Introduction

Carrot (Daucus carota L.) is most important root crop worldwide nutritionally and as a protective food, because it is a rich source of β-carotene, fiber and other dietary nutrients (Simon, 1990). Carrot is the most economically important vegetable crop worldwide (Simon et al., 2008) and it is the most widely cultivated vegetable among the vegetables of the Apiaceae family (Rubatzky et al., 1999). It belongs to the family Umbelliferae (Apiaceae) and having a chromosome number 2n=18. Carrot is originated from Southwestern Asia, especially Afghanistan (Banga, 1976).

It is a popular cool season vegetable. In temperate region, it is cultivated during spring and summer season, while in tropical region during winter season. It is grown as biennial for seed production and annual for its roots. In India, carrot is mainly cultivated in the states of Haryana, Punjab, Uttar Pradesh, Karnataka and Tamil Nadu. In Karnataka, carrot is mainly cultivated in the districts of Kolar, Chikkaballapur, Belagavi, Bengaluru Rural, Gulbarga and Bidar. The nutritional composition of carrot roots are moisture (88.8%), protein (0.7%), carbohydrates (6%), total sugars (5.6%), carotene (5.33 mg), fiber (2.4%) and vitamin C (4 mg) per 100 g edible portion (Sharma et al., 2012). It also contains...
rich amount of minerals (Ca, Fe and P), thiamine, riboflavin and niacin.

The success of breeding programme is based on the association among different characters and their influence on yield and quality (Rizvy et al., 2007). Yield was a complex character controlled by polygene and depends upon several attributes of the plant. Therefore, it was important to know the association of yield contributing traits with yield. Correlation provides information on yield components and it helps in selection of superior genotypes from diverse genetic population. The correlation analysis assesses the association between yield and other characters (Chakraborty et al., 2016). Keeping in view the above points as landmarks, the present investigation was conducted.

Materials and Methods

The present investigation was carried out during the kharif season, 2017-18 at Kittur Rani Channamma College of Horticulture, Arambhavi, Belagavi district (Karnataka). The details of the experiment, materials used and methodology followed during the course of investigation were described below. Twenty five genotypes of carrot collected from different sources including one recommended variety Hisar Gairic as check were used for the present experiment. Details of the genotypes used in the study were presented in Table 1. The experiment was laid out in randomized complete block design (RCBD) with two replications. Between the rows, a distance of 30 cm was maintained and 10 cm between the plants within the each plot. The standard package of practice was followed for raising the crop. The observations on various parameters were recorded from five randomly selected plants for each treatment in each replication. The mean values of various parameters were subjected to analysis of variance as described by Gomez and Gomez (1983). Statistical analyses were carried out using INDOSTAT software. Correlation coefficients among all possible character combinations were estimated as suggested by Al-Jibourie et al., (1958).

Results and Discussion

The nature and degree of association between various yield attributes were useful in formulating an effective breeding approach. The information about inter-relationship among different characters was important in breeding for direct and indirect selection of characters that were not easily assessed and characters with low heritability. The constant relationship of yield characters over environment was of great importance and the efficiency of the breeding was also improved (Adunga and Labuschangne, 2003). The genotypic and phenotypic correlation coefficient between yield and its attributes were presented in the Table 2 and 3.

Total yield/ha exhibited positive significant association with plant height at 60 DAS, plant height at harvest, leaf length, petiole length, root weight, core diameter, core thickness and cortex thickness, while negative significant association was found with root/top length ratio at both genotypic and phenotypic level. Root length and days to first root harvest were negatively and significantly associated with total yield/ha at genotypic level only. Yield supported by plant height provides better standability and more number of leaves. Thus, there was increase in the photosynthetic activity due to increase in biomass. These results were also reported by Panwar et al., (2003), Gupta and Verma (2007), Silva and Vieira (2008), Yadav et al., (2009), Ullah et al., (2010), Jatoi et al., (2011), Gupta et al., (2012), Sivathanu et al., (2014), Priya and Santhi (2015), Chakraborty et al., (2016), Kiraci and Padem (2016), Nagar et al., (2016), Kaur et al., (2017) and Naseeruddin et al.,
Plant height at 60 DAS exhibited positive significant association with plant height at harvest, petiole length, leaf length, number of leaves/plant, root weight, root diameter, core thickness, cortex thickness and total yield/ha. However, it was negatively and significantly associated with root/top length ratio and β-carotene content at both genotypic and phenotypic level. Core diameter exhibited positive significant association, whereas days to first root harvest and root length showed negative significant association with this trait only at genotypic level. These results were close to the findings of Kaur et al., (2017).

