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GENETICAL STUDIES OF QUALITY TRAITS IN CARROT (*DAUCUS CAROTA* L.)

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ABSTRACT

Genetical studies were conducted in carrot (*Daucus carota* L.) in triple test-cross design involving European and Asiatic cultivars to determine the role of additive, dominance and epistatic genetic components in five selected quality traits. Epistasis was observed for all the traits. The additive x dominance ($\hat{j}$) and dominance x dominance ($\hat{l}$) gene interactions were important for dry matter and total sugar content. Both additive and nonadditive genetic variances were significant for total soluble solids and β-carotene contents. The additive (D) genetic components of variation were more pronounced for ascorbic acid content. Dominance in the range of overdominance was recorded for total soluble solids, while it was partial in the expression of other traits.

Key words: Carrot, Asiatic, European, β-carotene, total sugars, gene action.

Carrot is grown all over the world, both for fresh as well as processed vegetable. Its roots are rich source of β-carotene (a precursor of vitamin A), sugars and fibre. Asiatic type carrots are poor in quality traits, while several European types are rich in β-carotene, total soluble solids, dry matter and total sugar contents. The knowledge of the magnitude and relative importance of additive, dominance and epistatic gene effects will be helpful in deciding suitable breeding strategy for improvement of quality attributes of the Asiatic type carrots. The triple test-cross method of Kearsey and Jinks [1] was used, which serves not only a precise test for epistatis but also gives unambiguous estimates of additive (D) and dominance (H) components of genetic variation, when epistasis is absent. The present investigation has been undertaken to determine the genetic system controlling the quality traits in carrot involving inbred lines of Asiatic and European origin.

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MATERIALS AND METHODS

Inbreds of carrot cultivar No. 29 (Asiatic) and Chantenay (European), and their F_1 hybrids were crossed with five desirable selected individual plants (P_1–P_5) from their F_2 populations (5ji parental lines) resulting in fifteen triple test-cross progenies. The fifteen families along with 5ji parental lines and 3 female testers were grown in randomized block design with three replications. Data were recorded for five quality traits. Total soluble solids were estimated with the help of hand refractrometer. Root samples of randomly selected roots were crushed and the juice squeezed through a double layer of fine mesh cloth into a centrifuge tubes. After centrifugation for 2 minutes, the soluble solids were determined in percentage. Dry matter contents were estimated by drying 100 g of root sample in oven at 50–60°C and the weight recorded after complete drying was expressed in percentage. Ascorbic acid content was estimated by the titrimetric method as described by Hortwitz and William [2]. β-carotene content was determined by the procedure of Thomas and Joshi [3], and total-sugars according to the A.O.A.C. methodology [4].

Analysis of variance for the design of experiment was done as per the model of Fisher [5]. Epistasis, additive and dominance genetic components were determined as described by Kearsey and Jinks [1] which is based on the following model:

$$Lijk = \mu + Gij + rk + eijk$$

where Lijk—the phenotypic value in replication K of cross between tester L_1 and cv. j, μ—mean of all single and three way crosses, Gij—genotypic value of the cross between tester L_1 and cv. j, rk—effect of replication K, and eijk—error variance.

The epistatic deviations ($\overline{L_1jk} + \overline{L_2jk} - \overline{2L_3jk}$) and their means over replications were calculated for each cultivar. When the overall means of the epistatic deviations ($\overline{L_1j} + \overline{L_2j} - \overline{2L_3j}$) were significant, the presence of epistasis was taken to be confirmed.

Additive (D) and dominance (H) components of genetic variations were calculated by fitting the additive—dominance model by obtaining variance of sums ($\overline{L1j} + \overline{L2j}$) and the variance of differences ($\overline{L_1j} - \overline{L_2j}$). The degree of dominance $\sqrt{H/D}$ was obtained as the ratio of dominance genetic variance to the additive genetic variance.

RESULTS AND DISCUSSION

The mean values for different quality traits and the analysis of variance for epistasis, $\hat{i}$, $\hat{j}$ and $\hat{l}$, and D and H components in the triple test-cross progenies of the carrot cultivar No. 29 and Chantenay are given in Tables 1 and 2. Presence of large genetic variation is indicated by the significant values of mean squares for the progenies, parental lines, and the

Table 1. Character means in triple test-cross progenies of cv. No. 29 and Chantenay

Treatment	Total soluble solids (%)	Dry matter content (g/100 g)	Ascorbic acid content (mg/100 g)	β-carotene content (mg/100 g)	Total sugar content (g/100 g)
P_1 x No. 29	4.20	8.80	6.08	5.26	4.08
P_1 x F_1	8.00	10.87	4.33	7.17	5.53
P_1 x Chantenay	5.53	9.33	5.04	4.02	5.33
P_2 x No. 2	6.98	10.97	7.72	8.99	7.76
P_2 x F_1	6.83	9.93	6.40	4.74	6.96
P_2 x Chantenay	6.40	9.33	6.67	4.08	5.52
P_3 x No. 29	6.00	8.13	7.35	4.46	3.54
P_3 x F_1	6.20	9.20	2.97	6.89	5.87
P_3 x Chantenay	6.00	9.33	7.13	5.87	3.45
P_4 x No. 29	5.60	6.13	2.53	3.48	4.47
P_4 x F_1	6.87	11.89	3.02	7.64	3.56
P_4 x Chantenay	7.20	10.87	3.97	7.88	7.33
P_5 x No. 29	8.47	12.93	4.08	8.69	8.64
P_5 x F_1	7.09	9.73	4.04	5.06	3.41
P_5 x Chantenay	8.63	13.20	5.90	9.91	7.70
P_1 (F_2 selection)	6.33	9.47	3.83	5.80	4.50
P_2 (-do-)	6.40	10.12	5.88	7.96	6.25
P_3 (-do-)	5.47	8.40	4.34	5.33	5.07
P_4 (-do-)	6.33	8.27	4.90	5.22	4.84
P_5 (-do-)	6.13	9.20	4.08	6.59	4.45
No. 29	4.23	8.73	2.86	3.29	3.54
Chantenay	6.00	9.93	5.52	7.08	6.85
F_1 (No. 29 x Chantenay)	6.13	10.00	4.92	6.32	6.12
SE	0.54	0.40	0.65	0.40	0.42
CD at 5%	0.77	0.80	1.31	0.80	0.84

