Genetic Variabilities and Association of Component Characters for Some Varieties of Carrot (Daucus Carota L.) in the Forestsavannah Transition Zone, Ekpoma, Edo State Nigeria

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Research Article

Keywords:

Posted Date: November 11th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7895684/v1

Additional Declarations: No competing interests reported.

Abstract

The genetic variability and association of component characters for some carrot varieties (*Daucus carota* L.) were conducted at the Teaching and Research Farm, Ambrose Alli University, Emaudo Anex, Ekpoma. The experiment was a Randomized Complete Block Design (RCBD) with 4 Replicates. Results showed that Nantes 2 castle had the highest plant height at 4 WAP, while at 8 and 12 WAP, Thema had the highest. Bakers brother had the highest number of leaves per plant at 4 WAP, while Thema had the highest at 8 and 12 WAP. Baker's brother had the biggest Stem girth, 16 WAP. Thema had the highest root length, diameter, and yield at 16 WAP. Root diameter is positively correlated with root yield. High heritability and genetic gain were observed for plant height and number of leaves per plant at 4, 8, and 12 WAP. Regarding stem girth, High heritability and Genetic gain were observed at 16 WAP (Ho 94.38%, GG 122.01). Moreso, High heritability and genetic gain were observed for root length, root diameter, and root yield at 16 WAP (Ho 94.80%, 91.99% and 84.51%) and (GG 21.15%, 49.35% and 33.98%). A high value of heritability and genetic gain resulted from the additive gene effect. Characters with low heritability and genetic gain were a result of non-additive gene effects; thus, characters cannot be easily improved upon, hence cannot be used as a basis of selection. Thus, Thema with a higher yield attribute is recommended for farmers in this locality.

INTRODUCTION

Genetic variability forms the foundation of any successful crop improvement program, as it provides the essential genetic pool for the selection and breeding of superior varieties. In carrot (*Daucus carota L.*), a globally significant root vegetable, there exists considerable variability in key traits such as root length, diameter, shape, color, dry matter content, and yield per plant (Mou, 2017). This genetic diversity is a critical resource for developing improved cultivars with enhanced yield, quality, and adaptability to varying environmental conditions. Carrots are valued for their high beta-carotene content, antioxidants, and dietary fiber, making them an important component in addressing food and nutritional security globally (Simon et al., 2020).

Recent advancements in carrot breeding have demonstrated the importance of association analysis in understanding how different component characters contribute to yield and quality. Root yield in carrots, a complex and multi-trait characteristic, is influenced by numerous factors, making direct selection for yield alone challenging. Studies have shown that traits such as root length, diameter, and foliage biomass are strongly correlated with root yield, while undesirable traits like bolting tendency and root cracking negatively affect performance (Abebe et al., 2021). Path coefficient analysis has further elucidated the direct and indirect effects of these traits, offering valuable insights for breeders to prioritize the most influential parameters in their selection process for high-yielding varieties (Hafız et al., 2018).

Recent studies on carrot accessions worldwide have revealed significant genetic variability among both open-pollinated landraces and improved varieties. These studies show diverse expressions of yield and quality traits, further highlighting the potential for genetic improvement in carrot breeding programs (Iorizzo et al., 2016). Furthermore, a growing body of research has highlighted the significance of carrot cultivation in diverse agro-ecological zones, especially in regions with varying soil fertility, rainfall patterns, and temperature conditions, which influence trait expression (Iorizzo et al., 2021). In Africa, including Nigeria, while studies on carrot genetic variability are still emerging, there is increasing recognition of its potential to contribute to improved agricultural and nutritional outcomes.

In Africa, including Nigeria, research on carrot genetic variability remains limited compared to cereals and legumes, despite its growing economic and nutritional importance (Bamire & Manyong, 2003). Carrots are increasingly cultivated in the forest–savanna transition zone, where variations in soil fertility, temperature, and rainfall patterns significantly influence trait expression (Osunleti & Lagoke, 2024). Therefore, evaluating carrot varieties under local agro-ecological conditions is necessary to identify genotypes that combine high root yield with desirable quality attributes while adapting to prevailing climatic challenges (Adigun et al., 2018).

