




# Correlation coefficient analyses of horticultural characteristics of carrot genotypes (*Daucus carota* L.) in Southeastern Nigeria

 **Chizaram-Ndubuaku Chiamaka Adaeze<sup>1\*</sup>**  
**Baiyeri, Kayode Paul<sup>2</sup>**

<sup>1,2</sup>Department of Crop Science, University of Nigeria, Nsukka, Nigeria.

<sup>1</sup>Email: [chiamakachizaram@gmail.com](mailto:chiamakachizaram@gmail.com)

<sup>2</sup>Email: [paul.baiyeri@gmail.com](mailto:paul.baiyeri@gmail.com)



(+ Corresponding author)

## ABSTRACT

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A field experiment was conducted in 2018 and repeated in 2019 cropping season at the teaching and research farm of Crop Science, University of Nigeria, Nsukka to evaluate the horticultural characteristics of three genotypes of carrot. The experiment was a 3 x 5 split-plot laid out in a Randomized Complete Block Design and replicated four times. The treatments were three carrot genotypes (Safety Touchon France, Carotte Touchon AM and Carotte Touchon ETS) treated with organic and inorganic fertilizer combinations. The data collection and statistical analysis focused on key traits such as the number of harvested roots (NHR), root uniformity (RU), number of sorting groups (NSG), number of marketable roots (NMR), harvest index (HI), Root yield (RY) and whole plant biomass yield (WPBY). Results of the analysis of variance showed non-significant varietal effect for all characters in both years of study. Results of the correlation analysis indicated highly positive correlations between number of harvested roots and root uniformity (0.993) in 2018 and (0.729) in 2019, respectively. Root yield per plot exhibited similar positive correlations with NHR, RU, NMR, HI, FW, and WPBY during the two cropping seasons. Conversely, significant negative correlations were observed between number of sorting groups and number of harvested roots (-0.997) and number of marketable roots (-0.976). The harvest index showed highly negative relationships with NHR (-0.757) and percent marketable yield (-0.994). The principal component analysis (PCA) identified foliage weight, whole plant biomass yield and number of marketable roots as the major contributors of variation in both years.

**Contribution/Originality:** This study is one of very few studies which uniquely compare three carrot genotypes across organic–inorganic fertilizer over two seasons, linking yield, root quality, and PCA-identified traits to reveal consistent trait correlations and variation drivers. Understanding of relationships among horticultural traits can guide resource maximization in carrot production.

## 1. INTRODUCTION

Carrot is a root vegetable in the family Apiaceae, valued for its nutritional benefits and sensory qualities, and is among the top ten economically significant vegetable crops based on global production and market value [1-3]. In the largest carrot-growing countries, yields can range from 30 to 100 tonnes per hectare with Asia as the leading continent for carrot production followed by Europe, North America and Africa [4].

Djoufack et al. [5] reported that among West African countries, Morocco is the leading producer of carrots, having the highest yields, which can reach approximately 32.38 tons per hectare. Morocco's position as a significant player in the African carrot market is largely due to its well-developed farming practices and favorable growing

conditions [5]. In contrast, other countries in the region, such as Nigeria, Cameroon, Senegal, and Ghana, experience lower yields from 10 to 25 tons per hectare, due to various challenges including ecological factors, availability of resources and pest and disease prevalence [5, 6]. It has been equally observed that carrot production in the southeastern Nigeria has low yield relative to carrot production in the Northern regions of the country and it is due to genetic diversity, environmental conditions, and cultivation practices [7].

Growth and yield response of carrot is highly influenced by fertilizers, varieties and other environmental variations [3, 7, 8]. Root yield of carrot is the key quantitative trait affecting the economic value in carrot production hence, an observation into the association of traits related to yield is required [3, 8]. In carrot production, growth and yield are associated with root weight, foliage weight, harvest index, whole plant biomass yield, and metric traits of the roots [5-7]. Therefore, maximizing yield in carrot production and obtaining cultivars that will adapt to the southeastern region of Nigeria involves a holistic approach considering environmental conditions, cultivation practices and management strategies [7, 9, 10].

