plant was positively correlated with number of leaves per pant, length of root, plant top height, root index and total biomass. Total soluble sugar as an important quality parameter showed positive correlation with plant top height, core size and root index.

Key words : Carrot, genetic variability, heritability, genetic advance and correlation

Carrot (*Daucus carota* L.), is an important root vegetable crop worldwide, both economically and as a source of provitamine 'A' carotenes. Carrot is cultivated in India, China, Malaysia, Indonesia, Philippines, European countries, West Africa and north-south America. In India the important carrot growing states are Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana. Carrot (Daucus carota var. Sativus) belongs to family Apiaceae which also includes cumin, coriander and parsley. The cultivated types of this species crosses readily with wild *Daucus carota* L. which is distributed worldwide. Approximately 80 Daucus species have been identified. Almost all species, including carrot, are diploid, where n = 7 to 11. Carrot varieties are divided into two groups viz., Asiatic or Tropical types and European or temperate types. Most of the tropical varieties are red coloured due to the presence of the pigment lycopene. Orange colour of the European types is due to β-carotene pigment, a precursor of vitamin 'A.' Purple and yellow colour of carrots is due to pigments anthocynin and xanthophylls, respectively.

Estimation of genetic variability of a particular crop is prerequisite for making any effective breeding programme. Selection of genotypes to be included in the hybridization programme is possible only in presence of appropriate genetic variability. Most of the important characters including marketable yield are highly influenced by environment, since they are polygenically controlled. This makes selection process difficult. Thus, knowledge of heritability of yield component traits is the consequence of genotype and is inherited from generation to generation (Wright, 1921).Estimation of coefficient

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of variation together with heritability estimates and genetic advance gives reliable information about the amount and extent of improvement possible from selection and the nature of gene action in the inheritance of polygenic traits.

MATERIALS AND METHODS

The present investigation was carried out during rabi 2011-2012 at two different locations (Four Environments) viz., at Botanical Garden, Department of Genetics and Plant Breeding, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar and Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa Among 24 diverse lines of carrot obtained from different sources. Each entry was planted with a spacing of 30 cm between rows and 10 cm between plants. The experiment was laid out in a randomized block design with three replications. Observations were made for the characters viz., number of leaves per plant, petiole length (cm), length of root (cm), root diameter (cm), weight of root (g/plant), plant top height (cm), root laterals, core size (mm), harvest index (%), root index, total biomass, β-carotene contents (µg/g) and total soluble sugar. Analysis of variance was calculated on the method suggested by Panse and Sukhatme, 1978. The Genotypic and Phenotypic coefficient of variation (PCV and GCV) were estimated as per Burton, 1953. Heritability in the broad sense, suggested by Allard, 1960 and genetic advance (In term of percentage of mean) were computed according to Johnson et al., 1955.

RESULTS AND DISCUSSION

The Analysis of variance for individual environments revealed highly significant mean squares due to genotypes for all the characters except root laterals and total biomass in E-I which indicate the presence of genetic variation for different characters (Table 1). The estimates of genetic parameters of variability, viz., phenotypic and genotypic coefficient of variation (PCV and GCV) along with heritability in broad sense(h^2) and genetic advance (GA) as percentage of mean for different characters (Table

