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ASSESSMENT OF GENETIC POTENTIAL OF ORANGE COLOURED CARROT GENOTYPES FOR YIELD AND QUALITY TRAITS

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ABSTRACT

The present investigation was carried out in twenty-five orange-coloured carrot genotypes for their economic traits. The analysis of variance showed that significant variability existed in all the sixteen traits under evaluation. Genotype P-16-2 attained marketable root maturity the earliest. The root length, root weight, total root yield and marketable root yield were observed to be the highest in genotype P-4-2. Genotype PCO-15 had the highest sugar content and juice yield. Genotype P-17-1 obtained the highest dry matter content whereas the highest carotene content was observed in genotype P-41-1. Overall, the performance of genotypes P-4-2, TS-15 and P-41-1 was found to be significantly better than the other genotypes in terms of majority of the economic traits. The degree of GCV was the highest for marketable root yield per plot (16.68%) and PCV was found to be the highest for flesh thickness (24.02%). The maximum heritability (85.12%) was found for plant height. The genetic gain was found to be maximum (33.19%) for marketable root yield per acre.

Keywords: Morphological analysis, Nutritional analysis, Orange carrot

Carrot *(Daucus carota* L.) belongs to Umbelliferae family and has chromosome number of 2n=2x=18. It is one of the most important root vegetable crops suitable for both fresh market and processing purposes (Kalia, 2005). The presence of different pigments in carrot roots results in the formation of different coloured roots like red, yellow, white, orange, black and purple (Haq and Prasad, 2014) and each of them contributes unique source of dietary compounds to human nutrition. Amongst the vegetables, carrot is known to be the single major source of β-carotene which provides 17% of the overall vitamin A consumption (Saha *et al.,* 2015). Apart from this, carrot is also a rich source of nutrients like leutin, lycopene and anthocynin. Orange coloured carrots are high in β-carotene which is the leading anti-cancerous vitamin along with being a good source of vitamin A and other minerals like potassium, phosphorus, calcium, etc. (Saha *et al.,* 2015). In Punjab, two types of carrot varieties are grown i.e. Asiatic type and European type which are red and orange coloured due to presence of lycopene and carotene, respectively. But European types which are rice in carotene are not able to set seeds under Punjab conditions therefore to introgress carotene into red colored genotypes a breeding programme was started at Punjab Agricultural University, Ludhiana in the year 2013-14. The orange coloured germplasm thus developed over the years was tested in this investigation to determine the genetic variability present in yield and quality parameters so that promising genotypes could be directly used as cultivar or used as inbred in the breeding programme.

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MATERIALS AND METHODS

The present study was conducted at Research Farm, Director (Seeds), Punjab Agricultural University, Ludhiana during the years 2019-20 and 2020-21 in which twenty-five orange-coloured genotypes of carrot were evaluated for their morphological and biochemical traits. Sowing was done on raised beds of 67.5 cm each in a Randomized Block Design (RBD) with three replications during the second week of October in both years. For maintaining a healthy crop, all the recommended cultural practices like seed rate, spacing, fertilizer application, weeding, thinning, earthing up, etc. were adopted as per the recommendation of Punjab Agricultural University, Ludhiana (Anonymous, 2021). The roots were harvested when they attained full maturity.

Observations were recorded for sixteen morphological and biochemical characters *viz.,* shoot length (cm), shoot weight (g), root length (cm), root weight (g), plant height (cm), root girth (cm), core girth (cm), flesh thickness (cm), root : shoot ratio, days to first root harvest, total root yield (q/acre), marketable root yield (q/acre), dry matter content (%), sugar content (%), carotene content (%) and juice yield (ml/kg roots). In addition to this, observations were also made for root and core colour, root forking (%) and the incidence of *Alternaria* blight in which the categorization for the infected plants was done into low (<5% leaf area damaged), medium (5-40% leaf area damaged) and high (more than 60% leaf area damaged/ severe defoliation) categories.

The estimation of genetic parameters like GCV, PCV, heritability and genetic gain was also done. The calculation of coefficients of variation was done with the help of the formula recommended by Burton and Devane (1953). The heritability was calculated by the formula suggested by Weber and Moorthy (1952). For the estimation of genetic gain, formula given by Johnson *et al.,* (1955) was followed. The genotypic and phenotypic levels of correlation were computed using the formula suggested by Al Jibouri *et al.,* (1958) and the path co-efficient analysis was conducted using the formula given by Dewey and Lu (1959). The estimation for total sugars was done using the formula suggested by Dubios *et al.* (1956). For the estimation of dry mater content and carotene content in carrot AOAC methods were used.

