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Studied on genetic variability, heritability and genetic advance in some cultivated genotypes of carrot (*Daucus carota* L.) under two different seasons

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Abstract
The purpose of this research was to investigate the genetic variability, heritability, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance among 15 genotypes of carrot in terms of quantitative, qualitative and nutritional important characters for the effective selection of genotypes. So, a total of fifteen carrot genotypes were studied based on nineteen quantitative, qualitative and nutritional characters at North Eastern part of Rajasthan during the 2018 and 2019 cropping season respectively. Investigation were carried out in randomized block design (RBD) in two different seasons *i.e.*, environment 1 (E 1) and environment 2 (E 2) with the objectives to assess the magnitude of genetic variability, heritability and genetic advance of fifteen genotypes of carrot (*Daucus carota* L) among 19 characters. Based on the performance and variance the genotypes, selection M E 01 was found to be the best with respect to growth, yield, quality and nutritional attributes followed by Shin Kuroda, Selection Red and Pearl Red for both the season respectively. The highly significance difference among all the characters *viz.* inner core diameter (cm), flesh thickness (cm), plant height (cm) at 60 DAS, plant height (cm) at 90 DAS, harvest index (%), gross root weight / 5 plants (kg), net root weight / 5 plants (kg), dry matter (%), TSS (^{o} brix %), β carotene content (mg / 100 g fresh wt.) and vitamin A (I U) except days to seed germination, number of leaves / plants and moisture % in roots for both the season (E 1 and E 2), were observed sufficient amount of genetic variability. The highest pooled genotypic co-efficient of variation was found in flesh thickness (24.18 cm), followed by net root wt. / five plants (21.85 kg), vitamin A (19.62 I U), β carotene content (19.61 mg / 100 g fresh wt.), yield qt / hectare (18.42) and harvest index (17.11 kg). The maximum estimate of heritability (h^2) was observed in inner core diameter (97.74 cm) for environment 2 (E 2), followed by vitamin A (96.22 IU) and β carotene content (95.37 mg / 100 g fresh wt.) in environment 1 (E 1). The correlation study revealed that majority of the characters were positively correlated with each other. The highest total sugar (0.64* %) over the genotypic environment was found positively and significantly at 5 % with gross root weight / 5 plant (kg). TSS (1.00** ^{0}brix %) was found maximum significantly at 1 % correlated with root girth (cm) over the genotypic environments. Similarly, total sugar (0.64* %) was found positively significant at 5 % correlated with TSS (^{0}brix %) and vitamin A (0.96** I U) was recorded positively significant at 1 % correlated with β carotene (mg / 100 g fresh weight) over the phenotypic environments.

Keywords: Genotypic coefficient of variation, phenotypic coefficient of variation, genetic gain, environments, quantitative, qualitative and nutritional traits

Introduction
Carrot (*Daucus carota* L.) 2n = 2x = 18, is a member of the Apiaceae family. Carrot is a prevalent cool season root vegetable. It has got fleshy edible tap root which is botanically designated as conical root. The most commonly eaten part of the plant is the tap root, although the stem and leaves are eaten as well. Carrot has two groups: Asiatic and European types. The Asiatic carrots are generally red coloured because of anthocyanin pigment. The European types are orange coloured because of carotene a precursor of vitamin A. Initially the roots were long and thin, and either purple or yellow in colour. Though different colours are also found such as white, black and purple, with the orange or orange – red colours. Many shapes of roots also exit, from rather long and thin to shorter and thick. Roots may be cylindrical, conical or even spherical in shape. Carrot is originated to Europe and Southwestern Asia, especially Afghanistan (Banga, 1976). It is an important root vegetable grown all over India on an area of 88.00 thousand hectare with 1446.00 thousand tonnes production and 164.30 quintal / hectare productivity (NHB 2017). Suitable time for sowing of carrot seed is varied from early September to early November and it take about 80-90 days from sowing to root formation.

The ideal temperature is 16 to 21 ºC (Anonymous, 2017) [6].
Simon (1990) [47] have reported that, carrot juice is a rich source of carotene, which is an important source of pro-vitamin A, fibre and other dietary nutrients. Carrots are good source of carotenoids and can be used in carrot beverage products such as carrot juice. B.H. Chen *et al.* 1995 [13] has been reported that β carotene constitutes a large portion (60-80 %) of carotenoids in carrot, followed by alpha – carotene (10 – 40 %), lutein (1-5 %), and other minor carotenoids (0.12 – 1.0 %). Orange coloured carrot are rich in carotene. Thamburaj and Singh, 2005 have reported that, it has good nutritional value with 42 kcal of energy, 1.1 g protein, 1100 I U vitamin A, 8 mg ascorbic acid, 0.06 mg thiamine, Ca 37 mg, P 36 mg and iron 0.7 mg / 100 g of fresh sample. Carrots are good source of carbohydrates and minerals like Ca, P, Fe and Mg. Gopalan *et al.*, 1991 [23], have reported the chemical constituents of carrot as moisture 86 %, protein (0.9 %), fat (0.2 %), carbohydrate (10.6 %), crude fibre (1.2 %), total ash (1.1%), Ca (80 mg /1 00 g), fe (2.2 mg / 100 g). Howard *et al.*, 1962, have reported that the edible portion of carrots contains about 10 % carbohydrates having soluble carbohydrates ranging from 6.6 to 7.7 g / 100 g and protein from 0.8 to 1.1 g / 100 g in 4 carrot cultivars. Kaur *et al.*, 1976 have reported, 1.67-3.35 % reducing sugars, 1.02 – 1.18 % non-reducing sugars and 2.71 – 4.53 total sugars in 6 cultivars in carrot. According to Kalra *et al.*, 1987, the free sugars identified are sucrose, glucose, xylose and fructose. Kochar and Sharma, 1992 [45] have reported the crude fibre in carrots roots consists of 71.7, 13.0 and 15.2 % cellulose, hemicellulose and lignin, respectively. The test of carrots is mainly due to the presence of glutamic acid and the buffering action of free amino acids.