Correlation is a statistical measure that depicts the degree to which different traits in carrot genotypes are interdependent [11]. The overall yield and quality of carrot can be influenced by identifying which traits are positively and negatively correlated [11]. The attributes of carrot such as root biomass and uniformity often relate to marketability and consumer preference, and correlation helps in predicting outcomes and guiding cultivation practices such as fertilizer use, irrigation strategies, and pest and disease management [5, 8]. Furthermore, several studies imply that soil and climatic conditions can significantly impact these traits, leading to variations in performance across diverse growing seasons [5, 8]. The use of principal component analysis (PCA) offers deep understanding of the interactions among factors that influence variation in carrot performance [3]. Consequently, the study evaluates the association of carrot growth and yield-related characteristics among three genotypes grown in Nsukka, southeastern Nigeria.

## 2. MATERIALS AND METHODS

The field experiments were conducted during the 2018 and 2019 cropping seasons at the teaching and research farm of Crop Science, University of Nigeria, Nsukka. Nsukka lies in the derived savanna zone at latitude 06°52'N and longitude 07°24'E, with an altitude of 447.26 m above sea level. The area had total rainfall of 1,614.81 mm and 1,384.29 mm for the years 2018 and 2019, respectively. For temperature range, the mean values recorded for minimum and maximum temperatures were 21.49°C and 29.14°C for 2018, and 21.61°C to 24.35°C for 2019. Relative humidity of 48.18% and 52.85% was recorded as the mean value for the months in 2018 and 2019, respectively. The soil of the experimental site is a sandy clay loam with pH 3.8–4.7.

A field area of 50m x 25m was ploughed, harrowed and ridged. The field was divided into 3.0m x 1.5m plots and ridges of 1.5m long with spacing of 1m x 50cm. The appropriate rate of organic manures was thoroughly mixed with the soil in each ridge. Planting of carrot seeds were done two weeks after organic manure application. The experiment was a 3 x 5 Split plot laid out in a Randomized Complete Block Design and replicated four times. The treatments were three carrot genotypes (Safety Touchon France, Carotte Touchon AM and Carotte Touchon ETS) sourced from seed companies in Jos Plateau State and Five (5) Fertilizer rates. Data were collected on the following growth and yield parameters; Number of harvested roots, Root yield, Whole Plant biomass yield, Percent marketable yield from total harvested yield, Root uniformity, Harvest index on fresh weight basis and Total marketable yield. Data collected were subjected to analysis of variance (ANOVA) while means separation was carried out using Least Significant Difference (LSD) by GENSTAT Discovery Edition 3, Release 7.2 DE [12]. Principal Component Analysis (PCA) and correlation analyses were performed for growth and yield components using SPSS Release 16.0.0 [13].

### 3. RESULTS

#### 3.1. Yield Performance

Table 1 presents the performance of different carrot genotypes grown in Nsukka during the 2018 and 2019 cropping seasons. There were a non-significant ( $p > 0.05$ ) differences among the horticultural traits across the genotypes evaluated. The genotypes exhibited similar values in number of harvested roots (NHR) in both years where Safety Touchon France had the highest NHR values in both years, Root Uniformity (RU) values were relatively consistent across genotypes and years, ranging from 2.4 to 3.1. NSG was highest in 2018 for Carotte Touchon ETS (9.1) and lowest for Safety Touchon France (7.8). Safety Touchon France recorded the highest value for number of marketable roots (33.8) in both years. Carotte Touchon AM obtained the highest harvest index (HI) (57.4% and 66%) in 2018 and 2019, respectively. Percent Marketable Yield (%MY): The percentage of marketable yield was constant, with Carotte Touchon AM having the highest values in both years (57.4% in 2018 and 66% in 2019). Root Yield per Plot (RYP) showed a notable increase in 2019 compared to 2018 for all genotypes, with Safety Touchon France leading in both years. Whole Plant Biomass Yield (WPBY) values were higher in 2019, with Safety Touchon France obtaining 1.1 kg/plot.

