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Short communication

Evaluation of carrot (*Daucus carota* L.) hybrids at mid-elevation and higher in the Nilgiris

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ABSTRACT

Investigations were made on yield and quality in six hybrids of carrot spanning two seasons under Nilgiri hill conditions during the year 2012-2013. The hybrids were evaluated for *per se* performance, genotypic coefficient of variance, heritability and genetic advance. A high estimate for genotypic coefficient of variation was observed in root-splitting percentage, total chlorophyll, root carotenoids, leaf carotenoids and root-forking percentage in the hybrids, indicating a potential for improvement of these traits by simple selection, in *kharif* and summer. Leaf and root carotenoid content, total chlorophyll, number of leaves and root weight exhibited higher values for heritability, coupled with a high genetic advance, revealing these traits to be under the control of gene action. Simple selection can, therefore, effect improvement in these characters.

Key words: Genetic variability, hybrids, heritability, genetic advance

Carrot (*Daucus carota* L.) of the family Apiaceae is a cool-season crop grown across the world - in spring, summer and autumn in the temperate countries, and during winters in the tropical and subtropical countries. It has a fleshy, edible tap root botanically designated as a conical root. Carrot is classified into two groups: Asiatic (tropical) and European (temperate) types. World-wide consumption of carrot has increased over the past years, and, it is now one of the most popular vegetable crops.

Asiatic carrots are generally red in colour owing to anthocyanin pigments. The European types are orange due to carotene, a precursor of Vitamin A. In India, Asiatic types are the ones mostly grown, probably due to their appealing red colour. Carrot improves the quantity of urine and helps eliminate uric acid. Chopra *et al* (1933) reported carrot as curing diseases of the kidney, and dropsy. Dietary supplement of a combination of carrot and orange juices has been found to reduce oxidation of low-density lipoprotein in habitual cigarette smokers.

The Nilgiris district of Tamil Nadu is unique in being all hilly, 90% area of which is covered by horticultural crops, viz., plantation crops, vegetable crops, flower crops, etc. Potato and carrot are the two major vegetable crops occupying a substantial area, the latter cultivated in about 2,677 ha, with a production of 75,818.64 metric tonnes, and productivity of 28.17 MT/ ha. Hence, developing high-yielding hybrids with resistance to physiological disorders is of great importance. Selection of desirable genotypes needs to be performed with reliable estimates. Genetic parameters like coefficient of variation, heritability and genetic advance provide a clear insight into the extent of available variability and gives a relative measure of efficiency of selection of a genotype based on its phenotype in a highly variable population. Therefore, the present study was carried out assess genetic parameters for yield, quality and resistance to physiological disorders under Nilgiris' conditions.

The present study on evaluation of carrot (*Daucus carota* L.) hybrids for high yield and for quality suited to the Nilgiri conditions was conducted at Nanjanad Farm of Horticultural Research Station, Tamil Nadu Agricultural University, Udhagamandalam, and at a farmer's field at Muthorai Palada, Udhagamandalam, during the year 2012-2013. The land was brought to a fine tilth by repeated ploughing and harrowing. Clods were broken and debris removed. The soil was levelled and made into 30cm high raised beds with plot size of 2x1m^2. The experimental field was divided into 24 plots. The experiment was laid out in Randomized Blocks Design. Six hybrids, namely, Alamada F1, Century F1, NS 854 F1, Clause Nant into F1, Takii No.

555 F1 and Vivek F1 were replicated four times. Seeds were sown at row-to-row spacing of 15cm and plant-to-plant spacing of 10cm, at a depth of 1cm and covered with a thin layer of soil. Thinning was done at 45 days after sowing. Five plants were selected at random from each plot for recording observations at 90 days after sowing, and, at harvest.

Estimates for genetic parameters

Phenotypic and genotypic variance

Phenotypic and genotypic variance was estimated as per Lush (1940).

$$\text{a) Genotypic variance } (\sigma^2 g) = \frac{(MS_1 - MS_2)}{r}$$

where,

MS_1 = Mean sum of squares for genotypes
MS_2 = Mean sum of squares for error
r = Number of replications

b) Phenotypic variance $(\sigma^2 ph) = \sigma^2 g + \sigma^2 e$

where,

$\sigma^2 g$ = Genotypic variance
$\sigma^2 e$ = Error variance

Phenotypic and genotypic coefficient of variation

Phenotypic and genotypic coefficient of variation was estimated as per Burton (1952) and expressed in percentage.

a) Phenotypic coefficient of variation (per cent)

$$PCV = \frac{(\text{Phenotypic variance})^{1/2}}{\text{General Mean}} \times 100$$

b) Genotypic coefficient of variation (per cent)

$$GCV = \frac{(\text{Genotypic variation})^{1/2}}{\text{General Mean}} \times 100$$