Fig 1: Genetic variability of carrot genotypes

Diversity of cultivated carrot roots varying from white, yellow, orange, red, purple and pink types are also known to exist. Yellow carrot contains xanthophyll, which helps in developing healthy eyes and in preventing lung and other cancers. Red colour also contains lycopene, which help to prevent heart diseases and some cancers including prostate cancers. Purple carrot contains pigments called anthocyanins.
The great importance of carrot is developing of high yielding varieties / hybrids with resistance of physiological disorder Selection of desirable genotypes must be performed with reliable estimates. The genetic parameters like co-efficient of variation, heritability and genetic advance provide clear in sight into the extent of variability and relatives measures of the efficiency of selection of genotypes based on phenotype in a highly variable population. Peterson and Siman, 1986 [41] and Rubatzky *et al.*,1999 [43] have reported that among the carrot root morphology, uniformity in root shapes, size, external root colour are some of the most important characters. In carrot roots are very greatly in shape, size and other characteristics. Therefore, to enhance productivity, genetic restructuring of carrot germplasm is requiring to develop high yielding hybrids with desired traits. Most of the desired traits are qualitative, quantitative and nutritional in nature and influenced by the environment for their expression. According to Fisher (1918) [18], the quantitative traits exhibiting continuous variation are under the control of heritable and non-heritable factors. Vavilov 1949 [43] have reported that the greater variability in population for these traits, there are the greater chances for effective selection for desirable types of traits. Phenotypic and genotypic co-efficient of variation are useful in detecting amount of variability present in germplasm. According to Singh and Mittal 2003 [37] response to selection is depends on the relative proportion of the heritable component in the continuous. The heritable components are due to genotype, which the non-heritable portion is mainly due to the environment factors. Heritability estimate may not provide clear predictability of the breeding value. Johnson *et al.*, 1955 [23] have reported that the estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect for selecting the best individuals. According to Santhi *et al.*, 2015 [34] the variability, heritability and genetic advance were relative measure of the efficiency of selecting genotypic from a highly variable population based on phenotypic. Jain *et al.*, 2010 [22] have reported that heritability is also an indicator for measuring the relative influence of environment on expression of genotypes. According to Lush (1940) [28] in this work the phenotypic and genotypic of variance were estimated. The range of heritability and genetic advance were categorized according to Johnson *et al.*, (1955) [23].
Hence, the present study was carried out at North Eastern part of Rajasthan (India), during the different seasons in the year 2018 and 2019 respectively, for estimating genetic variability, heritability and genetic advance among various characters in 15 selected genotypes of carrot.

Materials and Methods

The experiment was conducted at Agriculture Research Farm, SunRise University Campus, Bagad Rajput, Ramgarh PIN - 301026, District Alwar (Rajasthan), India during autumn winter *i.e.*, September to November, Season – 1 (E 1) for the year 2018 and September to November, Season – 2 (E 2) for the year 2019, respectively. The site is situated at latitude $27^0.34'$ N and longitude $76^0.35'$ E with an altitude of 271 m (889 fit) mean above sea level. The area receives mean annual rainfall of 722 mm with mean maximum and minimum temperature of 38^0 C and 30^0 C, respectively with 27 % relative humidity. The soil of the sandy loam with pH of 7.6. The land was brought to a fine tilth by repeated ploughing and harrowing. The clods were broken and debris were removed. About 25 tonnes of fully decomposed farm yard manure (FYM) was applied at the time of field preparation. Fertilizers was incorporated of 40 kg Nitrogen, 40 kg Phosphorus and 80 kg Potash / hectare. The soil was levelled and made into raised beds with a plot size of 1.5 X 1.5 m^2. The experimental field was divided into 45 plots. The experiment field was laid out in a Randomized Blocks Design (RBD). A total number

of fifteen genotypes were replicated three times subjected for the study. The seeds were sown with a spaced 35 cm apart between rows and 10 -12 cm between plants. After the crop established well, earthing up and weeding were carried out when necessary.

The material consisted of 15 genotypes of carrot were collected from different locations. Fifteen carrot genotypes *viz.* Shin Kuroda, Early Nantes, Pusa Rudhira, Super Red (Sun Grow), Pearl Red, Selection Red, Selection M E 01, Deep Red, Super Red (Super Seed), J K 24, J K 241, Pusa Kesar, Black Wonder, Dark Red and Desi Red etc. Early Nantes genotype was used as check. This panel represents a large diversity present in carrot genotypes especially for the colour *viz.* white, yellow, red, orange, dark orange, purple and black. The data were collected for 2 qualitative traits *viz.* exterior root colour, inner core colour, 11 quantitative traits *viz*. days to seed germination, plant height (cm), number of leaves / plants, harvest index (%), root length (cm), root girth (cm), inner core diameter (cm), flesh thickness (cm), gross root weight / five plants (kg), net root weight / five plants (kg) and yield (q / ha), 6 nutritional traits *viz*. dry Matter (%), moisture % in root, β carotene content (mg / 100 g fresh weight), vitamin A (I U / 100 g fresh wt.), total soluble solids (^{o} brix %) and total Sugar content (%). The quantitative and qualitative observations were recorded based on the IPGRI descriptor (IPGRI 1998). The observations were recorded on five randomly selected plants per replication for each genotype after of 30, 60 and 90 days after sowing and at harvest. The data based on the mean of individual plants selected for observation were statistically analysis described by Burton (1952) to find out overall total variability present in the material under study for each character and for all the populations. The data collected for each quantitative trait was subjected to analysis of variance (ANOVA) for simple lattice design. Analysis of variance was done using Proc lattice and Proc GLM procedures of SAS version 9.2 (SAS, 2008).

The skeleton of analysis of variance used is given below.