In the forest–savanna transition zone of Ekpoma, Edo State, carrot production is gaining attention among smallholder farmers due to increasing market demand and dietary awareness (Adavbiele et al., 2024). However, limited research has been conducted to assess the genetic variability and association of component characters of carrot in this zone (Adavbiele et al., 2024). Recent studies have highlighted the importance of understanding the genetic diversity of crops in this region to enhance agricultural productivity and sustainability (Bamire & Manyong, 2003; Adigun et al., 2018).

Understanding these relationships will provide valuable information for developing improved varieties that are locally adapted, high-yielding, and nutritionally rich. Such efforts will enhance food and income security and strengthen Nigeria's capacity to diversify its horticultural production base and compete in local and international vegetable markets (FAO, 2023; Anyanwu et al., 2021).

The overall aim of this study is to evaluate the genetic variability and association of component characters among four carrot (Daucus carota L.) varieties, namely Nantes 2 'Castle', Nantes Improved, Thema, and Bakers Brother, in the forest–savannah transition zone of Ekpoma, Edo State, Nigeria. Specifically, the study seeks to: i. assess the extent of genetic variation among the varieties, ii. identify the genetic factors associated with high yield, iii. determine the most promising high-yielding varieties, and iv. identify characters with improvement potential for selection in future breeding programs.

MATERIALS AND METHODS

Experimental Location

The experiment was conducted at the Teaching and Research Farm, Emaudo Annex, Faculty of Agriculture, Ambrose Alli University, Ekpoma, Edo State, Nigeria, situated at latitude 6°45'N and longitude 6°08'E. The study area falls within the forest–savannah transition zone with an average annual temperature of 29°C, relative humidity of about 70%, and mean annual rainfall ranging between 1200 mm and 1500 mm.

Experimental Materials

Four carrot (*Daucus carota* L.) varieties, namely Nantes 2 'Castle', Nantes Improved, Thema, and Bakers Brother, were evaluated in this study. The seeds of these varieties were procured from Certy Agroallied Store, Ibadan, Oyo State, Nigeria, and used as planting materials.

Experimental Design

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The site was manually cleared by slashing the weeds, and the debris was removed from the field. The experimental area measured 7.2 m × 7.2 m (51.84 m^2 or 0.005184 ha), which was demarcated into 16 plots, each with a plot size of 1.8 m × 1.8 m. Planting was done at a spacing of 30 cm × 30 cm, with a discard of 60 cm between and within the rows, resulting in a plant population of approximately 81,000 plants per hectare. A pinch of carrot seeds was planted per hole, and weeding was manually carried out using a hoe at the third, seventh, and eleventh weeks after planting (WAP).

Data Collection

Plant growth and yield-related data were collected using standard procedures. Plant height was measured with a meter rule at 4, 8, and 12 WAP from four randomly selected plants per plot, from the ground level to the apex, and the mean recorded. The number of leaves per plant was determined by counting the leaves of four randomly sampled plants per plot at the same growth intervals, with the average recorded. Stem girth was measured on four plants per plot using a Vernier caliper, and mean values were documented. Root length was measured in centimeters using a measuring tape from four randomly selected roots per plot, and root diameter was recorded using a Vernier caliper to determine the broadest part of the roots. Root yield was estimated by weighing the roots from four randomly selected plants per plot using a sensitive digital scale and was extrapolated to tonnes per hectare (t/ha).

Data Analysis

Data obtained from the field experiment were subjected to analysis of variance (ANOVA), and treatment means were separated using the Least Significant Difference (LSD) test at a 5% probability level.

Genetic Analysis

Genetic parameters were estimated using agronomic and yield traits based on genotypic and phenotypic expressions. The treatment mean square values were considered as phenotypic variance, while genotypic variance was obtained by subtracting error mean square values from their corresponding phenotypic variance. The methods of Sylvester (1998) and Allard (1999) were employed to calculate the genetic parameters, including heritability and genetic gain.