Estimates for PCV and GCV were categorized on the scale given below (Sivasubramanian and Menon, 1973):

Category	Range
Low	< 10 per cent
Moderate	11 to 20 per cent
High	> 20 per cent

Heritability (h^2)

Heritability in the broad sense was calculated as per Lush (1940) and expressed in percentage.

$$\text{Heritability in broad sense } (h^2) = \frac{Vg}{Vph} \times 100$$

where,
Vg = Genotypic variance
Vph = Phenotypic variance

Range of heritability was categorized as per Johnson *et al* (1955)

Category	Range
Low	0-30 per cent
Moderate	30-60 per cent
High	61 per cent and above

Genetic advance (GA)

Genetic advance was worked out as per the formula of Johnson *et al* (1955).

$$\text{Genetic advance (GA)} = \frac{Vg}{(Vph)^{1/2}} \times K$$

where,
Vg = Genotypic variance
Vph = Phenotypic variance
K = 2.06 (Selection differential at 5 per cent selection intensity)

$$\text{b) Genetic advance as per cent of mean} = \frac{GA}{\text{Grand Mean}} \times 100$$

The range of genetic advance as per cent of mean was classified as per Johnson *et al* (1955).

Category	Range
Low	0-10 per cent
Moderate	11-20 per cent
High	21 per cent and above

Phenotypic and genotypic variance was estimated as per Lush (1940). Range of heritability and genetic advance were categorized as per Johnson *et al* (1955) and Panse (1957).

Genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance as per cent mean in *kharif*, summer and pooled mean data are presented in Tables 1, 2 and 3, and in Fig 1 and 2.

Highest genotypic coefficient of variation was observed during *kharif* for total chlorophyll (38.84), followed by root carotenoids (35.71), root-splitting percentage (23.00) and leaf carotenoids (22.78). However, low genotypic coefficient of variation was noticed for plant height (5.90), leaf width (5.32), root length (0.67), root

diameter (8.47), inner-core diameter (5.66), root-to-top ratio (2.97) and yield per hectare (8.13). In our study, high heritability values were noticed for root carotenoids content (99.94), leaf carotenoids (99.91), total chlorophyll (98.32) and root-splitting percentage (60.99). The lowest estimates of heritability were observed for plant height (23.67), leaf width (19.34), root length (0.92), inner-core diameter (12.29) and root-to-top ratio (3.17). Expected genetic advance (expressed as percentage of mean) was relatively high for characters like total chlorophyll (79.35), root carotenoids (73.55), leaf carotenoids (46.91), root-splitting percentage (37.01) and root-forking percentage (28.07)

In summer, the highest genotypic coefficient of variation was observed for total chlorophyll (40.51), followed by root carotenoids (36.06), root-forking percentage (22.97) and leaf carotenoids (22.53). However, low genotypic coefficient of variation was noticed for traits like plant height (4.55), number of leaves (9.68), leaf width (7.30) and root-to-top ratio (7.39). In the present study, high heritability values were noticed for plant height (99.96), number of leaves (99.98), leaf width (99.98), root length (83.86), root weight (81.72), root-to-top ratio (61.23), root diameter (85.23), total chlorophyll (97.97), leaf carotenoids (99.96) and root carotenoids (99.93). Lowest estimates of heritability were observed for root-splitting percentage (16.94) and root-forking percentage (27.94). Expected genetic advance (expressed as percentage of mean) was relatively high for characters like root length (23.83), root weight (22.51), root diameter (24.52), root-forking percentage (25.01), total chlorophyll (82.61), leaf carotenoids (46.41) and root carotenoids (74.26).

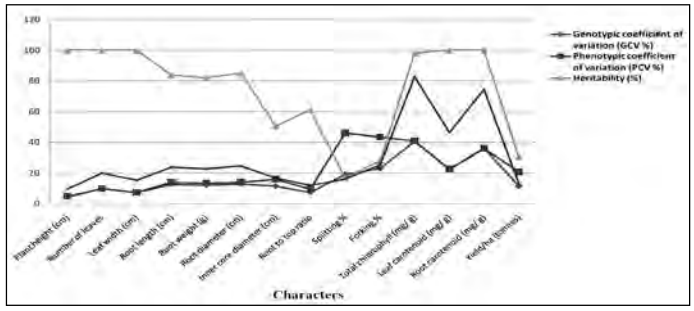

Fig 1. Genetic advance, variability and heritability as per cent of mean in carrot hybrids for 14 characters during summer