Plant height at harvest showed significant positive correlation with petiole length, leaf length, number of leaves/plant, root weight, core diameter, core thickness, cortex thickness and total yield/ha. Negative significant correlation was expressed for this trait with root/top length ratio and β-carotene content at both genotypic and phenotypic level. Days to first root harvest and root length were negatively and significantly associated with this trait at genotypic level only. These results were close to the findings of Kaur et al., (2017).

Table 1 List of genotypes with their sources used in the experiment

| Sl. No. | Entry       | Source                      |
|--------|-------------|-----------------------------|
| 1.     | VRCAR – 90  | IIVR, Varanasi              |
| 2.     | VRCAR - 109 | IIVR, Varanasi              |
| 3.     | VRCAR-117   | IIVR, Varanasi              |
| 4.     | VRCAR-126   | IIVR, Varanasi              |
| 5.     | VRCAR-127   | IIVR, Varanasi              |
| 6.     | VRCAR-153   | IIVR, Varanasi              |
| 7.     | VRCAR-178   | IIVR, Varanasi              |
| 8.     | VRCAR-179   | IIVR, Varanasi              |
| 9.     | VRCAR-184   | IIVR, Varanasi              |
| 10.    | VRCAR-186   | IIVR, Varanasi              |
| 11.    | VRCAR-197   | IIVR, Varanasi              |
| 12.    | VRCAR-199   | IIVR, Varanasi              |
| 13.    | VRCAR-201   | IIVR, Varanasi              |
| 14.    | HUB-1       | KRCCH, Arabhavi             |
| 15.    | HUB-2       | L C from Bangalore          |
| 16.    | HUB-3       | L C from Dharwad            |
| 17.    | HUB-4       | L C from Dharwad            |
| 18.    | HUB-5       | KRCCH, Arabhavi             |
| 19.    | HUB-6       | L C from Ghataprabha        |
| 20.    | HUB-7       | KRCCH, Arabhavi             |
| 21.    | HUB-8       | L C from Koppal             |
| 22.    | HUB-9       | L C from Mahisyala          |
| 23.    | HUB-10      | L C from Mudalgi            |
| 24.    | HUB-11      | L C from Upparhatti         |
| 25.    | Hisar Gairic* | HAU, Hisar               |

*Check cultivar
HAU: Hisar Agriculture University, Hisar, Haryana
IIVR: Indian Institute of Vegetable Science, Varanasi, UP
### Table 2: Genotypic correlation coefficients among growth, yield and quality parameters in carrot (*Kharif* season)

|       | PHS   | PHH   | NL    | LL    | PL    | PT    | RL    | RD    | RW    | CD    | CT    | CtT   | DRH   | RTLR  | CC    | TSS   | TY/ha |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| PHS   | 1.000 | 0.992**| 0.494**| 0.830**| 0.904**| 0.229 | -0.443**| 0.279* | 0.589**| 0.334* | 0.577**| 0.497**| -0.467**| -0.961**| -0.555**| 0.186 | 0.589**|
| PHH   | 1.000 | 0.598**| 0.864**| 0.878**| 0.240 | -0.469**| 0.246 | 0.622**| 0.401**| 0.543**| 0.502**| -0.479**| -0.904**| -0.575**| 0.171 | 0.623**|
| NL    | 1.000 | 0.744**| 0.390**| 0.630**| -0.065 | -0.409**| 0.038 | 0.085 | -0.013 | -0.017 | 0.234 | -0.811**| -0.794**| 0.336* | 0.039 |
| LL    | 1.000 | 0.692**| 0.350* | -0.038 | -0.212 | 0.625**| 0.252 | 0.285* | 0.468**| -0.091 | -0.900**| -0.630**| 0.216 | 0.625**|
| PL    | 1.000 | 0.358* | -0.078 | 0.220 | 0.418**| 0.540**| 0.179 | 0.215 | -0.122 | -0.684**| -0.718**| 0.264 | 0.418**|
| PT    | 1.000 | 0.166 | -0.413**| -0.002 | 0.165 | 0.267 | -0.270 | 0.301* | -0.293* | -0.535**| 0.449**| -0.002 |
| RL    | 1.000 | -0.314*| -0.290*| -0.099 | -0.480**| -0.446**| 0.559**| 0.464**| 0.135 | 0.089 | -0.290*|
| RD    | 1.000 | 0.256 | 0.750**| 0.389**| 0.301* | -0.804**| -0.121 | -0.095 | -0.405**| 0.256 |
| RW    | 1.000 | 0.527**| 0.331* | 0.452**| -0.356*| -0.686**| -0.116 | -0.079 | 0.999**|
| CD    | 1.000 | 0.069 | 0.230 | -0.225 | -0.403**| -0.407**| 0.017 | 0.527**|
| CT    | 1.000 | 0.388**| -0.458**| -0.393**| -0.133 | 0.079 | 0.331*|
| CtT   | 1.000 | -0.557**| -0.611**| -0.034 | -0.080 | 0.452**|
| DRH   | 1.000 | 0.306* | -0.070 | 0.520**| -0.356*|
| RTLR  | 1.000 | 0.733**| -0.175 | -0.686**|
| CC    | 1.000 | -0.320**| -0.116 |
| TSS   | 1.000 | -0.079 |
| TY/ha | 1.000 |