The data was statistically analyzed using computer programme CPCS1 (Cheema and Singh 1990) for the analysis of variance for estimating significance of differences in mean values.

RESULTS AND DISCUSSION

The analysis of variance presented Table 1 showed that significant variability existed amongst the evaluated genotypes in all the characters under study at 5% level of significance which indicated that there is a good scope of improvement in them.

The *per se* performance of the genotypes is presented in Tables 2 and 3 and it was found that Genotype P-23-1 recorded a shoot length of 45.77 cm and a shoot weight of 30.73 g which was significantly better than all other genotypes. The maximum root length and root weight was recorded in genotype P-4-2 i.e. 26.37 cm and 97.23 g, respectively, which was significantly better than other genotypes indicating genotypic differences. Plant height of genotype P-23-1 (71.43 cm) was higher than all the other genotypes. Meghashree *et al.* (2018) also reported genotypic differences for the plant height. Root girth and flesh thickness of 5.39 cm and 3.49 cm were respectively recorded in genotype P-4-2. Kumar *et al*. (2010) also found that flesh thickness was genotype dependent trait. Genotype PCO-19 possessed the lowest core girth which was 1.0 cm. The range for root: shoot ratio was 3.00-3.97 with the highest being in genotype P-41-1 which differed significantly from other genotypes. Tewatia *et al.* (1990) also reported that genotypes played important role in determining the root: shoot ratio.

The minimum number of days to first root harvest were taken by genotype P-16-2 which was harvested 95.67 days after sowing. Highest total root yield and marketable root were recorded in genotype P-4-2 i.e., 224.21 and 208.72 q/acre, respectively. The total root yield ranged from 121.69 to 224.21 q/acre among different genotypes. Meghashree *et al.* (2018) also reported that genotypes play important role in determining the yield potential of carrot crop. Simon and Wolf (1987) also reported varied performance of cultivars with regard of genotype, location and season.

Table 1. Analysis of variance for different traits under evaluation

Character	Mean squares		
	Replications	Treatments	Error
Shoot length	19.24	204.59*	8.01
Shoot weight	10.48	44.37*	5.33
Root length	12.04	40.63*	2.18
Root weight	9.09	286.97*	14.44
Plant height	53.74	355.22*	10.06
Root shoot ratio	0.26	0.44*	0.15
Root girth	0.11	2.38*	0.11
Core girth	0.16	0.37*	0.05
Flesh thickness	0.09	1.15*	0.18
Total root yield	1682.22	5893.13*	227.20
Marketable root yield	138.09	5593.19*	191.37
Days to first root harvest	3.43	30.10*	8.12
Dry matter	0.73	1.14*	0.69
Sugar content	0.36	4.67*	0.52
Carotene content	0.75	1.32*	0.11
Juice yield	1134.05	837.28*	207.33

* Significant at 5% level

Table 2. ***Per se*** **performance of different genotypes for morphological traits**