#### 3.2. Principal Component Analysis (PCA) for Year 2018

The results of Principal Component Analysis (PCA) in Table 2 revealed the extent to which various carrot yield characters contributed to total variation for the year 2018.

**Table 1.** Performance of Carrot genotypes grown in Nsukka during 2018 and 2019 cropping seasons.

Effects	NHR	RU	NSG	NMR	HI (%)	%MY	FW kg/plot	RYP (kg/plot)	RYH (t/ha)	WPBYP (kg/plot)	WPBYH (t/ha)
2018 Cropping Season											
Genotypes											
Safety Touchon France	36	2.9	7.8	29.5	57.1	84.4	0.9	1.3	3.0	2.2	4.8
Carotte Touchon AM	34.8	2.8	8.1	30.7	57.4	88.3	0.9	1.3	3.1	2.2	4.7
Carotte Touchon ETS	32.1	2.4	9.1	27.6	56.6	86.1	0.9	1.3	3.0	2.2	4.9
LSD <sub>(0.05)</sub>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2019 Cropping Season											
Genotypes											
Safety Touchon France	36.1	2.6	9.9	33.8	61.2	93.5	1.1	1.7	3.8	2.8	6.1
Carotte Touchon AM	35.3	2.7	10	33.2	66	93.2	0.8	1.6	3.6	2.4	5.4
Carotte Touchon ETS	35.4	3.1	8.7	32.3	62.3	91.4	1.0	1.7	3.9	2.7	5.9
LSD <sub>(0.05)</sub>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Note:** NHR: Number of harvested roots, RU: Root uniformity, NSG: Number of sorting Group, NMR: Number of marketable roots, HI: Harvest Index, MY: percent marketable yield, WPBYP: Whole plant biomass yield per plot, WPBYH: Whole plant biomass yield per hectare, RYP: Root yield per plot, RYH: Root yield per hectare. NS: Not Significant.

**Table 2.** Principal component analysis showing the percentage contribution of carrot yield characters to total variation for year 2018.

Variable	PC1	PC2
Number of Harvested Roots	0.945	0.327
Root Uniformity	0.901	0.433
Number of Sorting Group	-0.915	-0.404
Number of Marketable Roots	0.513	0.858
Harvest Index (%)	0.525	0.851
Percent Marketable Yield	-0.535	0.845
Foliage Weight (kg/plot)	0.976	-0.217
Root Yield per plot (kg/plot)	0.398	0.917
Root Yield per hectare (t/ha)	-0.114	0.993
Whole Plant Biomass Yield (kg/plot)	0.993	0.114
Whole Plant Biomass Yield per hectare (t/ha)	-0.398	-0.917
<b>Proportion (%)</b>	51.24	48.76
<b>Cumulative (%)</b>	51.24	100.00

PC1 and PC2 showed 51.24% and 48.76% respectively of the total variation that was present in the horticultural characters of the genotypes, while both components explained 100% of the variance obtained. Foliage Weight (0.976) and Whole Plant Biomass Yield (0.993), Number of Harvested Roots (0.945) and Root Uniformity (0.901) contributed significantly and positively to PC1. In PC2, Root Yield per Plot (0.917), Number of Marketable Roots (0.858), and Harvest Index (0.851) contributed positively for the variation in carrot yield performance.

### 3.3. Principal Component Analysis (PCA) for Year 2019

The Principal Component Analysis (PCA) results shown in Table 3 for the year 2019 revealed that Foliage Weight (0.976), Whole Plant Biomass Yield (0.993), Number of Harvested Roots (0.945) and Root Uniformity (0.901) remained the major traits influencing carrot yield variation in 2019. In PC2, Root Yield per Plot (0.917), Number of Marketable Roots (0.858), Harvest Index (0.851), Number of Sorting Groups (-0.915) and Whole Plant Biomass Yield per Hectare (-0.917) were the most varied directly and inversely.