Table 1: ANOVA for completely randomized block design (RBD)

Source of Variation	d. f.	Sum of square	Mean sum of square	F value	F t 5% or 1% Table Value
Replication	r-1	RSS	RMS	RMS/EMS	-
Genotype	g-1	GSS	GMS	GMS/EMS	-
Error	(r-1) (g-1)	ESS	EMS	-	-
Total	rg-1	TSS	-	-	-

Where,
r = Number of replications
g = Number of genotypes
d.f.= degree of freedom
RSS = Replication Sum of Square
GSS = Genotype Sum of Square
ESS = Error Sum of Square
TSS = Total Sum of Square
RMS = Replication Mean of Square
GMS = Genotype Mean of square
EMS = Error Mean of square

A significant value of F test indicates that the test entries differ significantly among themselves, which requires computing C.D.

$$C.V. = \frac{\sqrt{EMS}}{GM} \times 100$$

$$SE\ m\pm = \sqrt{EMS/r}$$

$$SE\ diff. = \sqrt{2EMS/r}$$

CD at 5% Probability Level = SE difference x t 5% (table value)

Where,
C.V. % = Coefficient of Variation
Sem ± = Standard error of means
S E diff = Standard Error of difference
GM = Grand Mean
C.D. = Critical Difference
t 5% = t, table value 5% probability level at error degree of freedom

Mean was calculated by using following formula.

$$\text{Mean } (X) = \frac{\sum^{n}_{i=0} x\ i}{N}$$

Where,
$\sum^{n}_{i=0} x\ i$ = The sum of all the observation
N = Number of observations

Among biochemical parameters, total soluble solids (TSS) were estimated using hand refractometer and the value were recorded and expressed in ^{0}brix. Carotene content (β carotene) and total sugar were determined by the method suggested by (Ranganna 1986). Taken 5 g of fresh sample and crush in 10 – 15 ml acetone, adding in few crystals of anhydrous sodium sulphate with the help of pestle and mortar. Decant the supernatant into a beaker. Repeat the process twice and transfer the combined supernatant to a separatory funnel, and add 10 – 15 ml petroleum ether and mix thoroughly. Two layers where be separated out on standing. Discard the lower layer and collect upper layer in 100 ml volumetric, make up the volume to 100 ml with petroleum ether and record by measuring the absorbance at 452 nm (neon meter) in an UV visible double bean spectrophotometer as per the standard procedure. Optical value at 452 nm using petroleum ether as blank. The specific absorbance values tabulate by Davies (1976) will be use for the calculation of carotene using the formula:

$$\beta \text{ carotene (mg / 100 g)} = \frac{\text{Optical Density X } 13.9 \text{ X } 10^4 \text{ X } 100}{\text{Wt. of Sample X } 560 \text{ X } 1000}$$

$$\text{Vitamin – A (I. U.) Content:} = \frac{\beta \text{ Carotene (mg /100 g)}}{0.6}$$

Total sugar analysis as per the standard procedure (Ranganna 1986), take 25 ml of fresh filtrate sample in a 50 ml volumetric flask and add 5 ml HCL. Allow to stand for 24 hours at room temperature. Neutralize exactly with NaOH using phenolphthalein as indicator as make up to volume with water. Take an aliquot and determine the total sugar as in case of reducing sugar.

$$\text{Calculation: \% Reducing Sugar} = \frac{\text{mg Dextrose X Volume made up X } 100}{5 \text{ g Wt. of sample taken X } 1000}$$

$$\% \text{ Total Sugar} = \frac{\text{mg Dextrose X Volume made up X 100}}{\text{Titrate X Volume of sample X 100}}$$

For dry matter content taken 5 randomly selected roots from each plot were washed, topped and peeled and then cut into 3 mm thin pieces. 50 g sample was taken and oven dried at 60 ± 2^0 C in hot air oven till constant weight. Weighed and dry matter was calculated using the formula:

Dry % = 100 – Moisture %

$$\text{Moisture \%} = \frac{\text{Fresh wt. (g)} - \text{Dry wt. (g)}}{\text{Fresh wt. (g)}} \text{ X } 100$$

Genotypic and phenotypic co efficient of variation were calculated as per the formula suggested by Burton and Devane (1953) [8]. Heritability in broad scene and genetic advance were calculated as per the formula given by Allard (1960) and Johnson *et al.,* (1955) [23], respectively. Whereas, the phenotypic correlation component between traits were estimated using the equation suggested by Johnson *et al.,* (1955) [23] as follow:

$$r_p = \frac{P\ cov_{xy}}{\sqrt{(V_{Px}.V_{Py})}}$$

$$r_g = \frac{G\ cov_{xy}}{\sqrt{(V_{gx}.V_{gy})}}$$

Where:
r_p = Phenotypic correlation coefficient
r_g = Genotypic correlation coefficient
P cov_{xy} = Phenotypic covariance between variable X and Y
G cov_{xy} = Genotypic covariance between variable X and Y
V_P^x = Phenotypic variance for variables x
V_P^y = Phenotypic variance for variables y
V_g^x = Genotypic variance for variables x
V_g^y = Genotypic variance for variables y

Results and Discussion

The significance difference among all the traits indicates the existence of sufficient amount of genetic variability, heritability in broad sense, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) and genetic advance as percent of mean for nineteen quantitative, qualitative, and nutritional traits in both the environments *i.e.*, E 1 and E 2 at 1 % and 5 % level of significance respectively are presented in Table-1. The highly significance difference at 1 % level of significance among all the characters *viz.* inner core diameter (cm), flesh thickness (cm), plant height (cm) at 90 DAS, harvest index (%), gross root weight / 5 plants (kg), net root weight / 5 plants (kg), TSS (^{o} brix %), β carotene content (mg / 100 g fresh wt.) and vitamin A (I U) except days to seed germination, number of leaves / plants and moisture % in roots for both the environments (E 1 and E 2), indicates the existence of sufficient amount of genetic variability. The highly significance difference at 5 % level of significance was found among the characters *viz.* plant height (cm) at 60 DAS, root length (cm) in environment 1 and dry matter (%) in environment 2. The result is in consonance with Chourasia and Shree (2012) [17], Shekar *et al.,* (2012) [46], Nayak and Nagre (2013) [48], Madavi *et al.,* (2015), Reshmika *et al.,* (2015) [42], Tripathy *et al.,* (2017) [57] and Tirkey *et al.,* (2018) [56].