Critical \(r_c\) value = 0.278 at 5 per cent and 0.361 at 1 per cent. * and ** indicate significant at 5 and 1 per cent probability level, respectively.

PHS – Plant height at 60 DAS (cm)  
PHH – Plant height at harvest (cm)  
NL – Number of leaves/plant  
LL – Leaf length (cm)  
PL – Petiole length (cm)  
PT – Petiole thickness (mm)  
RL – Root length (cm)  
RD – Root diameter (cm)  
RW – Root weight (g)  
CD – Core diameter (mm)  
CT – Core thickness (mm)  
CtT – Cortex thickness (mm)  
DRH – Days to first root harvest  
RTLR – Root/top length ratio  
CC – \(\beta\)-carotene content (µg/100 g)  
TSS – Total soluble solids (*Brix)  
TY/ha – Total yield/hectare (t)
### Table 3 Phenotypic correlation coefficients among growth, yield and quality parameters in carrot (*Kharif* season)

|     | PHS     | PHH     | NL   | LL   | PL   | PT   | RL   | RD   | RW   | CD   | CT   | CTT  | DRH  | RTLR | CC   | TSS  | TY/ha |
|-----|---------|---------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|
| PHS | 1.000   | 0.979** | 0.318* | 0.604** | 0.565** | 0.128 | -0.189 | 0.199 | 0.474** | 0.254 | 0.442** | 0.395** | -0.228 | -0.595** | -0.472** | 0.175 | 0.474** |
| PHH | 1.000   | 0.335*  | 0.646** | 0.549** | 0.159 | -0.183 | 0.200 | 0.508** | 0.293* | 0.430** | 0.412** | -0.251 | -0.632** | -0.507** | 0.161 | 0.508** |
| NL  | 1.000   | 0.427** | 0.194 | 0.274 | 0.023 | -0.193 | 0.074 | 0.156 | 0.006 | 0.046 | 0.211 | -0.348* | -0.527** | 0.201 | 0.074  |
| LL  | 1.000   | 0.397** | 0.223 | -0.087 | 0.172 | 0.518** | 0.232 | 0.253 | 0.393** | -0.107 | -0.801** | -0.539** | 0.182 | 0.518** |
| PL  | 1.000   | 0.289** | -0.061 | 0.230 | 0.289* | 0.309* | 0.057 | 0.134 | -0.158 | -0.416** | -0.508** | 0.183 | 0.280*  |
| PT  | 1.000   | -0.036 | -0.137 | 0.081 | 0.192 | 0.242 | -0.219 | 0.196 | -0.267 | -0.461** | 0.402** | 0.081  |
| RL  | 1.000   | -0.239 | -0.185 | -0.115 | -0.262 | -0.240 | 0.242 | 0.591** | 0.090 | 0.016 | -0.185  |
| RD  | 1.000   | 0.237 | 0.513** | 0.108 | 0.290* | -0.315* | -0.054 | -0.115 | -0.291* | 0.236  |
| RW  | 1.000   | 0.514** | 0.301* | 0.424** | -0.258 | -0.506** | -0.114 | -0.067 | 0.998** |
| CD  | 1.000   | 0.124 | 0.208 | -0.194 | -0.327* | -0.359* | 0.004 | 0.514** |
| CT  | 1.000   | 0.312* | -0.381** | -0.316* | -0.108 | 0.042 | 0.301*  |
| CTT | 1.000   | -0.365** | -0.416** | -0.045 | -0.086 | 0.424** |
| DRH | 1.000   | 0.229 | -0.090 | 0.405** | -0.258  |
| RTLR| 1.000   | 0.570** | -0.155 | -0.506** |
| CC  | 1.000   | -0.313* | -0.114  |
| TSS | 1.000   | -0.067  |
| TY/ha | 1.000  |       |        |        |        |        |        |        |        |        |        |        |        |        |        |       |

Critical $r_p$ value = 0.278 at 5 per cent and 0.361 at 1 per cent. * and ** indicate significant at 5 and 1 per cent probability level, respectively.

