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Assessment of genetic variability and path analysis in carrot (*Daucus carota* L.) genotypes

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Abstract
Studied of genetic variability and its component traits and path analysis were carried out among fifteen genotypes of carrot (*Daucus carota* L). Highly significant differences between genotypes were observed for all the characters. A moderate to wide range of mean value for different characters were observed among the genotypes. Moderate to high genotypic co-efficient of variation, phenotypic co-efficient of variation with moderate to high heritability, direct and indirect effect of genotypic and phenotypic path analysis on yield qt / ha. and genetic advance as percentage of mean was investigate for majority of the characters. High genotypic co-efficient of variation, phenotypic co-efficient of variation, heritability, genetic advance as percent of mean, genetic gain and path analysis were observed for flesh thickness (cm), net root weight / five plant (kg), yield (qt. / ha.), inner core diameter (cm), vitamin A (I U), β carotene content (mg / 100 g fresh weight), root girth (cm) and root length (cm). The present study revealed that, presence of substantial amount of variability in the genotypes and the important yield components are flesh thickness (cm), net root weight / five plant (kg), yield (qt / ha), vitamin A (IU), β carotene content (mg / 100 g fresh weight), root girth (cm) and root length (cm). It was concluded that selection based on flesh thickness (cm), root length (cm), root girth (cm), net root weight / five plants (kg), β carotene content (mg / 100 g fresh weight), vitamin A (I U) and yield (qt. / ha.) may improve yield.

Keywords: Genetic co-efficient of variation, phenotypic co-efficient of variation, heritability, path analysis, carrot

1. Introduction

Carrot (*Daucus carota* L.) 2n = 2x = 18 belong to the Apiaceae family. 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 to 90 days from sowing to marketable root development. The ideal temperature is 16 to 21° C (Anonymous, 2017) [4]. 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. Asiatic carrots are generally red coloured because of anthocyanin pigment. Whereas, European types are orange coloured because of carotene a precursor of vitamin A (Priya and Santhi 2015) [40, 42]. Carrot is major source of vitamin A and provides 14 to 17% of total vitamin A (Block 1994). Different colours of root are also found such as white, black and purple, with the orange or orange – red colours. In carrot roots are very greatly in shape, size and other characteristics. Many shapes of roots may be cylindrical, conical or even spherical in shape. Carrot is originated from South-western Asia, especially Afghanistan (Banga, 1976) [8].

Genetic parameters like co-efficient of variation, heritability, genetic advance and path analysis provide clear in sight into the extent of variability and relative measures of the efficiency of selection of genotypes based on phenotype, in a highly variable population. Heterosis can be very well exploited in terms of hybrids or by combining superior inbred having higher general combining ability (GCA). Among the carrot root morphology, uniformity in root shape, size, external root colour, core size (small), core colour (uniform xylem and phloem) is some of the most important characters (Peterson and Simon, 1986 and Rubatzky *et al*.,1999) [41]. 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.

Fisher (1918) [15, 19] reported that the quantitative traits exhibiting continuous variation are under the control of heritable and non-heritable factors. Greater the variability in population for these traits, there are the greater chances for effective selection for desirable types of traits (Vavilov, 1951). Phenotypic and genotypic co-efficient of variation are useful in detecting amount of variability present in germplasm. Response to selection depends on the relative proportion of the heritable component in the continuous variation (Singh and Mittal 2003) [44]. The heritable components are due to genotype, while the non-heritable portion is mainly due to the environment factors. Heritability estimate may not provide clear predictability of the breeding value. 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 (Johnson *et al*., 1955) [25]. Variability, heritability and genetic advance were relative measure of the efficiency of selecting genotypic from a highly variable population based on phenotypic (Santhi *et al.,* 2015) [42]. Heritability was an indicator for measuring the relative influence of environment on expression of genotypes (Jain *et al.,* 2010) [24]. Therefore, the present investigation was carried out to study for estimating genetic variability, heritability, genetic advance and path analysis among various qualitative, quantitative and nutritional traits in fifteen selected genotypes of carrot cultivated at North-Eastern part of Rajasthan (India) under Indira Gandhi National Open University, Maidan Garhi, New Delhi (India), during the two different seasons in the year 2018 and 2019 respectively.

2. Materials and Methods

An experiment was laid out in Randomized Block Design (RBD) with three replications in two different years *i.e.,* 2018 and 2019 at Agriculture Research Farm, SunRise University Campus, Bagad Rajput, Ramgarh - 301026, Alwar (Rajasthan), India under Indira Gandhi National Open University (IGNOU), Maidan Garhi, New Delhi – 110068, 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. Soil was of the sandy loam with pH of 7.6. Land was brought to a fine tilth by repeated ploughing and harrowing. 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. An experiment field was divided into 45 plots. A total number of fifteen genotypes were replicated three times subjected for the study. Seeds were sown with a spaced 35 cm apart between rows and 10 -12 cm between plants. Recommended agronomic and cultural practices were followed to obtain better phenotypic expression of the characters.