The variability, genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability, genetic advance as percent of mean and genetic gain in both the environment and pooled mean data are presented in Table 2. Highest genotypic coefficient of variation was observed in environment 1 for net root weight / five plants (32.62 %), followed by gross root weight / five plants (25.87 %), vitamin A (22.70 I U), β carotene (22.65 mg / 100 g fresh wt.), flesh thickness (21.73 cm) and total soluble solid (18.46 ^{0}brix %). Similarly, maximum genotypic coefficient of variation was recorded in environment 2 for flesh thickness (23.19 cm) followed by net root wt. / five plants (20.16 %) and gross root wt. / five plants (17.58 %). However, a low genotypic coefficient of variation was found in days to seed germination (0.00), number of leaves / plants (0.00), root length (0.00 cm) for environment 2 followed by moisture % in root (1.60), days to seed germination (2.63), root length (5.36 cm), number of leaves / plants (6.32) and plant height at 90 DAS (9.88 cm) for environment 1. Highest pooled genotypic coefficient of variation was found in flesh thickness (24.18 %), followed by net root wt. / five plants (21.85 %), vitamin A (19.62 I U), β carotene content (19.61 mg / 100 fresh wt.), yield qt / hectare (18.42) and harvest index (17.11 %). Highest phenotypic coefficient of variation was found in environment 1 for flesh thickness (33.62 %), followed by net root wt. / five plants (33.33 %) and plant height at 30 DAS (25.63 cm). Similarly, maximum phenotypic coefficient of variation (PCV) was observed in environment 2 for net root wt. / five plants (29.81 %) followed by yield quintal / hectare (28.84), flesh thickness (28.30 %) and root length (24.62 cm). However, minimum phenotypic coefficient of variation was found in environment 1 for moisture % in root (4.04) followed by root length (9.87 cm). Maximum pooled phenotypic coefficient of variation was found in net root wt. / five plants (32.23 %), followed by flesh thickness (30.99 %), yield quintal / hectare (24.48), gross root wt. / five plants (23.57 %), total sugar (22.34 %), β carotene content (22.14 mg / 100 g fresh wt.) and root girth (21.77 cm). Maximum environment co-efficient of variation (ECV) was found in environment 1 for flesh thickness (25.66 %) followed by plant height at 30 DAS (22.51 cm) and days to seed germination (20.36). Similarly, maximum environment coefficient of variation (ECV) was found in environment 2 for yield quintal / hectare (25.85) followed by root length (24.85 cm), number of leaves / plant (22.89) and root girth (22.06 cm). However, highest pooled mean of environment coefficient of variation (ECV) was observed in flesh thickness (21.31 %), followed by net root wt. / five plants (21.01 %), number of leaves / plant (20.20) and root girth (20.01 cm). Maximum estimate of heritability (h^2) was observed in inner core diameter (97.74 cm) for environment 2, followed by vitamin A (96.22 I U) and β carotene content (95.37 mg / 100 g fresh wt.) in environment 1 and found lowest negative in number of leaves / plants (-14.73), days to seed germination (-13.56) and root length (-1.92 cm) for environment 2. Maximum pooled estimate of heritability was recorded in vitamin A (86.22 I U), followed by β carotene content (78.48 mg / 100 g fresh wt.) and TSS (74.76 ^{0}brix %). Genetic advance expressed as pooled mean was relatively high for the characters *viz.* yield quintal / hectare (68.07) followed by plant height at 90 DAS (15.49 cm). However, the lowest genetic advance as pooled mean was found in net root

wt. / five plants (0.09 %) and gross root wt. / five plants (0.12 %). High genetic advance as percentage of mean was found for net root weight / 5 plants (65.79 %), followed by gross root weight / 5 plants (48.68 %) and vitamin A (45.86 I U) for environment 1 and found lowest negative in character number of leaves / plants (- 6.48) followed by days to seed germination (- 4.63) and root length (- 0.98 cm) for environment 2. Similarly, high genetic gain was observed by Jain *et al*., (2010) for fresh weight / plant, root weight and yield / hectare and by Amin and Singla (2010) [4] for yield / hectare and was notice for high carotene content by Priya and Santhi (2015) [34], while for root: shoot ratio was notice high genetic gain by Thakur and Jamwal (2015) [42].

Estimates of the genotypic and phenotypic correlation coefficient between each pair of the traits in environment - 1 are presented in Table 3. The magnitudes of genotypic correlation coefficient were mostly higher than phenotypic correlation. From the study, it was found that, among the characters, the maximum positive significant genotypic correlation at 1 % level of significant was observed for total sugar (0.97** %) with TSS (°brix %), β carotene content (0.97** mg / 100 g fresh weight) with total sugar % followed by net root wt. / five plants (0.95** kg) with gross root wt. / five plants (kg). It was found the maximum positive significant genotypic correlation at 5 % level of significant in characters total sugar (0.64* %) with plants height (cm) at 60 DAS followed by TSS °brix (0.63* %) with yield quintal / ha. The maximum positive insignificant genotypic correlation was observed in days to seed germination (2.91) with inner core diameter (cm) followed by plant height at 90 DAS (1.43 cm) with plant height (cm) at 60 DAS and vitamin A (1.02 I U) with β carotene content (mg / 100 g fresh wt.) and minimum positive insignificant genotypic correlation was found in character dry matter (0.01 %) with plant height (cm) at 30 DAS followed by dry matter (0.03 %) with root girth (cm) and maximum negative insignificant genotypic correlation were found in character harvest index (-1.46 %) with plant height (cm) at 30 DAS. The maximum negative significant genotypic correlation at 1 % level of significant was found in character plant height at 30 DAS (-7.24** cm) with days to seed germination followed by root length (-7.03** cm) with days to seed germination. Similarly, it was found the maximum positive significant phenotypic correlation at 5 % level of significant in character TSS (0.63* °brix %) with root girth (cm) and vitamin A (0.63* I U) with net root wt. / 5 plants (kg) followed by vitamin A (0.62* I U) with root girth (cm). The minimum positive significant phenotypic correlation at 5 % level of significant was found in character days to seed germination (0.52*) with inner core diameter (cm) and TSS (0.52* °brix %) with flesh thickness (cm) followed by root girth (0.53*cm) with root length (cm). The maximum insignificant phenotypic coefficient of variation was observed in character root girth (0.51cm) with flesh thickness (cm) followed by net root weight / 5 plants (0.50 kg) with root length (cm) and was found minimum in gross root wt. / 5 plants (0.00 kg) with days to seed germination and plant height at 90 DAS (0.00 cm) with plant height (cm) at 30 DAS followed by gross root wt. / 5 plants (0.01 kg) and net root wt. / 5 plants (0.01 kg) with number of leaves / plants. The maximum negative significant phenotypic correlation at 5 % level of significant was found in total sugar (- 0.59* %) with inner core diameter (cm) followed by total soluble solids (- 0.57* °brix %) with inner core diameter (cm).