female testers. The progenies of P_1 x F_1, P_2 x No. 29, P_4 x F_1, P_4 x Chantenay and P5 x No. 29 gave high mean squares for total soluble solids, dry matter, total sugars and β-carotene content. The increase in quality attributes was to the extent of 104.0, 51.2, 169.9, 144.1 and 173.3%. Epistasis was significant for all the traits over the Asiatic cultivar No. 29, indicating

Table 2. Analysis of variance (mean squares) for epistasis, $\hat{i}$, $\hat{j}$ & $\hat{l}$ and D & H components for different characters in triple test-cross progenies of cvs. 29 and Chantenay

Source	Total soluble solids	Dry matter content	Ascorbic acid content	β-carotene content	Total sugar content
Epistasis:					
$(\bar{L}_{1i} + \bar{L}_{2i} - 2\bar{L}_{3i})$	6.718**	5.911**	5.997**	10.716**	17.132**
$\hat{i}$ type gene action	9.152**	0.641	3.552**	1.113*	0.108
$\hat{j}$ and $\hat{l}$ type gene action	6.109**	7.228**	6.609**	13.117**	21.388**
Sums $(\bar{L}_{1i} + \bar{L}_{2i})$	14.385**	30.258**	27.377**	29.519**	21.230**
Sums x replicates	0.147	4.510**	0.619	0.885	2.091*
Differences $(\bar{L}_{1i} - \bar{L}_{2i})$	3.103**	11.234**	0.710	10.208**	6.740**
Differences x replicates	0.183	1.894*	0.999	0.454	1.519*
D	18.98	34.33	35.67	38.17	25.51
H	3.89	12.45	0.014	13.00	6.96
$\sqrt{H/D}$	0.205	0.60	0.01	0.58	0.52

*,**Significant at 5% and 1%, respectively.

the role of epistasis in the inheritance of these traits. The additive x additive ($\hat{i}$), additive x dominance ($\hat{j}$), and dominance x dominance ($\hat{l}$) gene interactions were significant for total soluble solids, ascorbic acid and β-carotene content, along with significant additive (D) and dominance (H) gene effects for total soluble solids, dry matter, β-carotene and total sugar content, suggesting thereby the combined role of additive and non-additive genetic variances in the control of these traits. The breeding approach should try to exploit both types of genetic variances which could be utilized through reciprocal recurrent selection for the improvement of these traits. By adopting recurrent selection it was possible to increase β-carotene [6, 7], total soluble solids and total sugar content in carrot through crossing and phenotypic recurrent selection [8].

The nonsignificant variance of the differences $(\bar{L}_{1j}-\bar{L}_{2j})$ and significant variance of sums $(\bar{L}_{1j} + \bar{L}_{2j})$ indicates the absence of dominance (H) and the presence of additive (D) genetic components for ascorbic acid content, which suggests that selection for improvement of this trait could be effective. The additive x dominance ($\hat{j}$) and dominance x dominance ($\hat{l}$) genetic interactions were more pronounced for dry matter and total sugar content which is not fixable by selection, hence could be useful in the development of hybrids.

One of the testers used in the present studies, Asiatic cultivar No. 29, has very low β-carotene content (3.29 mg/100 g). The European cultivar Chantenay has orange roots and high β-carotene content (7.08 mg/100 g). The level of total soluble solids, dry matter, total sugars and β-carotene content increased by 41.2, 32.9, 26.1 and 27.0%, respectively, over cv. Chantenay. It was reported earlier [9–12] that some promising hybrids of carrot had significantly higher level of total soluble solids, dry matter, total sugars and β-carotene. Visual selection for carotene is feasible up to 15 mg/100 g [13]. The desired bright orange colour must extend from the tap root and to crown with matching xylem and phloem colour with indistinct cambium zone.

The additive–dominance model was fitted to explain the cause of genetic variation by obtaining the variance of sums ($\overline{L_{1j}} + \overline{L_{2j}}$) and differences ($\overline{L_{1j}} - \overline{L_{2j}}$). Both the sums and differences were significant for total soluble solids, dry matter, β-carotene and total sugar content, indicating the presence of both additive (D) and dominance (H) components of genetic variation. However, the additive variance were biased by dominance variance and the presence of nonallelic interactions. The dominance was in the range of overdominance for total soluble solids, while partial dominance was observed in the case of other quality traits. The progenies P_2 x No. 29, P_5 x No. 29 and P_4 x Chantenay were outstanding for high mean values of the quality traits like total soluble solids, dry matter, β-carotene, total sugar content, and offer promise for selecting desirable lines with high carotene and other quality traits in the segregating populations.

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