Material consisted of fifteen genotypes of carrot *viz.* Shin Kuroda, Early Nantes, Pusa Rudhira, Super Red (Sungrow), 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 were collected from different locations. 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. Observations were collected for two qualitative traits *viz.* exterior root colour, inner core colour, eleven 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 (qt. / ha) and six 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 (%). Quantitative and qualitative observations were recorded based on the IPGRI descriptor (IPGRI 1998) [23]. 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. Data based on the mean of individual plants selected for observation were statistically analysis described by Burton (1952) [10] to find out overall total variability present in the material under study for each character and for all the populations. Data’s 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 (2008), version 9.2. Data’s were pooled and standard statistical procedures followed for estimating genetic components, genotypic and phenotypic coefficient of variation (Burton, 1952) [10], heritability (Hanson *et al*, 1956) [20] and genetic advance (Johnson *et al.,* 1955) [25]. Correlation and path analysis were calculated suggested by miller *et al.,* (1958) [33].

Table 1: Analysis of variance (ANOVA) for quantitative, qualitative and nutritional characters in carrot (*Daucus carota* L.) genotypes for the year - 2018 (E1).

Source of variation	df	Days to seed germination	Inner core diameter (cm)	Flesh thickness (cm)	Plant height (cm)			No of leaves / plant	Harvest Index (%)	Root length (cm)	Root girth (cm)	Gross root weight / 5 plant (kg)	Net root weight / 5 plant (kg)	Yield (qt. / ha)	Dry matter (%)	Moisture (%) in root	TSS (º brix%)	Total sugar (%)	β Carotene content (mg / 100 g fresh wt.)	Vitamin A (I U)
					30 DAS	60 DAS	90 DAS													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		17	18
Rep.	2	0.17	0.14**	0.24*	11.12	262.87*	117.07	1.51	12.08	0.00	0.01	0.00	0.00	227.50	0.12	3.91	0.16	0.18	0.05	0.50
Genotype	14	1.90	0.12**	0.21*	99.11	189.98*	244.81**	1.37	293.22**	3.59*	0.32**	0.02**	0.01**	4739.61**	10.16**	15.75	10.22**	0.98**	8.27**	23.16**
Error	28	1.81	0.00	0.07	52.50	72.65	79.52	0.88	103.65	1.59	0.08	0.00	0.00	91.70	1.19	10.12	0.41	0.11	0.13	0.30

* Significant at 5% level, ** Significant at 1% level.

Table 2: Analysis of variance (ANOVA) for quantitative and qualitative characters in carrot (*Daucus carota* L.) genotypes for year 2019 (E2).

Source of variation	df	Days to seed germination	Inner core diameter (cm)	Flesh thickness (cm)	Plant height (cm)			No of leaves / plant	Harvest Index (%)	Root length (cm)	Root girth (cm)	Gross root weight / 5 plant (kg)	Net root weight / 5 plant (kg)	Yield (qt. / ha.)	Dry matter (%)	Moisture (%) in root	TSS (º brix%)	Total sugar (%)	β Carotene content (mg /100 g fresh wt.)	Vitamin A (I U)
					30 DAS	60 DAS	90 DAS													
		1	2	3	4	5	6	7	8	9	10	11	12	12	14	15	16	17	18	19
Rep.	2	0.08	0.00	0.04	6.12	6.93	171.11**	4.66	64.50	0.67	0.08	0.00	0.00	24610.9**	2.98	35.86	3.48	0.43	0.06	0.08
Genotype	14	0.75	0.19**	0.21**	93.87**	249.86**	282.90**	2.05	260.04	17.08	0.85	0.05**	0.03**	7209.71	11.26*	54.60	6.79**	0.85	5.90**	16.40**
Error	28	1.17	0.00	0.03	12.28	17.04	27.98	3.34	52.77	18.11	0.67	0.01	0.01	4158.58	4.23	34.38	1.26	0.53	1.37	1.74

* Significant at 5% level, ** Significant at 1% level.

Note:

df = degree of freedom, rep. = replication, cm = centimetre, DAS = Days after sowing,% = percentage, kg = kilogram, g = gram, mg = milligram, β = beta, I U = International Unit, E = Environment.

Table 3: Analysis of variance over the environments.