Estimates of the genotypic and phenotypic correlation coefficient between each pair of the traits in environment 2 are presented in Table 4. From the study of environment 2, it was found that among the characters, the maximum positive significant genotypic correlation at 1 % level of significant was observed for gross root weight / 5plants (0.99** kg) with root girth (cm) followed by net root weight / 5 plants (0.98** kg) with flesh thickness (cm) and vitamin A (0.96** I U) with root girth (cm). It was found the maximum positive significant genotypic correlation at 5% level of significant in vitamin A (0.63* I U) with yield quintal / hectare and β carotene content (0.63* mg / 100 g fresh wt) with root girth (cm) followed by TSS (0.62* °brix %) with gross root weight / 5 plants (kg), β carotene content (0.61* mg / 100 g fresh weight) with net root weight / 5 plants (kg), TSS (0.61* °brix %) and plant height (cm) at 30 DAS. The maximum negative significant at 5 % level of significant genotypic correlation was observed in plant height at 30 DAS (- 0.62* cm) with inner core diameter (cm) followed by dry matter (- 0.59* %) with plant height (cm) at 90 DAS and yield quintal / hectare (- 0.57*) with harvest index (%). The maximum positive significant at 5 % level of significant phenotypic correlation was observed in vitamin A (0.63* I U) with TSS (°brix %) followed by vitamin A (0.61* I U) with root girth (cm). It was found the minimum positive significant phenotypic correlation at 5 % level of significant in character total soluble solids (0.52 °brix %) with flesh thickness (cm) followed by total sugar (0.53* %) with moisture % in root. The maximum positive insignificant phenotypic correlation was observed in total sugar (0.51%) with gross root weight / 5 plants (kg) and gross root weight / 5 plants (0.51 kg) with plant height (cm) at 90 DAS followed by root length (0.50 cm), gross root weight / 5 plants (0.50 kg), β carotene content (0.50 mg / 100 g fresh weight) and vitamin A (0.50 I U) with plant height (cm) at 60 DAS and minimum insignificant phenotypic correlation was observed in root length (0.00 cm) with harvest index (%) followed by plant height at 60 DAS (0.01 cm) with inner core diameter (cm). The maximum negative insignificant phenotypic correlation was found in plant height at 30 DAS (-0.51 cm) with inner core diameter (cm) followed by TSS (–0.42 °brix %) with inner core diameter (cm). The maximum significant phenotypic correlation at 1 % level of significant was found in vitamin A (0.96** I U) with β carotene content (mg / 100 g fresh weight) followed by β carotene content (0.80** mg / 100 g fresh weight) with total sugar (%) and β carotene (0.78** mg / 100 g fresh weight) with net root weight / 5 plant (kg).

Additionally, dendrogram pool cluster combine analysis of 15 carrot genotypes are depicted in (Figure – 2) based on ward method using correlation (genotypic and phenotypic) coefficient between genotypes grouped i.e., G 6 and G8 are more closely in cluster 1 followed by G2 and G12, G9 and G11in clusters 2 and 3 respectively. These two genotypes had the wider of correlation coefficient between group G 1 and G 13 in cluster 4.

Table 1: Analysis of variance for various quantitative, qualitative and nutritional traits in carrot for both the environments (Season) 1 and 2.

S. N	Characters	Env.	Mean sum of square		
			Replication	Genotype	Error
			[2]	[14]	[28]
1	Inner Core Diameter (cm)	E 1	0.14**	0.12**	0.00
		E 2	0.00	0.19**	0.00
2	Flesh Thickness (cm)	E 1	0.24*	0.21**	0.07
		E 2	0.04	0.21**	0.03
3	Days to Seed Germination	E 1	0.17	1.90	1.81
		E 2	0.08	0.75	1.17
4	Plant Height (cm) at 30 DAS	E 1	11.12	99.11	52.50
		E 2	6.12	93.87**	12.28
5	Plant Height (cm) at 60 DAS	E 1	262.87*	189.98*	72.65
		E 2	6.93	249.86**	17.04
6	Plant Height (cm) at 90 DAS	E 1	117.07	244.81**	79.52
		E 2	171.11**	282.90**	27.98
7	Number of Leaves per plant	E 1	1.51	1.37	0.88
		E 2	4.66	2.05	3.34
8	Harvest Index (%)	E 1	12.08	293.22**	103.65
		E 2	64.50	260.04**	52.77
9	Root Length (cm)	E 1	0.00	3.59*	1.59
		E 2	0.67	17.08	18.11
10	Root Girth (cm)	E 1	0.01	0.32**	0.08
		E 2	0.08	0.85	0.67
11	Gross Root Weight / 5 Plants (kg)	E 1	0.00	0.02**	0.00
		E 2	0.00	0.05**	0.01
12	Net Root Weight / 5 Plants (kg)	E 1	0.00	0.01**	0.00
		E 2	0.00	0.03**	0.01
13	Yield Quintal / Hectare	E 1	227.50	4739.61**	91.70
		E 2	24610.99**	7209.71	4158.58
14	Dry Matter (%)	E 1	0.12	10.16**	1.19
		E 2	2.98	11.26*	4.23
15	Moisture (%) in Root	E 1	3.91	15.75	10.12
		E 2	35.86	54.60	34.38
16	TSS (º brix %)	E 1	0.16	10.22**	0.41
		E 2	3.48	6.79**	1.26
17	Total Sugar (%)	E 1	0.18	0.98**	0.11
		E 2	0.43	0.85	0.53
18	β Carotene Content (mg / 100 g fresh wt.)	E 1	0.05	8.27**	0.13
		E 2	0.06	5.90**	1.37
19	Vitamin A (I U)	E 1	0.50	23.16**	0.30
		E 2	0.08	16.40**	1.74

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

Note: Env. = Environment, DAS = Days After Sowing, cm = Centimeter, kg = Kilogram, Mg = Milligram, β = Beta carotene, I U = International Unit

Table 2: Variability, heritability and genetic advance as percent of mean parameters in carrot genotypes for nineteen characters.