Table1. Analysis of variance (Mean square) for individual environment

Sources of variation	d.f	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β-Carotene contents (µg/g)	Total Soluble sugar
ENVIRONMENT- I														
Replication	2	3.76	100.17	5.49	6.99*	1064.92	155.60	3.10	10.72	832.32	3.18	14812.40*	4.43	0.00
Genotype	23	8.01**	22.82**	8.08**	1.43**	523.41**	114.07**	27.31	38.17**	134.56**	1.57**	2451.31	669.01**	1.35**
Error	46	1.05	7.79	2.53	0.23	215.06	32.92	24.0	1.82	47.26	0.37	1347.69	5.50	0.03
ENVIRONMENT- II														
Replication	2	1.17	143.40	11.74	0.09	992.40	65.45	1.82	4.62	423.40	0.49	31610.61*	4.04	0.01
Genotype	23	4.09**	33.99*	14.38**	13.3**	2265.97**	89.83**	2.72**	27.14**	190.36*	1.84**	2931.11**	657.49**	2.89**
Error	46	0.28	15.35	5.69	0.43	232.76	24.40	0.62	2.16	88.69	0.19	437.45	4.00	0.06
ENVIRONMENT- III														
Replication	2	3.02	69.89	29.56	0.84	175.32	53.55	0.45	1.62	130.69	2.36	1251.66	3.91	0.02
Genotype	23	10.79**	42.4**	11.46**	2.26**	285.22**	89.83**	1.66**	19.1**	426.19**	5.76**	3570.93**	563.72**	4.12**
Error	46	2.69	8.83	4.41	0.16	92.44	22.75	0.46	2.90	109.60	1.26	622.23	1.87	0.01
ENVIRONMENT- IV														
Replication	2	6.84	40.74	5.59	0.22	18.05	99.99	4.71	0.39	233.61	1.79	2931.58	3.23	0.11
Genotype	23	13.83**	48.34**	23.44**	0.84*	437.46**	137.95**	9.09**	19.10**	727.09**	2.40**	1584.33**	653.87**	1.80**
Error	46	1.23	11.77	3.04	0.12	107.95	40.29	1.49	2.43	76.69	0.30	169.05	2.01	0.02

*, ** Significant at 5 and 1 per cent levels, respectively.

Table 2 Mean, range, variability parameter, heritability and genetic advance for character in individual environment in carrot

Parameter	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β-Carotene contents (µg/g)	Total Soluble sugar
ENVIRONMENT – I													
Mean	8.86	26.83	15.81	4.18	94.02	67.49	2.26	20.15	51.51	3.86	186.52	35.29	5.7
Range	7.73-11.0	22.83-30.17	13.53-18.13	3.7-4.97	73.57-119.27	52.60-72.33	1.47-2.67	15.00-31.00	45.86-61.02	3.11-4.38	126.67-230.37	18.58-65.11	4.17-6.83
σ^2_g	0.32	5.01	1.85	0.4	102.78	27.05	1.10	12.11	29.1	0.4	367.84	221.17	0.44
σ^2_p	1.37	12.8	4.38	0.63	317.84	59.97	25.11	13.93	76.36	0.77	1715.56	226.67	0.47
σ^2_e	1.05	7.79	2.53	0.23	215.06	32.92	24.01	1.82	47.26	0.37	1347.72	5.5	0.03
GCV %	6.43	8.34	8.60	15.13	10.72	7.71	36.8	17.27	10.47	16.38	10.28	42.12	11.66
PCV %	13.21	13.33	13.24	18.99	18.96	11.47	175.82	18.52	16.96	22.73	22.21	42.66	12.03
Heritability	23.35	39.14	42.24	63.49	47.79	45.10	43.81	50.44	38.11	51.94	21.44	97.57	93.62
GA (% of mean)	6.35	10.75	11.52	24.18	18.66	10.64	15.57	19.07	13.27	23.88	9.81	85.24	23.04