SN	Characters	Environment [1]	Rep / Env. [4]	Genotypes [14]	G x E [14]	Pool Error [56]	Barlet [1]
1	Days to seed germination	5.08	0.12	2.35	0.30	1.49	5.31*
2	Inner core diameter (cm)	0.12**	0.07**	0.31**	0.01*	0.00	4.94*
3	Flesh thickness (cm)	0.03	0.14*	0.40**	0.02	0.05	1.29
4	Plant height (cm) at 30 DAS	43.43	8.62	130.60**	62.38*	32.39	13.63**
5	Plant height (cm) at 60 DAS	116.03	134.90*	433.33**	6.51	44.85	13.58**
6	Plant height (cm) at 90 DAS	1539.09**	144.09*	514.90**	12.80	53.75	7.31**
7	No of leaves / plant	56.50**	3.08	2.49	0.94	2.11	11.55**
8	Harvest index (%)	533.92*	38.29	546.73**	6.53	78.21	3.13
9	Root length (cm)	81.00**	0.33	17.32	3.35	9.85	33.99**
10	Root girth (cm)	38.40**	0.04	0.78*	0.39	0.38	27.25**
11	Gross root weight / 5 plant (kg)	2.80**	0.00	0.05**	0.01**	0.00	12.01*
12	Net root weight / 5 plant (kg)	0.89**	0.00	0.03**	0.01	0.00	67.37**
13	Yield (qt. / ha.)	10907.83*	12419.25**	11761.73**	187.58	2125.14	69.21**
14	Dry matter (%)	31.95**	1.55	20.20**	1.22	2.71	10.57**
15	Moisture (%) in root	0.07	19.89	54.45**	15.91	22.25	9.87**
16	TSS (º brix%)	2.29	1.82	16.11**	0.90	0.83	8.32**
17	Total sugar (%)	2.81**	0.31	1.76**	0.07	0.32	16.01**
18	β carotene content (mg / 100 g f wt)	12.50**	0.05	13.83**	0.35	0.75	13.91**
19	Vitamin A (I U)	32.33**	0.29	38.60**	0.97	1.02	19.32**

* Significant at 5% level, ** Significant at 1% level.

Note:

Env. = Environment, G = Genotypic, E = Environment

Table 4: Pooled estimate of range, mean, genotypic, phenotypic and environment co-efficient variation, variability, heritability and genetic advance for different characters in carrot (*Daucus carota* L.) genotypes.

S. No	Characters	Range	General Mean	SE Mean	C.V.	C.D at		Coefficient of variance (%)			Heritability	Genetic advance	Genetic Gain
						5%	1%	Genotypic (GCV%)	Phenotypic (PCV%)	Environment (ECV%)	($h^{2\%}{}_{bs}$)	(G A)	(G G)
1	Days to seed germination	5.49 – 7.71	6.36	0.50	19.18	1.41	1.88	9.17	18.83	19.18	23.75	0.59	9.21
2	Inner core diameter (cm)	1.25 – 2.09	1.62	0.02	3.11	0.06	0.08	13.91	14.38	3.11	93.50	0.45	27.70
3	Flesh thickness (cm)	0.73 – 1.85	1.03	0.09	21.31	0.25	0.34	24.18	30.99	21.31	60.88	0.40	38.87
4	Plant height (cm) at 30 DAS	25.48 – 42.28	32.88	2.32	17.31	6.58	8.77	10.26	22.30	17.31	21.15	3.19	9.72
5	Plant height (cm) at 60 DAS	42.02 – 73.77	54.91	2.73	12.20	7.75	10.31	15.36	18.50	12.20	68.93	14.42	26.27
6	Plant height (cm) at 90 DAS	57.02 – 93.61	79.29	2.99	9.25	8.48	11.29	11.54	14.03	9.25	67.61	15.49	19.54
7	No of leaves / plant	6.59 – 8.68	7.19	0.59	20.20	1.68	2.24	7.07	19.56	20.20	13.06	0.38	5.26
8	Harvest index (%)	37.80 – 74.53	55.46	3.61	15.95	10.23	13.62	17.11	21.66	15.95	62.37	15.44	27.83
9	Root length (cm)	13.99 – 19.86	16.17	1.28	19.41	3.63	4.83	9.43	19.57	19.41	23.25	1.52	9.37
10	Root girth (cm)	2.81 – 3.99	3.07	0.25	20.01	0.71	0.95	8.21	21.77	20.01	14.23	0.20	6.38
11	Gross root weight / 5 plant (kg)	0.36 – 0.68	0.49	0.02	11.53	0.07	0.09	16.67	23.57	11.53	49.98	0.12	24.27
12	Net root weight / 5 plant (kg)	0.20 – 0.45	0.30	0.03	21.01	0.07	0.10	21.85	32.23	21.01	45.95	0.09	30.51
13	Yield (qt. / ha.)	175.13-309.32	238.45	18.82	19.33	53.32	71.00	18.42	24.48	19.33	56.60	68.07	28.55
14	Dry matter (%)	10.84 – 18.53	14.52	0.67	11.33	1.90	2.53	12.25	15.97	11.33	58.85	2.81	19.36
15	Moisture (%) in root	81.19 – 90.80	85.79	1.93	5.50	5.46	7.26	2.95	6.01	5.50	24.19	2.57	2.99
16	TSS (º brix%)	7.62 – 14.23	9.96	0.37	9.17	1.06	1.41	15.99	18.49	9.17	74.76	2.84	28.48
17	Total Sugar (%)	2.46 – 4.47	3.22	0.23	17.52	0.65	0.87	16.46	22.34	17.52	54.30	0.81	24.99
18	β carotene content (mg / 100 g fresh weight)	5.132 – 11.40	7.64	0.35	11.34	1.00	1.34	19.61	22.14	11.34	78.48	2.74	35.79
19	Vitamin A (I U)	8.55 – 18.99	12.76	0.41	7.91	1.17	1.56	19.62	21.13	7.91	86.22	4.79	37.53