S. N	Characters	Env.	Coefficient of variation			h^2 (%)	GA (% of mean)	GG (%)
			GCV (%)	PCV (%)	ECV (%)			
1	Inner Core Diameter (cm)	E 1	12.50	13.07	3.79	91.59	0.39	24.65
		E 2	15.30	15.48	2.33	97.74	0.52	31.16
		Pool	13.91	14.38	3.11	93.50	0.45	27.70
2	Flesh Thickness (cm)	E 1	21.73	33.62	25.66	41.76	0.29	28.92
		E 2	23.19	28.30	16.21	67.18	0.41	39.16
		Pool	24.18	30.99	21.31	60.88	0.40	38.87
3	Days to Seed Germination	E 1	2.63	20.53	20.36	1.64	0.05	0.69
		E 2	0.00	16.59	17.68	-13.56	-0.28	-4.63
		Pool	9.17	18.83	19.18	23.75	0.59	9.21
4	Plant Height (cm) at 30 DAS	E 1	12.25	25.63	22.51	22.83	3.88	12.05
		E 2	15.53	18.71	10.44	68.89	8.92	26.56
		Pool	10.26	22.30	17.31	21.15	3.19	9.72
5	Plant Height (cm) at 60 DAS	E 1	11.63	19.66	15.85	34.99	7.62	14.17
		E 2	15.72	17.36	7.37	81.99	16.43	29.32
		Pool	15.36	18.50	12.20	68.93	14.42	26.27
6	Plant Height (cm) at 90 DAS	E 1	9.88	15.44	11.86	40.93	9.78	13.02
		E 2	11.05	12.74	6.34	75.23	16.47	19.74
		Pool	11.54	14.03	9.25	67.61	15.49	19.54

7	Number of Leaves per plant	E 1	6.32	16.00	14.69	15.63	0.33	5.15
		E 2	0.00	21.37	22.89	-14.73	-0.52	-6.48
		Pool	7.07	19.56	20.20	13.06	0.38	5.26
8	Harvest Index (%)	E 1	13.73	22.31	17.58	37.87	10.08	17.41
		E 2	15.68	20.82	13.70	56.70	12.89	24.31
		Pool	17.11	21.66	15.95	62.37	15.44	27.83
9	Root Length (cm)	E 1	5.36	9.87	8.29	29.52	0.91	6.00
		E 2	0.00	24.62	24.85	-1.92	-0.17	-0.98
		Pool	9.43	19.57	19.41	23.25	1.52	9.37
10	Root Girth (cm)	E 1	11.76	16.58	11.68	50.33	0.41	17.19
		E 2	6.48	22.99	22.06	7.94	0.14	3.76
		Pool	8.21	21.77	20.01	14.23	0.20	6.38
11	Gross Root Weight / 5 Plants	E 1	25.87	28.32	11.52	83.46	0.15	48.68
		E 2	17.58	20.58	10.70	72.98	0.21	30.93
		Pool	16.67	23.57	11.53	49.98	0.12	24.27
12	Net Root Weight / 5 Plants	E 1	32.62	33.33	6.81	95.82	0.13	65.79
		E 2	20.16	29.81	21.96	45.75	0.11	28.10
		Pool	21.85	32.23	21.01	45.95	0.09	30.51
13	Yield Quintal / Hectare	E 1	17.31	17.81	4.21	94.41	78.79	34.64
		E 2	12.78	28.84	25.85	19.65	29.12	11.67
		Pool	18.42	24.48	19.33	56.60	68.07	28.55
14	Dry Matter (%)	E 1	12.42	14.69	7.83	71.56	3.01	21.65
		E 2	10.13	16.96	13.60	35.69	1.88	12.47
		Pool	12.25	15.97	11.33	58.85	2.81	19.36
15	Moisture % in Root	E 1	1.60	4.04	3.71	15.64	1.12	1.30
		E 2	3.03	7.48	6.84	16.40	2.17	2.53
		Pool	2.95	6.01	5.50	24.19	2.57	2.99
16	TSS (º brix %)	E 1	18.46	19.59	6.54	88.85	3.51	35.85
		E 2	13.42	17.40	11.08	59.49	2.16	21.33
		Pool	15.99	18.49	9.17	74.76	2.84	28.48
17	Total Sugar (%)	E 1	17.74	20.77	10.81	72.91	0.95	31.20
		E 2	9.63	23.47	21.40	16.84	0.28	8.14
		Pool	16.46	22.34	17.52	54.30	0.81	24.99
18	β Carotene Content (mg / 100 g fresh wt.)	E 1	22.65	23.20	4.99	95.37	3.31	45.57
		E 2	15.33	21.18	14.61	52.41	1.83	22.87
		Pool	19.61	22.14	11.34	78.48	2.74	35.79
19	Vitamin A (I U)	E 1	22.70	23.14	4.50	96.22	5.58	45.86
		E 2	16.55	19.27	9.87	73.75	3.91	29.27
		Pool	19.62	21.13	7.91	86.22	4.79	37.53

Figure 2. The genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability, genetic advance as percent of mean and genetic gain in environment 1 and 2 and pooled mean data presented in table 2.

Note: GCV = Genetic Coefficient of variation, PCV = Phenotypic coefficient of variation, ECV = Environment coefficient of variation, h^2 = Heritability, GA = Genetic advance, GG Genetic gain.

Table 3: Correlation matrix for Genotypic (above diagonal) and Phenotypic (below diagonal) (P \ G) among nineteen parameters of carrot *(Daucus carota* L) for environment (Season) 1.