Table 1
Plant height (cm) of carrot at 4, 8 and 12 weeks after planting

Variety	Weeks after planting		
	4	8	12
Bakers Brother	15.7^{b}	25.4^{b}	28.35^{b}
Thema	27.02^{a}	34.52^{a}	48.65^{a}
Nantes improved	16.07^{b}	21.79^{c}	30.41^{b}
Nantes 2 castle	16.27^{b}	19.85^{c}	31.15^{b}
LSD (P < 0.05)	3.41	3.49	3.1

All the figures within a column with the same alphabet are not significantly different (P ≤ 0.05)

LSD: Least Significant Difference.

Table 2
Number of leaves/plant of carrot at 4, 8 and 12 weeks after planting

Variety	Weeks after planting		
	4	8	12
Bakers Brother	8.31^{a}	11^{b}	15.19^{b}
Thema	5.19^{b}	18.31^{a}	27.19^{a}
Nantes improved	5.9^{b}	10.19^{b}	13.06^{b}
Nantes 2 castle	5.38^{b}	10.06^{b}	13.94^{b}
LSD (P < 0.05)	1.33	1.43	6.73

All the figures within a column with the same alphabet are not significantly different (P ≤ 0.05)

LSD: Least Significant Difference.

Table 3
Stem girth of carrot at 16 weeks after planting and yield

Variety	Stem girth (cm)	length of roots (cm)	Root diameter (cm)	Root yield (t/ha)
Bakers Brother	2.35[a]	13.9[b]	2.50[b]	4.675[b]
Thema	1.54[b]	26.65[a]	6.52[a]	7.272[a]
Nantes improved	1.28[b]	13.15[b]	3.65[b]	4.865[b]
Nantes 2 castle	1.20[b]	16.28[b]	2.66[b]	3.66[b]
LSD ($P < 0.05$)	0.4	4.56	1.69	1.93

All the figures within a column with the same alphabet are not significantly different ($P \leq 0.05$)

LSD: Least Significant Difference.

Table 4
Correlation co-efficient among different characters in carrot

	Plant height	No. of leaves/plant	Stem girth	Root length	Root diameter	Root yield
Plant height		0.847ns	0.851ns	0.897ns	0.875ns	0.695ns
No. of leaves			0.667	0.729	0.709	0.747ns
Stem girth				0.694	0.801	0.688ns
Root length					0.785	0.624ns
Root diameter						0.622*
Root yield						
*: Significant at 5% level of probability; ns: not significant						

Table 5
Genetic analysis of vegetative and yield characters for some varieties of carrot

Characters	Weeks after planting	PCV (Phenotypic Variance)	GCV (Genotypic Character Variation)	Ho (%) (Heritability)	GA (Genetic Advance)	GG (Genetic Gain)
Plant Height	4	121.35	116.8	96.25	1.98	10.55
	8	169.19	164.44	97.17	2.00	7.88
No. of Leaves	12	354.39	350.63	98.94	2.04	5.89
Stem	4	8.34	7.65	91.72	1.89	30.53
Girth	8	63.04	62.23	98.73	2.03	16.38
Root Length	12	175.31	15.59	89.89	1.85	10.69
	16	1.10	1.04	94.38	1.94	122.01
Root Diameter	16	156.23	148.11	94.80	1.95	21.15
Root Weight	16	13.91	12.79	91.99	1.89	49.3533.98
	16	9.37	7.92	84.51	1.74	

*.: PCV = Phenotypic Variance, GCV = Genotypic Character Variation, Ho = Heritability,

GA = Genetic Advance, GG = Genetic Gain

RESULTS AND DISCUSSION

Results revealed that Thema was significantly different from Bakers Brother, Nantes 2 Castle, and Nantes Improved at 4, 8, and 12 weeks after planting (WAP). However, plant height did not differ significantly among Bakers Brother, Nantes Improved, and Nantes 2 Castle (Table 1). It was further observed that plant height had no significant effect on carrot yield. The variability in plant height across varieties may be attributed to their inherent genetic potential as well as environmental factors such as rainfall and soil nutrient status, as also reported by Nkansah et al. (2021).