* Significant at 5% level, ** Significant at 1% level.

Note:

SE = Standard Error, CD = Critical Difference, GCV = Genotypic Coefficient of Variation, PCV = Phenotypic Coefficient of Variation, ECV = Environment Coefficient of Variation, $h^2{}_{bs}$ = Heritability as broad sense, GA = Genetic Advance, GG = Genetic Gain.

Table 5: Estimate of direct (bold) and indirect (off diagonal) effect of genotypic path analysis for yield quintal / hectare for the year – 2018 (E 1)

SN	Character	Inner Core diameter (cm)	Flesh Thickness (cm)	Plant Height (cm) 60 DAS	Plant Height (cm) 90 DAS	Harvest Index (%)	Root Length (cm)	Root Girth (cm)	Gross Root Weight / 5 Plants (kg)	Net Root Weight / 5 Plants (kg)	Dry Matter (%)	TSS (º brix%)	Total Sugar (%)	β Carotene Content (mg / 100 g fresh wt.)	Vitamin A (I U)	r
1	Inner Core diameter (cm)	**-38.30**	15.76	-5.54	24.98	-22.37	3.88	22.17	-6.72	6.83	2.18	-3.94	1.02	2.94	-3.40	-0.51
2	Flesh Thickness (cm)	13.86	-43.57	-98.96	87.17	30.36	-5.82	-13.85	20.90	-17.14	0.55	3.93	-1.07	-4.74	5.17	0.48
3	Plant Height (cm) 60 DAS	-2.41	-48.91	-88.15	168.78	-22.19	-9.06	-10.26	32.40	-24.02	-0.35	4.43	-0.84	-3.38	4.32	0.37
4	Plant Height (cm) 90 DAS	-8.09	-32.13	-125.88	118.19	-29.51	-5.40	-2.62	35.71	-22.77	2.20	3.49	-0.71	-3.98	4.81	0.30
5	Harvest Index (%)	-15.09	23.29	-34.45	61.42	-56.78	5.61	10.27	11.59	-6.16	0.62	-0.20	0.17	0.11	-0.67	-0.26
6	Root Length (cm)	16.40	-27.98	-88.13	70.42	35.15	-9.07	-7.57	27.34	-25.84	2.83	4.29	-0.75	-4.44	4.50	0.05
7	Root Girth (cm)	33.63	-23.90	-35.81	12.27	23.09	-2.72	-25.25	11.25	-8.46	-0.27	4.48	-1.21	-4.60	4.81	0.43
8	Gross Root Weight / 5 Plants (kg)	5.68	-20.10	-63.03	93.13	-14.53	-5.47	-6.27	45.31	-37.75	0.23	4.27	-0.67	-4.18	4.79	0.48
9	Net Root Wt. / 5 Plants (kg)	6.60	-18.86	-53.48	67.95	-8.83	-5.92	-5.40	43.20	**-39.60**	-0.71	4.02	-0.57	-3.60	4.09	0.60*
10	Dry Matter (%)	9.32	2.67	-3.42	-29.06	3.92	2.87	-0.77	-1.16	-3.14	**-8.93**	0.96	-0.19	-0.21	-0.02	0.23