Genotype	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	Plant height (cm)	Root girth (cm)	Core girth (cm)	Flesh thickness (cm)	Root shoot ratio	Days to first root harvest	Total root yield (q/ac)	Marketable root yield (q/ac)
P-3-1	32.73	22.97	21.93	83.08	54.67	3.59	1.26	2.33	3.64	101.50	185.53	173.65
P-4-2	41.90	26.50	26.37	97.23	68.27	5.39	1.90	3.49	3.70	102.33	224.21	208.72
P-5-1	42.07	27.37	24.77	89.63	66.83	4.05	1.51	2.54	3.31	101.33	202.30	188.52
P-13-1	34.03	23.30	21.88	82.92	55.92	3.66	1.27	2.38	3.61	99.67	185.52	171.96
P-16-2	42.87	28.13	22.87	84.17	65.73	3.63	1.43	2.20	3.00	95.67	194.11	181.20
P-17-1	43.60	28.73	24.83	91.42	68.43	4.27	1.73	2.53	3.20	99.17	203.05	189.21
P-18-2	42.03	27.37	24.30	87.53	66.33	3.80	1.49	2.31	3.23	99.17	200.56	185.07
P-23-1	45.77	30.73	25.67	93.87	71.43	4.84	1.62	3.22	3.06	101.67	209.21	194.80
P-28-2	42.27	27.13	24.93	93.02	67.20	4.48	1.51	2.97	3.44	100.00	204.37	191.30
P-35-1	39.33	24.70	23.93	86.30	63.27	3.73	1.46	2.26	3.51	102.17	199.56	185.68
P-41-1	35.57	23.90	25.90	94.57	61.47	4.98	1.69	3.29	3.97	100.83	213.51	199.00
PCO-N-1	36.77	24.20	24.47	86.83	61.23	3.87	1.70	2.17	3.66	98.00	200.04	186.05
PCO-18	37.43	24.73	22.73	83.78	60.17	3.62	1.34	2.28	3.40	100.50	192.85	179.37
PCO-11	31.03	22.80	18.83	75.93	49.87	3.24	1.15	2.09	3.34	100.67	137.37	125.12
PCO-12	29.27	20.67	18.37	74.72	47.63	3.01	1.03	1.98	3.70	102.17	130.26	116.44
PCO-14	28.10	20.90	19.20	77.35	47.30	3.40	1.17	2.24	3.71	100.67	143.58	131.53
PCO-15	26.47	21.33	22.50	83.40	48.97	3.63	1.36	2.27	3.94	99.83	187.92	175.01
PCO-17	27.33	21.50	22.77	82.87	50.10	3.63	1.31	2.32	3.89	99.50	191.08	177.68
PCO-19	28.70	20.70	17.87	72.40	46.57	2.80	1.00	1.85	3.52	104.67	121.69	109.33
PCO-16	39.73	24.57	19.93	78.53	59.67	3.51	1.17	2.34	3.22	99.50	156.44	143.22
TS-15	42.80	27.43	26.07	95.48	68.87	4.69	1.64	3.05	3.54	97.50	217.64	202.01
PCO-2-2	40.13	24.50	18.63	75.00	58.77	3.10	1.09	2.01	3.10	100.50	129.67	116.40
PCO-6-2	33.73	23.00	21.67	83.03	55.40	3.57	1.24	2.33	3.65	100.17	183.97	170.94
PCO-SK-1	37.73	24.27	21.43	81.60	59.17	3.61	1.28	2.33	3.39	100.50	189.01	176.22
Arka Suraj	41.03	25.83	24.83	93.65	65.87	4.27	1.54	2.73	3.54	100.33	182.20	168.16
Mean	36.90	24.69	22.67	84.73	59.56	3.85	1.40	2.46	3.49	100.32	183.43	169.86
CD (5%)	3.34	2.46	1.53	3.69	3.55	0.36	0.29	0.48	0.38	2.36	16.21	15.70
CV	7.80	11.23	8.90	12.12	11.41	8.34	13.45	8.76	9.12	12.52	11.23	10.41

Forking of roots greatly influence the marketable yield of carrot which was very low in the tested genotypes. *Alternaria* blight is an important disease which affects the carrot crop and a 40-60% loss have been reported by Singh (2013) but in the present investigation incidence was low in all of the tested genotypes during both years.

Dry matter content was maximum in genotype P-17-1 i.e., 10.52% and ranged from 8.71-10.52% in different genotypes. Amin *et al* (2013) also reported genotypic difference in dry matter content ranging from 6.77-8.78%. The sugar content in the evaluated genotypes varied from 6.90-9.76%, highest being in genotype PCO-15. Yadav *et al.* (2009) also reported that total sugar content in the tested genotypes ranged from 7 to 7.8%. All of the tested cultivars were orange in colour due to the presence of carotene. Maximum carotene content was found in genotype P-41-1 (10.55 mg/100g) indicating it to be a rich source. Kumar *et al* (2010) also reported genotypic differences for the carotene content. The juice yield was the highest for genotype PCO-15 i.e., 535 ml/ kg root whereas the range varied from 488.33 to 535 ml/kg root. Kaur *et al.* (2009) also said to have juice yield ranging 440.0-559.45 ml/kg root in different genotypes.