S. N	Character	Inner core diameter (cm)	Flesh thickness (cm)	Days to seed germi.	Plant height (cm) at 30 DAS	Plant height (cm) at 60 DAS	Plant height (cm) at 90 DAS	Number of leaves / plants	Harvest Index (%)	Root length (cm)	Root girth (cm)	Gross root Wt / 5 plants (kg)	Net root Wt / 5 plants (kg)	Yield quintal / hectare	Dry matter (%)	Moisture (%) in root	TSS (ºbrix %)	Total sugar (%)	β Carotene content (mg / 100 g fresh wt)	Vitamin A
1	Inner core diameter (cm)		-0.36	2.91	-1.18	0.06	0.21	-0.62*	0.39	-0.43	-0.88**	-0.15	-0.17	-0.51	-0.24	-0.20	-0.67**	-0.78**	-.53*	-0.52*
2	Flesh thickness (cm)	-0.20		-2.97**	0.47	1.12	0.74**	0.43	-0.53*	0.64**	0.55*	0.46	0.43	0.48	-0.06	-0.11	0.66**	0.82**	0.85**	0.79**
3	Days to seed germination	0.52*	0.04		-7.24**	1.44	0.90**	-1.96**	0.31	-7.03**	-4.48**	-2.57**	-2.20**	-1.76**	-2.41**	-4.20**	-3.63**	-3.20**	-2.54**	-2.87**
4	Plant height at (cm) 30 DAS	-0.46	0.38	0.19		0.49	0.02	1.07	-1.46	-0.57*	0.41	0.36	0.40	0.88**	0.01	-0.40	0.58*	0.76**	0.72**	0.64**
5	Plant height at (cm) 60 DAS	-0.03	0.26	-0.18	-0.05		1.43	-0.30	0.39	1.00	0.41	0.72**	0.61*	0.37	0.04	0.90**	0.75**	0.64*	0.60*	0.66**
6	Plant height (cm) at 90 DAS	0.22	0.40	0.10	0.00	0.35		-0.49	0.52*	0.60*	0.10	0.79**	0.57*	0.30	-0.25	0.57*	0.59*	0.54*	0.71**	0.73**
7	Number of leaves per plant	-0.19	0.16	0.13	0.24	-0.09	-0.10		-0.65**	-0.92**	0.50	-0.22	-0.18	0.46	-0.73**	0.09	-0.05	0.05	0.13	0.11
8	Harvest Index (%)	0.25	0.03	0.49	0.16	0.02	0.13	-0.08		-0.62*	-0.41	0.26	0.16	-0.26	-0.07	-0.58*	-0.03	-0.13	-0.02	-0.10
9	Root length (cm)	-0.10	0.46	0.30	0.41	0.07	0.19	-0.04	0.24		0.30	0.60*	0.65**	0.05	-0.32	-0.37	0.72**	0.57*	0.79**	0.69**
10	Root girth (cm)	-0.48	0.51	0.10	0.44	-0.04	0.10	0.18	0.09	0.53*		0.25	0.21	0.43	0.03	-0.31	0.76**	0.92**	0.82**	0.73**
11	Gross root weight / 5 plants (kg)	-0.08	0.35	0.00	0.29	0.29	0.40	0.01	0.27	0.54*	0.33		0.95**	0.48	-0.03	0.28	0.72**	0.51	0.75**	0.73**
12	Net root weight / 5 plants (kg)	-0.14	0.34	-0.09	0.30	0.29	0.36	0.01	0.18	0.50	0.25	0.91**		0.60*	0.08	0.37	0.68**	0.44	0.64**	0.62*
13	Yield quintal / hectare	-0.47	0.36	-0.18	0.46	0.22	0.19	0.22	-0.10	0.05	0.33	0.43	0.58*		0.23	0.25	0.63*	0.67**	0.61*	0.61*
14	Dry matter (%)	-0.15	0.10	0.22	0.30	-0.08	-0.18	-0.07	0.23	0.24	0.24	0.12	0.16	0.21		-0.79**	0.16	0.14	0.04	-0.00
15	Moisture (%) in root	-0.04	0.24	0.46	0.31	-0.03	0.04	0.38	0.30	0.50	0.20	0.38	0.29	0.14	0.15		0.33	0.27	0.32	0.24
16	TSS (º brix %)	-0.57*	0.52*	-0.16	0.47	0.37	0.34	0.07	0.13	0.58*	0.63*	0.69**	0.68**	0.60*	0.28	0.31		0.97**	0.94**	0.92**
17	Total sugar (%)	-0.59*	0.36	-0.15	0.45	0.36	0.33	0.17	-0.04	0.36	0.57*	0.42	0.40	0.55*	0.20	0.15	0.83**		0.97**	0.96**
18	β Carotene content (mg / 100 g f wt)	-0.49	0.47	-0.33	0.30	0.36	0.45	0.02	-0.05	0.42	0.54*	0.66**	0.61*	0.56*	0.03	0.11	0.87**	0.80**		1.02
19	Vitamin A (I U)	-0.47	0.55*	-0.23	0.40	0.31	0.44	0.08	0.03	0.47	0.62*	0.69**	0.63*	0.59*	0.07	0.19	0.89**	0.81**	0.97**	

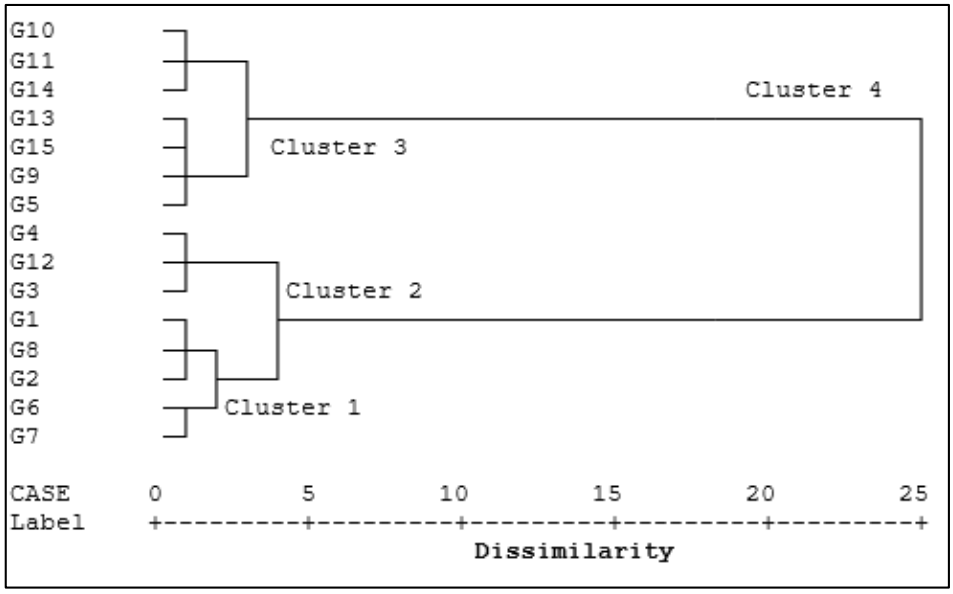
* ** significant at 5% and 1% respectively

Table 4: Correlation matrix for Genotypic (above diagonal) and Phenotypic (below diagonal) (P \ G) among nineteen parameters of carrot *(Daucus carota* L) for environment (Season) 2.