11	TSS (º brix%)	25.49	-28.88	-65.88	69.66	1.95	-6.57	-19.09	32.68	-26.84	-1.44	**5.93**	-1.27	-5.28	6.02	0.63*
12	Total Sugar (%)	29.75	-35.51	-56.32	63.46	7.35	-5.15	-23.15	23.00	-17.25	-1.26	5.74	**-1.32**	-5.41	6.29	0.67**
13	β Carotene Content (mg / 100 g f. Wt)	20.14	-36.96	-53.30	84.13	1.13	-7.20	-20.77	33.88	-25.49	-0.33	5.59	-1.27	**-5.59**	6.66	0.61*
14	Vitamin A (I U)	19.83	-34.38	-58.11	86.79	5.84	-6.22	-18.52	33.13	-24.72	0.02	5.44	-1.26	-5.68	**6.56**	0.61*

Residual is out of range = 4.14

*, ** Significant correlation with dependent characters at 5% and 1% level of significant respectively

Table 6: Estimate of direct (bold) and indirect (off diagonal) effect of phenotypic path analysis for yield quintal / hectare for the year – 2019 (E 2).

SN	Character	Inner Core diameter (cm)	Flesh Thickness (cm)	Plant Height (cm) at 60 DAS	Plant Height (cm) at 90 DAS	Harvest Index (%)	Root Length (cm)	Root Girth (cm)	Gross Root Weight / 5 Plants (kg)	Net Root Weight / 5 Plants (kg)	Dry Matter (%)	TSS (o brix%)	Total Sugar (%)	β Carotene Content (mg / 100 g fresh wt.)	Vitamin A (I U)	r
1	Inner Core diameter (cm)	-0.07	-0.03	0.00	-0.01	-0.01	0.05	-0.04	0.05	-0.14	-0.02	-0.03	-0.13	0.19	-0.28	-0.47
2	Flesh Thickness (Cm)	0.01	0.16	-0.01	-0.02	-0.00	-0.23	0.04	-0.21	0.36	0.01	0.02	0.08	-0.19	0.32	0.36
3	Plant Height (cm) at 60 DAS	0.00	0.04	-0.04	-0.02	-0.00	-0.03	-0.00	-0.17	0.31	-0.01	0.02	0.08	-0.14	0.18	0.22
4	Plant Height (cm) at 90 DAS	-0.02	0.06	-0.01	-0.05	-0.01	-0.09	0.01	-0.24	0.38	-0.02	0.02	0.07	-0.18	0.26	0.19
5	Harvest Index (%)	-0.02	0.01	-0.00	-0.01	-0.06	-0.12	0.01	-0.16	0.19	0.02	0.01	-0.01	0.02	0.02	-0.10
6	Root Length (cm)	0.01	0.07	-0.00	-0.01	-0.01	-0.50	0.04	-0.32	0.53	0.02	0.03	0.08	-0.17	0.28	0.05
7	Root Girth (cm)	0.03	0.08	0.00	-0.00	-0.01	-0.26	0.08	-0.20	0.27	0.02	0.03	0.13	-0.21	0.37	0.33
8	Gross Root Wt. / 5 Plants (kg)	0.01	0.06	-0.01	-0.02	-0.02	-0.27	0.03	-0.59	0.96	0.01	0.03	0.09	-0.26	0.41	0.43
9	Net Root wt. / 5 Plants (kg)	0.01	0.05	-0.01	-0.02	-0.01	-0.25	0.02	-0.54	1.06	0.02	0.03	0.09	-0.24	0.37	0.58*
10	Dry Matter (%)	0.01	0.02	0.00	0.01	-0.01	-0.12	0.02	-0.07	0.17	0.10	0.01	0.05	-0.01	0.04	0.21
11	TSS (º brix%)	0.04	0.08	-0.01	-0.02	-0.01	-0.29	0.05	-0.41	0.72	0.03	0.05	0.18	-0.34	0.52	0.60*
12	Total Sugar (%)	0.04	0.06	-0.01	-0.02	0.00	-0.18	0.05	-0.25	0.42	0.02	0.04	0.22	-0.31	0.48	0.55*
13	β Carotene Content (mg / 100 g f wt.)	0.03	0.08	-0.01	-0.02	0.00	-0.21	0.05	-0.39	0.65	0.00	0.04	0.18	-0.39	0.57	0.56*
14	Vitamin A (I U)	0.03	0.09	-0.01	-0.02	-0.00	-0.24	0.05	-0.41	0.67	0.01	0.04	0.18	-0.38	0.59	0.59*

Residual = 0.5102

*, ** Significant correlation with dependent characters at 5% and 1% level of significant respectively

3. Results and Discussion

Data's an analysis of variance for quantitative, qualitative, nutritional and yield traits are presented in Table 1 and 2 for both the environment (E1) for the year 2018 and environment (E2) for the year 2019 respectively. Fifteen genotypes of carrot involved in the study varied significantly for all the traits. Analysis of variance was observed highly significant differences between genotypes for all the characters studied. Maximum variability was observed for yield (qt. / ha), harvest index (%), plant height (cm) at 90 DAS and plant height (cm) at 60 DAS at 1% level of significant for both the environment. Whereas, highest variability was observed for plant height (cm) at 60 DAS 189.98* and flesh thickness (cm) 0.21* for (E 1) and dry matter (%) 11.26* for (E 2) at 5% level of significant. Such results were findings of Asima *et al.* (2013) [5, 7].