The data pertaining to the genetic estimates of variability and heritability are depicted in Fig. 1. It was observed that the range for GCV varied from 1.91% to 17.74% and it was found to be moderate in marketable root yield (17.74%), total root yield (17.20%), flesh thickness (16.59%), core girth (16.53%), root girth (16.05%) and shoot length (15.51%). Low genotypic

Table 3. ***Per se*** **performance of different genotype for their nutritional analysis**

Genotype	Dry matter (%)	Sugar content (%)	Carotene content (mg/100g)	Juice yield (ml/kg root)
P-3-1	9.55	7.55	9.85	503.33
P-4-2	10.14	9.51	9.50	533.33
P-5-1	9.57	9.60	10.51	515.00
P-13-1	9.41	7.86	9.55	520.00
P-16-2	8.83	8.73	10.11	508.33
P-17-1	10.52	8.51	9.28	520.00
P-18-2	9.98	7.61	10.43	526.67
P-23-1	8.71	7.61	9.45	526.67
P-28-2	9.38	6.95	9.90	516.67
P-35-1	9.68	8.93	10.54	520.00
P-41-1	10.11	9.64	10.55	530.00
PCO-N-1	9.47	8.07	8.82	520.00
PCO-18	9.29	8.10	9.75	521.67
PCO-11	8.84	8.93	10.53	503.33
PCO-12	9.58	9.09	9.96	523.33
PCO-14	9.20	9.58	10.27	523.33
PCO-15	10.01	9.76	9.32	535.00
PCO-17	9.66	6.90	9.56	525.00
PCO-19	9.63	7.73	9.72	531.67
PCO-16	10.01	8.89	10.07	518.33
TS-15	9.30	8.08	10.15	533.33
PCO-2-2	9.97	7.48	9.53	511.67
PCO-6-2	9.34	7.42	9.64	513.33
PCO-SK-1	9.38	8.41	9.23	495.00
Arka Suraj	9.32	9.54	9.79	488.33
Mean	9.55	8.42	9.84	518.53
CD (5%)	0.76	0.75	0.26	16.58
CV	7.81	6.12	4.15	6.41

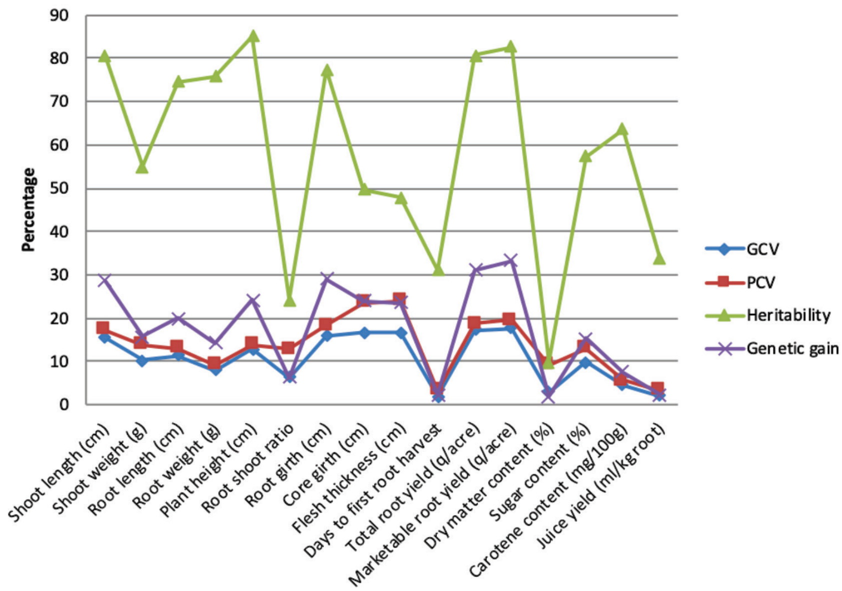

Fig. 1. Graphical representation of genetic variability and heritability components in carrot

coefficient of variation was observed for plant height (12.76%), root length (11.23%), shoot weight (10.33%), sugar content (9.87%), root weight (7.95%), root shoot ratio (6.28%), carotene content (4.55%), dry matter content (2.88%) and juice yield (1.97%). The lowest GCV was observed in days to first root harvest (1.91%). Yadav *et al* (2009) found the percentage of GCV in a range between 2.46 to 15.75. The lowest and the highest GCV was found to be for total sugars and root: shoot ratio, respectively. Meghashree *et al.* (2018) found the highest value of GCV for root splitting (%) and lowest value for the number of leaves per plant. The range for PCV was found to be between 3.40-24.02%. Moderate level of phenotypic coefficient of variation was found in flesh thickness (24.02%), core girth (23.45%), marketable root yield.