S. N	Character	Inner core diameter (cm)	Flesh thickness (cm)	Days to seed germination	Plant height (cm) at 30 DAS	Plant height (cm) at 60 DAS	Plant height (cm) at 90 DAS	Number of leaves / plants	Harvest Index (%)	Root length (cm)	Root girth (cm)	Gross root Weight / 5 Plants (kg)	Net root weight / 5 plants (kg)	Yield quintal / hectare	Dry matter (%)	Moisture (%) in root	TSS (ºbrix %)	Total sugar (%)	β Carotene content (mg / 100 g fresh wt)	Vitamin A
1	Inner core diameter (cm)		-0.39	9.00	-0.62*	0.01	0.16	9.00	0.42	9.00	-0.15	0.06	-0.38	-0.74**	-0.41	-0.27	-0.56*	-1.03	-0.50	-0.47
2	Flesh thickness (cm)	-0.33		9.00	0.57*	0.74**	0.56*	9.00	0.08	9.00	1.82	0.70**	0.98**	0.64**	0.06	0.44	0.76**	0.87**	0.87**	0.81**
3	Days to seed germination	0.29	-0.28		9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
4	Plant height (cm) at 30 DAS	-0.51	0.42	-0.22		0.37	0.27	9.00	-0.55*	9.00	0.92**	0.11	0.82**	1.07	0.37	0.42	0.61*	0.86**	0.47	0.43
5	Plant height (cm) at 60 DAS	0.01	0.48	-0.02	0.23		0.91**	9.00	0.12	9.00	0.92**	0.42	0.32	0.30	-0.51	0.66**	0.74**	0.46	0.40	0.40
6	Plant height (cm) at 90 DAS	0.14	0.39	0.11	0.16	0.74**		9.00	0.33	9.00	1.32	0.65**	0.54*	0.52*	-0.59*	0.92**	0.67**	0.68**	0.60*	0.56*
7	Number of leaves / plants	-0.13	0.10	0.12	-0.01	0.23	0.11		9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
8	Harvest Index (%)	0.31	-0.02	0.10	-0.36	0.14	0.15	0.27		9.00	0.42	0.35	-0.32	-0.57*	-0.22	0.13	-0.23	-0.19	0.00	-0.01
9	Root length (cm)	-0.17	0.21	-0.21	0.11	0.50	0.28	0.33	0.00		9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
10	Root girth (cm)	-0.07	0.27	-0.01	0.09	0.49	0.38	0.32	0.17	0.73**		0.99**	0.29	0.87**	-1.20	-0.30	1.59	-0.22	0.63*	0.96**
11	Gross root weight/5 plants (kg)	0.04	0.43	0.02	-0.02	0.50	0.51	0.34	0.26	0.43	0.65**		0.66**	0.75**	-0.36	0.19	0.62*	0.25	0.65**	0.65**
12	Net root weight / 5 plants (kg)	-0.27	0.41	-0.19	0.34	0.45	0.38	0.38	-0.09	0.71**	0.68**	0.73**		1.31	-0.37	-0.10	0.79**	-0.10	0.61*	0.65**
13	Yield quintal /hectare	-0.30	0.37	-0.33	0.34	0.32	0.19	0.21	-0.05	0.32	0.22	0.41	0.56*		0.13	1.04	0.71**	0.31	0.65**	0.63*
14	Dry matter (%)	-0.25	-0.06	-0.21	0.10	-0.09	-0.21	0.04	-0.11	0.24	0.16	0.05	0.26	0.08		-0.40	0.30	-0.43	-0.39	-0.28
15	Moisture (%) in root	-0.12	-0.05	-0.01	0.06	0.42	0.47	0.12	-0.08	0.44	0.46	0.37	0.43	0.16	0.31		1.15	0.37	0.24	0.28
16	TSS (º brix %)	-0.42	0.52*	-0.21	0.38	0.48	0.38	0.23	0.12	0.44	0.31	0.40	0.42	0.38	0.08	0.20		1.52	1.01	0.92**
17	Total sugar (%)	-0.43	0.17	-0.13	0.12	0.49	0.29	0.38	0.02	0.69**	0.66**	0.51	0.60*	0.38	0.38	0.53*	0.49		0.82**	0.92**
18	β Carotene content (mg / 100 g f wt)	-0.38	0.45	-0.30	0.18	0.50	0.42	0.32	0.03	0.65**	0.72**	0.72**	0.78**	0.39	0.20	0.40	0.56*	0.80**		1.03
19	Vitamin A	-0.41	0.48	-0.27	0.21	0.50	0.45	0.32	0.06	0.59*	0.61*	0.72**	0.75**	0.40	0.14	0.40	0.63*	0.76**	0.96**	

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

Dendrogram Pool



Note: G1 (Shin Kuroda), G2 (Early Nantes), G3 (Pusa Kesar), G4 (Super Red-Sun Grow), G5 (Pearl Red), G6 (Selection Red), G7 (Selection ME-01), G8 (Super Red-Super Seeds), G9 (Deep Red), G10 (JK 24), G11 (JK 241), G12 (Black Wonder), G13 (Pusa Kesar), G14 (Dark Red) and G15 (Desi Red)

Fig 2: Dendrogram pool distance cluster combine analysis of 15 genotypes of carrot based on ward method using correlation (Genotypic and Phenotypic) coefficient.

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