Extent of variability was measured in term of range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), environment coefficient of variance (ECV), heritability (h^2_{bs}), genetic advance (GA) as percent of mean and genetic gain (GG) for all the nineteen characters as pooled mean data are presented in Table 4. Assessment of variability parameters revealed that there is a lot of variability present among all the genotypes studied. The value of phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters studied. In the present investigation, indicating the considerable influence of environmental factor on the performance of genotypes for different characters. Wide range of variation was observed for yield (qt. / ha.) 175.13 to 309.32 with a mean value of 238.45 qt. / ha followed by moisture (%) in root 81.19 to 90.80 with a mean value of 85.79%, harvest index (%) 37.80 to 74.53 with a mean value of 55.46 (%) and plant height (cm) at 60 DAS 42.02 to 73.77 with a mean value of 54.91 (cm). Similar reports have been reported by Kumar *et al.*, (2010) [27], Gupta *et al.*, (2012) [18], and Priya and Santhi (2015) [40, 42]. Therefore, it is necessary to estimate phenotypic and genotypic co-efficient of variation based on genotypic and phenotypic variance respectively. Sivasubramanian and Menon (1973) [49] reported that estimate of phenotypic co-efficient of variation and genotypic co-efficient of variation are classified as low (0-10%), moderate (11-20%) and high (more than 21%). Among fifteen genotypes of carrot, maximum genotypic coefficient of variation (GCV) was noted for flesh thickness (cm) 24.18 followed by net root weight / five plant (kg) 21.85 and vitamin A (IU) 19.62 characters. Moderate estimate of genotypes coefficient of variation was observed for β carotene content (mg / 100 g fresh wt.) 19.61 followed by yield (qt. / ha.) 18.42, harvest index (%) 17.11 and gross root weight / 5 plant (kg) 16.67, total sugar (%) 16.46, total soluble solids (º brix%) 15.99, plant height (cm) at 60 DAS 15.36, inner core diameter (cm) 13.91, dry matter (%) 12.25 and plant height (cm) at 90 DAS 11.54. reasonable amount of variability was found in these characters and can be used in further crop improvement. Genotypic coefficient of variation (GCV) was noted low for moisture (%) in root 2.95, no. of leaves / plant 7.07 and root girth (cm) 8.21 characters. This indicated that, there was a less chance of improving of these traits by direct visual selection. These results were also noticed by Dod *et al.*, (2013) [13], Prajapati *et al.*, (2014) [39], Sivathanu *et al.*, (2014) [48], Mallikarjunarao *et al.*, (2015) [31], Priya and Santhi (2015) [40, 42], Nagar *et al.*, (2016) [34] and Teli *et al.*, (2017) [50]. Phenotypic co-efficient of variation was slightly higher than genotypic co-efficient of variation for all the characters. Net root weight / five plant (kg) 32.23 showed the maximum phenotypic co-efficient of variation (PCV) value followed by flesh thickness (cm) 30.99 and yield (qt. / ha.) 24.48, gross root weight / five plants (kg) 23.57, total sugar (%) 22.34, plant height (cm) at 30 DAS 22.30 and β carotene content (mg / 100 g fresh wt.) 22.14 characters. Moderate phenotypic co-efficient of variation was observed for root length (cm) 19.57 followed by no of leaves / plant 19.56, days to seed germination 18.83, plant height (cm) at 60 DAS 18.50, total soluble solids (º brix%) 18.49 and dry matter (%) 15.97 characters. Phenotypic coefficient of variation (PCV) was noted low for moisture (%) in root (6.01) character. These indicates that, there was a less chance of improving these parameters by direct selection. Similar result was also found by Tewatia and Dudi (1999) [52], Asima *et al.*, (2013) [5, 7] and Singh *et al.*, (2014). Similarly, environment co-efficient of variation (ECV) was found highest for flesh thickness (cm) 21.31 followed by net root weight / five plant (kg) 21.01 and no of leaves / plant 20.20 characters. Environment co-efficient of variation (ECV) was observed moderate for root girth (cm) 20.01, root length (cm) 19.41 and yield (qt. / ha.) 19.33 characters and was noted low for inner core diameter (cm) 3.11, moisture (%) in root 5.50 and vitamin A (I U) 7.91 characters.