Heritability in the current study varied from 9.92-85.12%. The values of heritability were high for plant height (85.12%), marketable root yield (82.47%), total root yield (80.61%) and shoot length (80.36%); moderate for root girth (77.2%), root weight (75.87%), root length (74.62%), carotene content (63.62%), sugar content (57.20%) and shoot weight (54.99%); low in core girth (49.68%), flesh thickness (47.69%), juice yield (33.62%), days to first root harvest (31.08%) and root shoot ratio (24.15%). The lowest heritability amongst all the characters was for dry matter content which was 9.9%. Kumar *et al.* (2010) had found the heritability to be high for total root yield. Higher heritability indicates that the traits are less influenced by environment and selection based on phenotypic variation can be effective whereas low heritability shows that there is more effect of environment on the traits and their ability to transmit to the next generation is low.

Table 4. Pooled analysis for genotypic and phenotypic correlation for root yield and its contributing traits

Trait		Root length (cm)	Root weight (g)	Root girth (cm)	Total root yield (q/acre)
Root length (cm)	G	1.000	0.998**	0.941**	0.999**
	P	1.000	0.921**	0.818**	0.909**
Root weight (g)	G		1.000	0.990**	0.954**
	P		1.000	0.897**	0.890**
Root girth (cm)	G			1.000	0.859**
	P			1.000	0.789**
Total root yield (q/acre)	G				1.000
	P				1.000

** Significant at 1% level

Table 5. Direct and indirect effect of characters on root yield

Trait		Root length (cm)	Root weight (g)	Root girth (cm)	Correlation with total root yield
Root length (cm)	G	**0.860**	0.606	-0.709	0.999**
	P	**0.198**	0.088	0.022	0.909**
Root weight (g)	G	0.869	**0.599**	-0.745	0.954**
	P	0.182	**0.096**	0.024	0.890**
Root girth (cm)	G	0.809	0.593	**-0.753**	0.859**
	P	0.162	0.086	**0.027**	0.789**

** Significant at 1% level

Genetic gain is referred to as improvement in the mean of genotypic values of some selected families over the base population. The phenotypic superiority of a plant over its original population is not exclusively because of genotypic superiority but could result because of favorable environment. Therefore, heritability alone cannot be stated as an effective parameter on which selection is based. According to Burton (1953), heritability alone is not enough to make an effective selection until it is complemented by a good amount of genetic advance. In the present study, genetic gain was found between the range of 1.87 to 33.19 per cent (Table 4). Moderate level of genetic gain was observed in marketable root yield (33.19%), total root yield (31.12%), root girth (29.06%) and shoot length (28.65%). The magnitude of genetic gain was low for plant height (24.25%), core girth (24%), flesh thickness (23.60%), root length (19.98%), shoot weight (15.78%), sugar content (15.38%), root weight (14.27%), carotene showing the highest genotypic (0.999**) and phenotypic (0.994**) correlation with total root yield was root length (Table 4). The magnitude of genotypic correlation was higher from phenotypic correlation which indicated that the association between them is mainly because of genetic factors.

The path coefficient analysis divides correlation into direct and indirect effects and evaluates the impact of independent traits on the dependent character. When correlation is analysed in conjugation with path analysis, more accurate information is obtained which can be used for carrying out crop improvement program successfully. Total root yield was considered as the dependent variable which is dependent on the traits namely root length, root weight and root girth. It was observed that root length (0.860) and root weight (0.599) have a positive direct effect on yield whilst root girth (-0.753) has a negative direct effect on this trait (Table 5). From this analysis, it is evident that emphasis should be given to the characters like root length and root weight for effective selection as they have positive direct effect on the total root yield of carrot.

Genotypes different significantly from each other in morphological as well as quality traits. Genotype P-4-2 followed by TS-15 recorded maximum root length, root weight, total root yield and marketable root yield. Genotype P-41-1 was better in majority of parameters including biochemical traits. Phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all evaluated traits which indicated the role of environment.

Authors' contribution

Conceptualization of research work and designing of experiments (TSD, RD, NKS); Execution of field/ lab experiments (NKS, TSD, RD); Analysis of data and interpretation of results (NKS, TSD, RD); Preparation of manuscript (NKS, TSD, RD).

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