ENVIRONMENT– II													
Mean	9.2	30.71	17.15	4.92	152.30	74.29	2.66	24.37	52.39	3.47	303.02	36.00	6.06
Range	7.60-10.87	22.43-34.67	13.87-19.13	4.13-5.47	103.87-239.30	66.53-81.93	1.80-3.60	20.00-30.33	38.67-67.97	3.01-4.14	250.17-399.83	17.03-69.08	4.00-7.90
σ^2_g	1.27	6.18	2.9	0.3	677.73	21.81	0.7	8.33	180.45	0.55	831.22	217.83	0.96
σ^2_p	1.81	21.53	8.58	0.73	910.49	46.21	1.32	10.49	269.14	0.74	1268.67	221.83	1.02
σ^2_e	0.28	15.35	5.68	0.43	232.76	24.40	0.62	2.16	88.69	0.19	437.45	4.00	0.06
GCV %	10.40	8.09	9.93	11.13	17.09	6.28	31.45	11.84	25.64	21.37	9.51	40.99	16.16
PCV %	12.40	15.10	17.08	17.36	19.81	9.15	43.19	13.29	31.31	24.79	11.75	41.37	16.66
Heritability	70.40	28.70	33.80	41.09	74.43	47.20	53.03	79.40	67.05	74.32	65.52	98.19	94.11
GA (% of mean)	17.96	8.93	11.61	14.69	30.38	8.89	47.16	21.73	43.25	37.95	15.87	86.00	32.27
ENVIRONMENT- III													
Mean	9.55	18.11	14.81	2.95	45.91	45.17	1.67	17.04	50.21	5.09	95.18	33.98	5.96
Range	7.83-11.10	14.70-23.60	11.67-17.50	2.57-3.47	26.80-73.70	36.5-56.43	1.10-2.50	14.00-19.67	39.31-56.05	3.81-6.55	73.8-151.93	17.12-67.54	4.00-7.96
σ^2_g	2.7	11.19	2.35	0.70	64.26	22.36	0.40	5.4	105.53	1.5	982.9	183.74	1.37
σ^2_p	5.39	20.02	6.76	0.86	156.7	45.11	0.86	8.39	215.13	2.76	1551.13	185.61	1.38
σ^2_e	2.69	8.83	4.41	0.16	92.44	22.75	0.46	2.90	109.60	1.26	622.23	1.87	0.01
GCV %	17.20	18.47	10.35	31.14	17.46	10.47	37.87	13.63	20.46	24.49	32.02	39.89	19.66
PCV %	24.31	24.471	17.56	31.43	27.27	14.87	49.59	16.99	29.21	32.63	41.38	40.09	19.71
Heritability	50.09	55.89	34.76	81.39	41.01	49.57	46.51	64.36	49.05	54.35	60.00	98.99	99.20
GA (% of mean)	25.08	28.44	12.57	52.70	23.03	15.18	52.62	22.41	29.48	31.18	51.14	71.29	40.19
ENVIRONMENT- IV													
Mean	9.37	25.93	16.63	3.66	81.62	62.52	2.59	20.24	43.32	4.56	197.19	34.97	5.67
Range	7.47-10.83	17.4-33.4	14.57-18.63	2.97-4.1	62.56-109.83	47.07-69.53	1.63-3.8	13.67-24.00	33.91-52.66	3.79-5.16	135.93-237.93	16.39-70.08	4.20-6.66
σ^2_g	4.2	12.19	6.8	0.24	109.84	32.58	2.4	4.44	216.8	0.7	471.76	217.29	0.59
σ^2_p	5.43	23.96	9.84	0.36	217.79	72.79	3.89	6.87	293.49	1.00	640.81	219.29	0.61
σ^2_e	1.23	11.77	3.04	0.12	107.95	40.21	1.49	2.43	76.69	0.30	169.05	2.00	0.02
GCV %	21.87	13.46	14.00	13.06	12.84	8.60	59.81	10.41	33.98	18.34	11.01	42.21	13.58
PCV %	24.86	18.87	16.94	16.18	18.08	13.64	76.15	12.94	35.72	21.92	12.83	42.35	13.77
Heritability	77.34	50.87	69.10	65.10	50.43	44.76	61.70	64.62	73.86	69.31	73.62	99.08	96.72
GA (% of mean)	39.4	19.44	24.10	21.81	18.78	12.57	95.69	17.23	19.5	31.17	19.30	86.21	27.30