Highest estimate of heritability was recorded for inner core diameter (cm) 93.50 followed by vitamin A (I U) 86.22, β carotene content (mg / 100 g fresh wt.) 78.48, total soluble solids (º brix%) 74.76, plant height (cm) at 60 DAS 68.93 and plant height (cm) at 90 DAS 67.61 characters. High heritability indicated less influence of environment and controlled by additive gene action of these traits. Therefore, it helps to make selection for a particular character was easy when heritability is high. Heritability was observed moderate for root girth (cm) 14.23 and no of leaves / plant 13.06 characters. Similar result was also found by Yadav *et al.*, (2009) [56], Amin and Singla (2010) [6], Jain *et al.*, (2010) [24], Naseeruddin *et al.*, (2011) [36], Gupta *et al.*, (2012) [18], Asima *et al.*, 2013 [5, 7], Prajapati *et al.*, (2014) [39], Sivathanu *et al.*, (2014) [48], Priya and Santhi (2015) [40, 42] and Teli *et al.*, (2017) [50]. Maximum genetic advance as percentage of mean was observed for yield (qt. / ha.) 68.07. Panse (1957) [37] reported that a higher value of genetic advance accompanied with high heritability estimates for different traits was obtained due to additive gene effect. Moderate genetic advance was recorded for plant height (cm) at 90 DAS 15.49 followed by harvest index (%) 15.44 and plant height (cm) at 60 DAS 14.42 characters. Sharma *et al.*, (2000) [47] and Das *et al.*, (2010) [12] reported that genetic advance was worked out to assess the responses to selection likely to occur in selection breeding programme. Genetic advance was noted low for net root weight / five plant (kg) 0.09, root girth (cm) 0.20 and no of leaves / plant 0.38 characters. These characters were governed by non-additive gene action and selection based on these parameters found not effective. Similar result was also founded by Gupta *et al.*, (2012) [18], Kumar *et al.*, (2012) [28], Asima *et al.*, (2013) [5, 7], Sivathanu *et al.*, (2014) [48], Mallikarjunarao *et al.*, (2015) [31], Dutta *et al.*, (2015) [14] and Teli *et al.*, (2017) [50]. Similarly, highest genetic gain was recorded for flesh thickness (cm) 38.87, vitamin A (I U) 37.53 and β carotene content (mg / 100 g fresh weight) 35.79 and was noted low for moisture (%) in root 2.99, no of leaves / plant 5.26 and root girth (cm) 6.38 characters respectively. Genetic gain was computed to accomplish the comparison of the traits in relation to environment.

Hiremath and Rao (1974) [21] reported that, the genetic variability can thus be a choice of selection of suitable parents however, the quantitative and qualitative characters are proven to environmental influence that necessitates the partitioning of overall variance as heritable and non-heritable components for efficient breeding programme.

Result of the present investigation on path coefficient analysis at the genotypic level for the year 2018 are presented in Table 5. The indicated that plant height (cm) at 90 DAS 118.19 had observed maximum direct genotypic positive effect on yield (qt./ha.) followed by gross root weight / five plants (kg) 45.31, vitamin A (I U) 6.56 and total soluble solids (º brix%) 5.93. Direct positive effect ranged value was observed total soluble solids º brix (%) 5.93 to plant height (cm) at 90 DAS 118 in traits. Tewatia *et al.,* (2000) [53] reported that positive direct effect of root diameter on marketable root yield per plot at the genotypic level in carrot. Result of genotypic as well as phenotypic correlation coefficient proved by path analysis, that plant height (cm) at 90 DAS, gross root weight / five plants (kg), vitamin A (I U) and total soluble solids (º brix%) had positive direct effect on yield. But this direct effect was little bit reduce by the negative indirect effect of inner core diameter (cm), flesh thickness (cm), harvest index (%), root length (cm), root girth (cm), net root weight / five plants (kg), dry matter (%), total sugar (%) and β carotene content (mg / 100 g fresh weight). Whereas, plant height (cm) at 60 DAS - 88.15, harvest index (%) - 56.78, flesh thickness (cm) - 43.57, net root weight / five plants (kg) - 39.60 and inner core diameter (cm) -38.30 had observed negative direct effect on carrot yield (qt. / ha.) While, direct negative effect ranged value was recorded in traits total sugar (%) - 1.32 to plant height (cm) at 60 DAS - 88.15. Indirect positive effect ranged was observed 0.02 to 168. While, indirect negative effect ranged was recorded in traits total sugar (%) – 0.19 to plant height (cm) at 60 DAS - 125.88. Total sugar (%) r_g = 0.67** had observed maximum positive significant genotypic correlation with yield (qt. / ha) at 1% level of significance. Whereas, TSS (º brix%) r_g = 0.63*, followed by β carotene content (mg / 100 g fresh weight) r_g = 0.61*, vitamin A (I U) r_g = 0.61* and net root weight / five plants (kg) r_g = 0.60* had observed maximum positive significant genotypic correlation with yield (qt. / ha) at 5% level of significance. Inner core diameter (cm) r_g = - 0.51 and harvest index (%) r_g = - 0.26 had negative genotypic correlation with yield (qt. / ha). Residual effect of the genotypic coefficient was obtained 4.14, suggesting inclusion of maximum root yield influencing characters analysed.