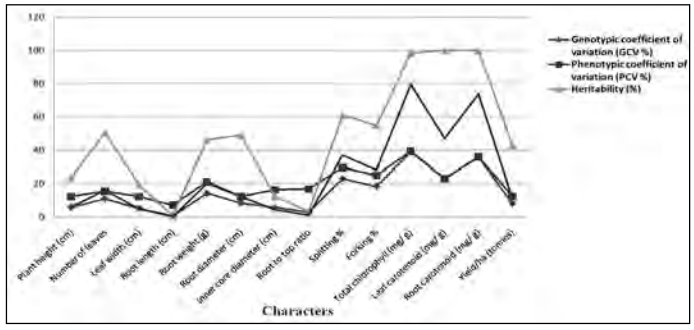

Fig 2. Genetic advance, variability and heritability as per cent of mean in carrot hybrids for 14 characters during *kharif*

Table 1. Variability, heritability and genetic advance as per cent of Mean for different parameters in carrot hybrids for 14 characters during *kharif*

Character	Genotypic coefficient of variation (GCV %)	Phenotypic coefficient of variation (PCV %)	Heritability (%)	Genetic advance as per cent of Mean
Plant height (cm)	5.90	12.13	23.67	5.91
Number of leaves	10.95	15.43	50.37	16.01
Leaf width (cm)	5.32	12.09	19.34	4.82
Root length (cm)	0.67	7.04	0.92	0.13
Root weight (g)	14.24	20.97	46.14	19.93
Root diameter (cm)	8.47	12.11	48.93	12.21
Inner-core diameter (cm)	5.66	16.16	12.29	4.09
Root-to-top ratio	2.97	16.69	3.17	1.09
Root splitting %	23.00	29.45	60.99	37.01
Root forking %	18.41	24.87	54.78	28.07
Total chlorophyll (mg/g)	38.84	39.18	98.32	79.35
Leaf carotenoids (mg/g)	22.78	22.79	99.91	46.91
Root carotenoids (mg/g)	35.71	35.73	99.94	73.55
Yield/ha (tonnes)	8.13	12.42	42.87	10.97

Table 2. Variability, heritability and genetic advance as per cent of Mean for different parameters in carrot hybrids for 14 characters during summer

Character	Genotypic coefficient of variation (GCV %)	Phenotypic coefficient of variation (PCV %)	Heritability (%)	Genetic advance as per cent of Mean
Plant height (cm)	4.55	4.55	99.96	9.38
Number of leaves	9.68	9.68	99.98	19.94
Leaf width (cm)	7.30	7.30	99.98	15.04
Root length (cm)	12.63	13.79	83.86	23.83
Root weight (g)	12.08	13.37	81.72	22.51
Root diameter (cm)	12.89	13.96	85.23	24.52
Inner-core diameter (cm)	11.31	15.92	50.52	16.56
Root-to-top ratio	7.39	9.45	61.23	11.92
Root splitting %	18.99	46.13	16.94	16.10
Root forking %	22.97	43.46	27.94	25.01
Total chlorophyll (mg/ g)	40.51	40.93	97.97	82.61
Leaf carotenoids (mg/ g)	22.53	22.54	99.96	46.41
Root carotenoids (mg/ g)	36.06	36.07	99.93	74.26
Yield/ha (tonnes)	11.35	20.67	30.18	12.85

Table 3. Pooled analysis for variability, heritability and genetic advance as per cent of Mean for different parameters in carrot hybrid for 14 characters

Character	Genotypic coefficient of variation (GCV %)	Phenotypic coefficient of variation (PCV %)	Heritability (%)	Genetic advance as per cent of Mean
Plant height (cm)	5.54	7.69	52.02	8.24
Number of leaves	9.77	11.30	74.76	17.40
Leaf width (cm)	6.41	8.56	56.06	9.88
Root length (cm)	7.36	8.15	81.61	13.70
Root weight (g)	13.51	16.26	69.06	23.14
Root diameter (cm)	9.89	11.31	76.56	17.84
Inner-core diameter (cm)	8.55	13.32	41.27	11.32
Root-to-top ratio	2.26	6.39	12.48	1.64
Root splitting %	12.34	23.02	28.76	13.64
Root forking %	20.36	23.36	75.99	36.56
Total chlorophyll (mg/ g)	37.85	38.33	97.53	77.01
Leaf carotenoids (mg/ g)	22.66	22.67	99.93	46.67
Root carotenoids (mg/ g)	34.18	34.19	99.94	70.39
Yield/ha (tonnes)	8.64	14.20	37.01	10.83

In pooled analysis, highest genotypic coefficient of variation was observed for total chlorophyll (37.85), root carotenoids (34.18), leaf carotenoids (22.66) and root-forking percentage (20.36). However, low genotypic coefficient of variation was noticed for traits such as plant height (5.54), number of leaves (9.77), leaf width (6.41), root length (7.36), root diameter (9.89), inner-core diameter (8.55), root-to-top ratio (2.26) and yield per hectare (8.64). In this study, high heritability values were recorded for root carotenoids content (99.94), leaf carotenoids (99.93), total chlorophyll (97.53), root length (81.61), root diameter (76.56), root-forking percentage (75.99), number of leaves (74.76) and root weight (69.06). Lowest estimates of heritability were observed for root-splitting percentage (28.76) and root-to-top ratio (12.48).