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Root Yield per hectare (t/ha)	-0.114	0.993
Whole Plant Biomass Yield (kg/plot)	0.993	0.114
Whole Plant Biomass Yield per hectare (t/ha)	-0.398	-0.917
<b>Proportion (%)</b>	57.68	42.32
<b>Cumulative (%)</b>	57.68	100.00

### 3.4. The Correlation Coefficient Matrix of Horticultural Characters for Years 2018 and 2019

The correlation coefficient matrix of horticultural characters of carrot studied in 2018 and 2019 are shown in Tables 3 and 4. The results revealed that RY (Per plot and Hectare) had a highly Positive correlation with NMR, FW, and WPBY (Per Plot and Hectare). HI (%) and WPBYP have significant positive correlation with each other. RY (Per Plot and Hectare) was significantly and negatively correlated with WPBYPH, NSG, FW in 2018 and NMR, HI, FW and % MY in 2019.

**Table 4.** Correlation matrix of some horticultural characters of carrot genotypes evaluated at Nsukka in 2018.

Horticultural characters	NHR	RU	NSG	NMR	HI (%)	%MY	FW (kg/plot)	RYP (kg/plot)	RYH (t/ha)	WPBYP (kg/plot)	WPBYH (t/ha)
NHR	1	0.993	-0.997	0.765	0.774	-0.229	0.851	0.676	0.217	0.954	-0.676
RU		1	-0.999*	0.834	0.842	-0.116	0.786	0.756	0.327	0.982	-0.756
NSG			1	-0.816	-0.824	0.148	-0.805	-0.735	-0.297	-0.975	0.735
NMR				1	1.000**	0.451	0.314	0.992	0.794	0.923	-0.992
HI (%)					1	0.439	0.327	0.990	0.786	0.929	-0.990
%MY						1	-0.706	0.563	0.901	0.074	-0.563
FW (kg/plot)							1	0.189	-0.327	0.655	-0.189
RYP (kg/plot)								1	0.866	0.866	-1.000**
RYH (t/ha)									1	0.500	-0.866
WPBYP (kg/plot)										1	-0.866
H (t/ha)											1

**Note:** \*. Correlation is significant at the 0.05 level (2-tailed).

\*\*\*. Correlation is significant at the 0.01 level (2-tailed).

NHR: Number of harvested roots, RU: Root uniformity, NSG: Number of sorting Group, NMR: Number of marketable roots, HI: Harvest Index, MY: percent marketable yield, FW: Foliage weight, WPBYP: Whole plant biomass yield per plot, WPBYH: Whole plant biomass yield per hectare, RYP: Root yield per plot, RYH: Root yield per hectare. NS: Not Significant.

**Table 5.** Linear Correlation coefficients of some horticultural characters of carrot genotypes evaluated at Nsukka in 2019.

Horticultural characters	NHR	RU	NSG	NMR	HI (%)	%MY	FW (kg/plot)	RYP (kg/plot)	RYH (t/ha)	WPBYP (kg/plot)	WPBYH (t/ha)
NHR	1	-0.564	0.333	0.729	-0.757	0.515	0.826	0.596	0.300	0.771	0.795
RU		1	-0.967	-0.976	-0.113	-0.998*	0.000	0.327	0.619	0.091	0.052
NSG			1	0.888	0.364	0.98	-0.256	-0.559	-0.799	-0.343	-0.307
NMR				1	-0.105	0.962	0.217	-0.115	-0.434	0.127	0.165
HI (%)					1	0.17	-0.994	-0.976	-0.85	-1.000*	-0.998*
%MY						1	-0.058	-0.381	-0.663	-0.148	-0.110
FW (kg/plot)							1	0.945	0.786	0.996	0.999*
RYP (kg/plot)								1	0.945	0.971	0.961
RYH (t/ha)									1	0.839	0.817
WPBYP (kg/plot)										1	0.999*
WPBYH (t/ha)											1