Path analysis at phenotypic level for the year 2019 are presented in Table 6. Path analysis at the phenotypic level revealed that net root weight / five plants (kg) 1.06 had the maximum direct positive effect on carrot yield (qt. / ha) followed by vitamin A (I U) 0.59, total sugar (%) 0.22, flesh thickness (cm) 0.16, dry matter (%) 0.10, root girth (cm) 0.08 and total soluble solid (º brix%) 0.05 characters. Such finding results on positive direct effect of root length by Tewatia *et al.,* 1990 [51] and Tewatia *et al.,* 2000 [53], root diameter (Tewatia *et al.,* 2000 and Gupta and Verma *et al.,* 2007) [53], biological yield per plant (Singh *et al.,* 2002 and Gupta *et al.,* 2012) [43, 18], root to top ratio (Gupta and Verma, 2007) [17], leaf length (Singh *et al.,* 2002) [43], No of leaf per plant (Tewatia *et al.,*2000) [53] on root yield per plot have also been reported. Whereas, gross root weight / five plants (kg) - 0.59 followed by root length (cm) -0.50, β carotene content (mg / 100 g fresh weight) - 0.39 and inner core diameter (cm) - 0.07 had observed maximum direct negative effect on carrot yield (qt. / ha). Direct positive effect ranged value was recorded in traits total soluble solid (º brix%) 0.05 to vitamin A (I U) 0.59. Direct negative effect ranged was observed in traits plant height (cm) at 60 DAS - 0.04 to gross root weight / five plants (kg) - 0.59. While, the indirect positive effect ranged were observed 0.00 to 0.96 and the indirect negative effect ranged was observed – 0.01 to – 0.54. Total soluble solids (º brix%) r_p = 0.60*, vitamin A (I U) r_p = 0.59*, β carotene (mg / 100 g fresh weight) r_p = 0.56* and total sugar (%) r_p = 0.55* had observed maximum positive phenotypic correlation with yield (qt. / ha) at 5% level of significance. Gross root weight / five plants (kg) r_p = 0.43, flesh thickness (cm) r_p = 0.36 and root girth (cm) r_p = 0.33 had observed maximum positive phenotypic correlation with yield (qt. / ha). While, inner core diameter (cm) r_p = - 0.47 and harvest index (%) r_p = - 0.10 had observed negative phenotypic correlation with yield (qt. / ha). Due to high positive direct effect of plant height (cm) at 90 DAS, root girth (cm), flesh thickness (cm), gross root weight / five plants (kg), net root weight / five plants (kg), TSS (º brix%), total sugar (%) and vitamin A (I U) and their significant and positive correlation with carrot root yield as well as heritability with genetic advance showed the improvement of these traits. Similar, observations has been made by Alves *et al*., (2006) [2] and Gupta *et al*., (2012) [18]. Residual effect of the phenotypic path analysis was obtained r = 0.510 indicated that nineteen characters included in this study explained maximum percentage of the total variation in carrot yield. Therefore, these characters should be considered for yield improvement in carrot breeding programme.

4. Conclusion

The results from the analysed of genetic variability and its component traits and path analysed of 15 genotypes of carrot under two different seasons. Highly significant differences among all the genotypes of carrot were observed for all the characters under study. Higher value of genetic coefficient of variation, phenotypic coefficient of variation, heritability as broad sense, genetic advance as percentage of mean, genetic gain and path analysis were observed for flesh thickness (cm), net root weight / five plants (kg), yield (qt. / ha.), inner core diameter (cm), vitamin A (I U), β carotene content (mg / 100 g fresh wt.), root girth (cm) and root length (cm). All these parameters should be considered to effective improvement in quantitative and other characters.

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