For the number of leaves per plant, Thema was significantly different from Bakers Brother at 4 WAP, but not from Nantes Improved and Nantes 2 Castle at the same growth stage. At both 8 and 12 WAP, however, Thema differed significantly from all varieties (Table 2), indicating stronger growth performance. These differences support the findings of Abdulai et al. (2018), who emphasized that yield stability is often influenced by varietal sensitivity to environmental conditions.

In terms of stem girth, Bakers Brother was significantly different from the other varieties at 16 WAP, whereas there were no significant differences among Thema, Nantes Improved, and Nantes 2 Castle (Table 3). At 16 WAP, Thema exhibited significant differences from the other varieties for root length, root diameter, and root yield. Root diameter showed a positive correlation with root yield, suggesting that improvement in root diameter can directly enhance root yield potential. High heritability (Ho) and high genetic gain (GG) were also observed for plant height and number of leaves at 4, 8, and 12 WAP (Ho values of 96.25%, 97.17%, 98.94%, 91.72%, 98.73%, and 89.89%) with corresponding GG values of 10.55, 7.88, 5.89, 30.53, 16.38, and 10.69. Similarly, high heritability and genetic gain were recorded for stem girth at 16 WAP (Ho = 94.38%, GG = 122.01) as well as for root length, root diameter, and root yield at 16 WAP (Ho values of 94.80%, 91.99%, and 84.51% with GG of 21.15, 49.35, and 33.98, respectively). These results indicate the presence of additive gene effects, which facilitate efficient improvement and selection for these traits.

Recent studies have also highlighted the importance of high heritability and genetic gain in breeding programs. For example, studies by Al-Bashir et al. (2020) and Shrestha et al. (2022) confirmed that high heritability values in carrots can be attributed to additive gene effects, making these traits highly amenable to breeding for improved root yield and quality. Additionally, Soliman et al. (2021) found that traits like root diameter and yield in carrots were significantly affected by environmental factors and the genetic diversity of the varieties, supporting the findings observed in this study.

Conversely, traits with low heritability and genetic gain were influenced by non-additive gene effects, which reduce their potential for genetic improvement and limit their use as selection criteria. As highlighted by Singh et al. (2019) and Chen et al. (2020), non-additive gene effects are often associated with traits that are difficult to improve through conventional breeding methods, underscoring the need for advanced breeding techniques, such as molecular markers and gene editing, to address these challenges in carrot improvement.

CONCLUSION

The study identified the Thema variety as the most superior in terms of root length, diameter, and yield, demonstrating its strong adaptability and productivity potential. Root diameter showed a positive correlation with root yield, underscoring its importance as a key selection trait in breeding programs. High heritability and genetic gain values across most traits indicated the predominance of additive gene effects, suggesting that these traits can be effectively improved through selection. In contrast, traits with low heritability and genetic gain were governed by non-additive gene effects, limiting their breeding potential. Overall, the Thema variety is recommended for cultivation in the study area due to its high yield performance and adaptability. The findings also highlight the feasibility of sustainable carrot production in the forest–savanna transition zone, contributing to local food security and economic diversification.

Declarations

Ethics Approval and Compliance with Regulations:

The field study involving cultivated carrot (Daucus carota L.) complied with institutional, national, and international guidelines and legislation. No endangered or protected plant species were collected or used. The research adhered to the International Union for Conservation of Nature (IUCN) Policy Statement on Research Involving Species at Risk of Extinction and followed best practices for sustainable experimental fieldwork.

Conflicts of Interest:

The authors declare that they have no competing interests that could have affected the conduct or results of this study.

Funding:

This study did not receive any financial support from any agency or institution.

Author Contribution

Akhigbe Endurance and Adavbiele J. Victor contributed equally to the manuscript. Akhigbe Endurance contributed to the study conceptualization, data acquisition, data analysis, and manuscript writing. Adavbiele J. Victor contributed to the study design, data interpretation, and manuscript review. Both authors have read and approved the final manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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