- **PHS** – Plant height at 60 DAS (cm)
- **PHH** – Plant height at harvest (cm)
- **NL** – Number of leaves/plant
- **LL** – Leaf length (cm)
- **PL** – Petiole length (cm)
- **PT** – Petiole thickness (mm)
- **RL** – Root length (cm)
- **RD** – Root diameter (cm)
- **RW** – Root weight (g)
- **CD** – Core diameter (mm)
- **CT** – Core thickness (mm)
- **Ctt** – Cortex thickness (mm)
- **DRH** – Days to first root harvest
- **RTLR** – Root /top length ratio
- **CC** – β-carotene content (µg/100 g)
- **TSS** – Total soluble solids (*ºBrix*)
- **TY/ha** – Total yield/hectare (t)
Leaf length exhibited positive and significant association with number of leaves/plant. Negative significant association was observed for this parameter with root/top length ratio and β-carotene content at both genotypic and phenotypic level. Petiole thickness, petiole length and TSS expressed positive significant association, whereas root diameter expressed negative significant association with this trait only at genotypic level. The findings were similar to other studies of Panwar et al., (2003), Mallikarjunarao et al., (2015) and Kaur et al., (2017).

Leaf length showed positive significant correlation with petiole length, root weight, cortex thickness, and total yield/ha. Negative significant association was found with root/top length ratio and β-carotene content at both genotypic and phenotypic level.

Petiole thickness and core thickness showed positive significant correlation at genotypic level only with this trait. Earlier, these findings were reported by Chakraborty et al., (2016), Mallikarjunarao et al., (2015) and Kaur et al., (2017).

Positive significant association was exhibited by petiole thickness, core diameter, root weight and total yield/ha for petiole length. β-carotene content and root/top length ratio had negative significant association with this parameter at both genotypic and phenotypic level. Similar results were reported by the earlier studies of Chakraborty et al., (2016).

Positive significant relationship was exhibited for petiole thickness with TSS. It was negatively and significantly associated with β-carotene content at both genotypic and phenotypic level. Days to first root harvest exhibited positive significant relationship, while root diameter and root/top length ratio showed negative significant association with this character at only genotypic level.

Root length showed positive significant correlation with root/top length ratio at both genotypic and phenotypic level. Days to first root harvest expressed positive significant correlation, whereas it had negative significant correlation with root diameter, root weight, core thickness, cortex thickness and total yield/ha only at genotypic level with this trait.

Positive significant association was exhibited for root diameter with core diameter and cortex thickness. Negative and significant correlation was found with days to first root harvest and TSS at both genotypic and phenotypic level. Core thickness showed positive significant correlation with this at genotypic level only.

Root weight had positive and significant relationship with core diameter, core thickness, cortex thickness and total yield/ha. Negative significant association was found for root/top length ratio and days to first root harvest at both genotypic and phenotypic level. These results were in close harmony with the findings of Panwar et al., (2003), Chakraborty et al., (2016), Mallikarjunarao et al., (2015) and Kaur et al., (2017).

Core diameter exhibited positive significant association with total yield/ha. Negative and significant association was found with β-carotene content and root/top length ratio with this character at both genotypic and phenotypic level. Core thickness expressed positive significant correlation for cortex thickness and total yield/ha. Days to first root harvest and root/top length ratio had negative significant association with this trait at both genotypic and phenotypic level.

Core thickness showed positive significant correlation with total yield/ha, while it was negatively and significantly correlated with root/top length ratio and days to first root harvest.

Positive and significant association was found for cortex thickness with total yield/ha, while it was negatively and significantly correlated with root/top length ratio and days to first root harvest.
harvest at both genotypic and phenotypic level. Positive significant relationship was exhibited between days to first root harvest and TSS at both genotypic and phenotypic level. Root/top length ratio showed positive significant correlation, whereas negatively and significantly associated with total yield/ha at only genotypic level.

Root/top length ratio was positively and significantly correlated with β-carotene content, while negatively and significantly associated with total yield/ha. β-carotene content was negatively and significantly associated with TSS at both genotypic and phenotypic level.

Therefore, selection of parameters that are positively associated with yield helps in crop improvement by enhancing the yield of the genotypes. Selection with greater efficiency was practiced through these positively correlated traits on yield. Negatively related traits with yield influence other parameters that are positively correlated with yield factor.

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