2). The range was wide for weight of root (83.94 to 125.92 g), total biomass (170.5 to 226.33 g) and β-carotene content (18.28 to 66.57 µg/g). Moderate range was observed for plant top height (55.25 to 68.23 cm), harvest index (42.27 to 56.07 %), petiole length (19.47 to 28.15 cm) and core size (18.0 to 23.17 mm). The range was narrow in case of remaining characters *i.e.*, number of leaves per plant (8.09 to 10.22), length of root (14.43 to 17.76 cm), root diameter (3.67 to 4.13 cm), root laterals (1.74 to 2.87), root index (3.89 to 4.83) and total soluble sugar (4.09 to 7.15). Over all averages of different characters indicated that in general, genotypes performed better in E-II. High total biomass with higher range (250.17 to 399.83 g) was observed in E-II. Similarly, the lowest total biomass was (73.8 to 151.93 g) observed in E-III. The average biomass over environments was (170.5 to 226.33 g). Similarly, the highest weight of root with the widest range (103.87 to 239.30 g) was observed in E-II. While, the lower weight of roots with narrow range (26.8 to 73.7 g) was observed in E-III.

In environment-I (E-I), the higher values of genotypic and phenotypic variances were observed for total biomass (367.84 and 1715.56), weight of root (102.78 and 317.84) and β-carotene (221.17 and 226.67). In E-II, higher values of genotypic and phenotypic variances were recorded for total biomass (831.22 and 1268.67) and weight of root (677.73 and 910.49). Moderate amount of σ^2_g and σ^2_p values were recorded by harvest index (180.45 and 269.14) and β-carotene content (217.83 and 221.83.In E-III, total biomass (982.90 and 1551.13), β-carotene content (183.74 and 185.61), harvest index (105.53 and 215.13) and weight of root (64.26 and 156.70) showed higher σ^2_g and σ^2_p values. The moderate to low values at σ^2_g and σ^2_p were exhibited by the remaining characters. In E-IV, higher values of genotypic and phenotypic variance were recorded by total biomass (471.76 and 640.81), β-carotene content (217.29 and 219.29), harvest index (216.8 and 293.49) and weight of root (109.84 and 217.79). Moderate values were observed for plant top height (32.58 and 72.79) and petiole length (12.19 and 23.96) Table-2. The remaining characters showed low variation. The variance components estimated

Table 3 Mean, range,variability parameter, heritability and genetic advance for character in pooled over environment in carrot

Parameter	Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Weight of root (g/plant)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total Biomass	β-Carotene contents (µg/g)	Total Soluble sugar
Mean	9.23	25.39	16.10	3.93	93.46	62.34	2.29	20.41	49.34	4.25	195.48	35.03	5.84
Range	8.09-10.22	19.47-28.15	14.43-17.76	3.67-4.13	83.94-125.92	55.25-68.23	1.74-2.87	18.00-23.17	42.27-56.07	3.89-4.83	170.5-226.33	18.28-66.57	4.09-7.15
σ^2_g	0.09	3.31	0.16	0.002	3.83	0.76	0.001	0.27	3.58	0.013	34.74	13.06	0.57
σ^2_p	0.25	4.74	0.62	0.023	75.83	5.82	0.071	1.58	15.53	0.05	236.81	16.70	0.64
σ^2_e	0.135	0.91	0.32	0.020	13.50	2.91	0.05	0.19	6.71	0.04	167.18	1.60	0.002
GCV %	3.25	7.16	2.48	1.14	2.09	1.40	1.37	2.54	3.83	2.68	3.02	10.31	12.86
PCV %	5.42	8.57	4.86	3.86	9.32	3.87	11.58	6.15	7.98	5.26	7.88	11.66	13.63
Heritability	36.00	69.83	25.82	8.69	5.01	13.06	1.41	17.09	23.05	26.00	14.67	78.97	88.99
GA (% of mean)	4.01	12.18	2.50	0.80	0.96	1.04	0.33	2.20	3.79	2.80	2.27	18.97	25.03

Where, σ^2_g, σ^2_p and σ^2_e are the genotypic, phenotypic and environmental variance, respectively.

GCV % and PCV % are genotypic and phenotypic coefficient of variation, respectively.

GA (% mean) is genetic advance expressed as per cent of mean.

Table 4. Genotypic (G) and Phenotypic (P) correlation coefficient in carrot over pooled environment

Character		Number of leaves per plant	Petiole length (cm)	Length of root (cm)	Root diameter (cm)	Plant top height (cm)	Root laterals	Core size (mm)	Harvest index (%)	Root index	Total biomass (g)	β-Carotene contents (µg/g)	Total Soluble sugar
Weight of root (g/plant)	g	0.499*	0.163	0.828**	0.187	0.733**	-0.573**	-0.151	0.379	0.883**	-0.031	-0.506*	-0.625**
	p	0.087	0.155	0.247*	0.297*	0.151	0.010	0.004	0.163	-0.054	0.180	-0.153	-0.094
Number of leaves per plant	g		0.786**	0.038	0.716**	0.360	0.358	0.071	-0.132	0.310	0.282	0.254	-0.429*
	p		0.126	0.128	0.215	-0.046	-0.003	0.198	-0.390	-0.121	0.361**	0.045	-0.083
Petiole length (cm)	g			0.229	0.796**	0.182	-0.045	-0.383	0.919**	0.574**	0.193	-0.014	0.029
	p			0.167	-0.068	0.147	0.024	-0.057	0.347**	0.111	0.383**	-0.030	0.004
Length of root (cm)	g				-0.183	0.820**	0.764**	-0.056	0.434*	0.162	0.469*	0.198	-0.446*
	p				0.165	0.052	-0.018	0.117	-0.198	0.649**	0.361**	0.033	-0.081
Root diameter (cm)	g					-0.838**	0.540**	0.650**	0.045	-0.312	-0.090	-0.695**	-0.759**
	p					0.014	0.050	0.262*	-0.133	-0.470**	0.307**	-0.092	-0.044
Plant top height (cm)	g						0.807**	-0.207	-0.047	-0.070	0.552**	0.641**	0.976**
	p						0.024	0.072	-0.149	0.016	0.304**	0.017	0.063
Root laterals	g							0.105	0.529**	0.961**	-0.601**	0.620**	-0.955**
	p							0.001	0.042	-0.039	-0.034	0.051	-0.124
Core size (mm)	g								0.148	-0.794**	-0.094	0.445*	0.538**
	p								-0.145	-0.088	0.236*	-0.085	0.195
Harvest index (%)	g									0.133	0.201	0.065	-0.090
	p									-0.048	-0.702**	0.027	-0.009
Root index	g										0.385	0.107	0.448*
	p										-0.005	0.072	0.059
Total biomass (g)	g											-0.611**	-0.337
	p											-0.066	-0.051
β-Carotene contents (µg/g)	g												-0.174
	p												-0.112