Genetic advance (expressed as percentage of mean) was relatively high for characters like total chlorophyll (77.01), root carotenoids (70.39), leaf carotenoids (46.67), root-forking percentage (36.56) and root weight (23.14).

Improvement in crop yield depends upon the magnitude of genetic variability available in the breeding material, and the extent to which major yield component traits are heritable from generation to generation. Genetic variability can, thus, be a choice for selecting suitable parents. However, quantitative characters are prone to environmental influence, necessitating the partitioning of overall variances as heritable and non-heritable components, for efficient breeding programme (Hiremath and Rao, 1974). The present study reveals the extent of variability available in the six hybrids collected by us from various sources. The scope for selection through heritability and genetic advance estimates, and, results obtained are discussed hereunder. Analysis of Variance (ANOVA) revealed significant differences among the six hybrids studied for all the traits under consideration. The results support a selection programme for high root-yield.

Absolute variability in various characters cannot be considered as a critical factor for deciding upon a character showing the highest degree of variability. Relative values of phenotypic and genotypic coefficients of variation, therefore, give an idea of the magnitude of variability present in a population. As the estimates of genotypic variance, heritability and expected genetic advance are useful for yield improvement, the above values were estimated to assess the scope of improvement in yield in the carrot hybrids studied. Measurement of genotypic coefficient of variation is necessary to understand the role of environmental influences on various traits. In the present investigation, the six genotypes exhibited considerable variability for all the fourteen traits studied.

Variability

Highest genotypic coefficient of variation was observed during *kharif* for root-splitting percentage, followed by total chlorophyll, root carotenoids, leaf carotenoids and root-forking percentage. In summer, highest genotypic coefficient of variation was observed for total chlorophyll, followed by root carotenoids, root-splitting percentage, root-forking percentage and leaf carotenoids. This is in accordance with findings of Amin and Singla (2010). Phenotypic variance or phenotypic coefficient of variation was slightly higher than genotypic variance or genotypic coefficient of variation for all the characters studied, indicating environmental influence to some extent in expression of these characters. Similar results were obtained by Tewatia and Dudi (1999) in carrot, Rabbani *et al* (1998) in radish, and Tewatia *et al*, 2000.

Low estimates for genotypic coefficient of variation were observed for plant height, root length, inner-core diameter, root diameter and root-to-top ratio in *kharif*, and, plant height, root length, inner-core diameter, root diameter and root-to-top ratio during summer. In this experiment, our results are in accordance with Amin and Singla (2010), Ullah *et al* (2010), and Tewatia and Dudi (1999).

Heritability and genetic advance

Genotypic coefficient of variation does not give any idea of the total variation heritable. Further, it may not be feasible to determine the amount of heritable variation, or the relative degree to which a character is transmitted from a parent to the offspring, by the estimate of heritability. Heritability estimate in the broad sense, alone, does not serve as a true indicator of genetic potential of a genotype, since the scope is restricted by the crop's interaction with the environment. Hence, it is advisable to consider the predicted genetic advance as per cent of mean, along with heritability estimate, as a reliable tool in selection programmes (Johnson *et al*, 1955). Hence, both heritability and genetic advance (as per cent of mean) are determined, to get a clear picture of the scope for improvement in various characters through selection.

In the present study, high heritability was observed for leaf carotenoids, root carotenoids, root weight, inner-core diameter, plant height, leaf width, total chlorophyll, number of leaves and root diameter. High heritability in the broad sense indicated that a large proportion of the phenotypic variance was attributable to genotypic variance. Differences among genotypes were real, and showed that the above-mentioned traits with high heritability values, were less under the influence of environment. The above findings are in close conformity with Brar and Sukhija (1981) and Tewatia and Dudi (1999) who reported a high heritability for leaf length and root weight. High heritability for characters controlled by polygenes could be useful to plant breeders for making an effective selection. Genetic advance (expressed as percentage of mean) was relatively high for carotene content in root. These results are in line with findings of Amin and Singla (2010).

Low heritability was observed for root length and root-to-top ratio during both the seasons, and genetic advance (expressed as percentage of mean) was relatively low for characters like plant height, root length, root-to-top ratio and inner-core diameter. These results are in line with findings of Amin and Singla (2010) and Ullah *et al* (2010), and, Yadav *et al* (2009) for root length alone.

As the genetic coefficient of variability, phenotypic coefficient of variability and heritability estimates determine the component of heritable variation, and, genetic advance measures the extent of its suitability under selection all the above parameters should be considered simultaneously to bring about effective improvement in yield and other characters in carrot.

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