**Note:** \*. Correlation is significant at the 0.05 level (2-tailed).

NHR: Number of harvested roots, RU: Root uniformity, NSG: Number of sorting Group, NMR: Number of marketable roots, HI: Harvest Index, MY: percent marketable yield, FW: Foliage weight, WPBYP: Whole plant biomass yield per plot, WPBYH: Whole plant biomass yield per hectare, RYP: Root yield per plot, RYH: Root yield per hectare. NS: Not Significant.

#### 4. DISCUSSION

Non-significant ( $p > 0.05$ ) varietal effect was observed among the three genotypes across the traits. However, there were slight variations in the overall performance trends of the observed parameters across genotypes. The slight differences among the genotypes in traits like harvest index, fresh root yield, whole plant biomass, yield per hectare, and yield per ridge may be attributed to their genetic differences which validate the reports made by Kaack, et al. [14] and Gajewski, et al. [15] who reported that productivity and quality parameters of carrot root yield depend on cultivar-specificity, climate, soil, and agronomic factors.

Yield performance in carrot genotypes is influenced by several factors, including genetic traits and environmental conditions because these factors may define the cause of variation in the competitive ability among individuals within a plant community which may be a consequence of genetic variability [3, 5, 6, 9, 10]. Overall, the performance of carrot genotypes improved from 2018 to 2019, particularly in marketable traits and yields. Despite the similarities in the genotypes, Safety Touchon France consistently outperformed the other genotypes in several parameters studied, notably in NHR and NMR for both years and WPBYH in 2019, suggesting it may be the most suitable genotype for cultivation in Nsukka.

The results of the correlation coefficient analyses among the horticultural characteristics of carrot genotypes revealed the relationships in carrot yield performance and interdependencies of the variables. The result showed the strong positive correlations between the number of harvested roots (NHR) and root uniformity (RU) are consistent with the previous findings by Zhang, et al. [16] which emphasize that better cultivation practices enhance root consistency and marketability [5, 17]. Consistent uniformity of carrot roots often attracts better prices in commercial markets, stressing the economic significance of these traits [5].

The negative correlations observed, particularly among some of the parameter such as the number of sorting groups (NSG), number of harvested roots (NHR) and the number of marketable roots (NMR), indicating that increased uniformity can reduce the variability of sorting, which may affect marketability. Also meaning that uniformity of roots is advantageous and can also limit the diversity of marketable produce. Harvest Index was also positively correlated with Root Yield per plot indicating that a higher harvest index is associated with increased root yield per plot. Whole Plant Biomass Yield per Plot also correlated positively with Harvest index emphasizing that a good harvest index is linked to higher biomass yield, hence the effectiveness of their association in selection for higher productivity in carrot [16-18]. This indicates that increased Whole Plant Biomass Yield could invariably increase harvest index hence marketable yield of the roots [18].

Principal Component Analysis (PCA) showed that the main determinants contributing to variation in yield performance were whole plant biomass, root yield and number of marketable roots and can be used for varietal discrimination and establishing cultivation strategies [3]. The variations in PCA results across different years further emphasize the influence of environmental conditions and genetic diversity on trait performance [3]. The results give emphasis to the importance of optimizing both biomass production and marketable traits to enhance overall carrot yield and quality.

#### 5. CONCLUSION

From the experiment, it could be concluded that the yield performance of three carrot genotypes, the association among traits, and the extent of variation observed were influenced by genetic variability, environmental conditions, and agronomic practices adopted. However, with slight variation, Safety Touchon France is recommended as it consistently outperformed the other genotypes in biomass yield and marketable root yield. Therefore, in selecting varieties for carrot production in southeastern Nigeria, these horticultural yield characters should be given attention for productive cultivation.

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