*, ** Significant at 5 and 1 per cent levels, respectively.

from pooled data Table 3 naked the values of genotypic and phenotypic variances *i.e.*, 34.74 and 236.81 for total biomass, 3.83 and 75.83 for weight of root, 13.06 and 16.70 for β-carotene and 3.58 and 15.53 for harvest index, respectively. The moderate values of σ^2_g and σ^2_p were recorded for petiole length *i.e.*, 3.31 and 4.74 and plant top height *i.e.*, 0.76 and 5.82, respectively. The rest of the characters exhibited low values of genotypic and phenotypic variances. On pooled basis range of all the thirteen traits were compared, maximum variation was observed for total biomass pursued by weight of root per plant (Table 3). The comparable results were obtained by Amin and Singla (2010) and Kumar *et al.*, (2011). The study further revealed that the narrow range of phenotypic variation was observed for number of leaves per plant. This may be due to optimization of number of leaves per plant under natural selection pressure.

Heritability indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. High broad sense heritability estimates were observed for petiole length, β-carotene content and total soluble sugar in pooled analysis. The characters weight of root, root diameter, plant top height, root laterals and total biomass registered very low heritability estimates on pooled basis (Table 3). Similar results of lower heritability for root yield by Gupta *et al.*, (2012) and for root diameter core size and root length were observed by Amin and Singla, (2010). The heritability for weight of root was highest in environment E-II. From this result, it can be concluded that environment E-II was most favourable for expression of maximum genetic potential of genotypes. The expected genetic advance estimated over four environments was higher for total soluble sugar, while moderate values were observed for β-carotene content and petiole length. For all other traits including weight of root per plant, the genetic advance was very low. The root yield and root yield attributes like length of root, root diameter, harvest index, root index and total biomass registered lower heritability and lower genetic advance under selection. This shows influence of environment and G x E interaction in expression of phenotypes. Thus the selection is possible only after selecting a particular environment were heritability values and genetic advance are higher for the characters under improvement. Accordingly, heritability and genetic advance were higher for weight of root in environment-II (E-II). Therefore, selection for higher weight of root will be fruitful under environment-II (E-II). Similarly, yield components like harvest index, root index and total biomass having higher heritability and higher expected genetic advance can be improved under environment-II (E-II). The weight of root per plant was highly and positively correlated with root index, plant top height, length of root and number of leaves per plant. Thus, four characters were turned out to be the principle component traits of weight of root. Strong and positive correlation coefficients for weight of root per plant with these traits indicated that the selection for any of these traits will simultaneously improve the yield, depending upon the magnitude of correlation (Table 4). The above results are in accordance with the finding of earlier workers for correlation of weight of root with length of root, plant top height Natarajan and Arumugam (1980) and Bhagchandani and Chaudhary (1980) weight of root with number of leaves per plant by Bhatia *et al.*, (2002) and Singh *et al.*, (2005). The weight of root was negatively correlated with root laterals, β-carotene content and total soluble sugar. Singh *et al.* (2005) noticed negative correlation of weight of root with total soluble sugar and β-carotene content. Thus, important characters positively correlated with weight of root per plant were number of leaves per pant, length of root, plant top height, root index and total biomass.

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