A comparative study of some phenotypic traits of the *Brassica oleracea* L. *var. acephala* plant

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Abstract

An experiment was carried out at the research station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Tikrit, to estimate the genetic traits and correlation among six varieties of Kale (Scarlet kale, Dazzling blue kale, Dwarf siberina kale, Blue Curle D Scotch, Tronchuda kale, Nero di Toscana. It was designed according to the Randomized Complete Block Design (RCBD) design with three replicates for each treatment. The arithmetic means were compared according to Duncan's multiple range test at a significance level of (0.05). The results of the variance analysis showed that the varieties showed highly significant differences in all the studied traits. Hence, the V2 variety excelled in most of the studied traits and showed significant differences from other varieties, recording the highest height of the plant (41.997 cm) and the largest stem diameter (36.361 mm), with the longest and widest leaf (37.667 cm, 10.333 cm), respectively. All traits under study recorded a wide range of genetic and environmental variations. As for High values of genetic and phenotypic variation were observed for stem diameter and leaf length traits, but decreased in other traits. The heritability percentage and expected genetic advance were high in all traits studied. Concerning the correlation among the traits studied, it was highly significant among the plant height, the number of leaves and leaf length, as well as between the number of leaves and leaf length. Also, it was significant between the plant height and the stem diameter; however, it was negatively high significant between the traits of stem diameter and leaf width.

Keywords: correlation , genetic variations, heritability ratio, Kale, phenotypic, ,

Introduction

Kale (*Brassica oleracea* L. var. acephala) is one of the oldest cultivated species of plants of the Brassicaceae family. Its central leaves are green or purple in color. It resembles the wild oleracea more than most domesticated species. This *oleracea* species contains a wide range of vegetables, including broccoli, cauliflower, green cabbage, and Brussels cabbage, which are genetically similar (Ligor & Buszewski, 2012). The word Kale stems from (kale) of Danish, Swedish and Norwegian origins, the German word (khal), and the Welsh Scottish word (cal or kall) (Mihai *et al.*, 2021).

Kale is harvested throughout the autumn and winter seasons. The bright and vibrant color of the kale leaves is due to the pigment found in this plant, which is chlorophyll and carotenoid (Choudhury, 2022). Kale is considered a vegetable with high nutritional value, and has strong antioxidant properties and is anti-inflammatory. Kale contains a very high concentration of vitamins K and C, lutein, and zeaxanthin, in addition to beta-carotene (Elżbieta *et al.*, 2008). Kale is a valuable vegetable due to its richness in soluble sugars, proteins, and vitamins, as well as having high levels of bioactive compounds (Yue *et al.*, 2024). Due to its nutritional value, ensuring adequate amounts of cabbage is essential to meet the growing demand for this versatile crop.

In 2022, the Food and Agriculture Organization (FAO) reported that global production of cruciferous crops, including

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kale, amounted to 72,604 tons, representing an increase of 0.876% from the previous year, and a significant increase of 6.53% compared to the previous decade.

Variety selection, lighting conditions, including light quality, intensity and timing and environmental temperatures greatly affect vegetable growth and phytochemical composition. Modern programs in cultivar breeding and summer planting methods have made it possible to produce cabbage throughout the year instead of being limited to the autumn season (Haghighi *et al*., 2025). The kale varieties showed significant differences among themselves in terms of genetic content and origin, as they were classified according to their region of origin into German, Italian, American and Russian varieties (Hahn *et al*., 2022).

All plant breeding programs aim to increase yield and improve quantitative and qualitative properties; however, due to the low rate of quantitative properties heritability and the ineffectiveness of direct selection, indirect selection is preferred to increase yields. In this regard, plant breeders benefit from such methods as correlation, phenotypic traits, and the expected genetic advance during selection by improving their understanding of the inheritance of quantitative properties and yield components (Bashir, 2023).

In 2025, Haghighi *et al*. studied the effect of four kale varieties on growth traits. They showed that the Collard variety excelled in plant height, while the Curled variety excelled in the number of leaves in the spring season. Mishra *et al*. (2022) investigated the effect of variety and planting distance on kale productivity. The maximum height of the plant (36.7 cm), the number of leaves (20.9 cm), the leaf length (32.5 cm), and the leaf width (19.5 cm) were observed in the Pusa Drum Head variety.

Silva *et al*. (2024) studied some phenotypic traits and the correlation among thirty-seven genetic structures of the kale plant. They found that the ratio of broad-sense heritability, which ranged between 0.66 and 0.94, was high for all studied traits except for leaf color. The genetic and environmental variation was high in the number of marketable leaves and leaf weight, while it was average in the total number of leaves. The number of marketable leaves showed a highly significant correlation with the total number of leaves and the number of branches.

In their study of genetic variation, heritability, correlation, and pathway coefficient analysis of 29 genetic structures of kale, Bashir *et al.* (2023) showed that the heritability ratio was high for all seventeen traits studied. They revealed that the genetic correlation coefficient was higher than the phenotypic correlation coefficient in the majority of traits, indicating a strong correlation between the various traits. The total leaves trait showed a positive and statistically significant correlation with leaf length, width, and the number of leaves. This indicates that these traits were the main determinants of the total leaves.

When studying some genetic traits and correlation in the kale plant, Brito *et al*. (2020) used 33 genetic structures. They explained that the analysis of variance showed a high heterogeneity of the traits studied. They also showed that the heritability ratio was high for the traits of the number of leaves, plant height, stem length, plant yield and stem diameter, except for the trait of the number of leaves, in which the heritability ratio was low. They revealed a high correlation among the traits of the number of leaves, leaf productivity and stem diameter.

This study aimed to evaluate kale varieties by estimating some of their phenotypic traits and their correlation within the conditions of Salah al-Din Governorate/ Iraq.

Materials and Methods

Experiment Location and Planting Processes

The experiment was carried out at the research station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Tikrit, during the 2022-2023 autumn agricultural season. The seeds were planted directly in the field with two seeds in each hole on the 7th October, 2022, after preparing the land in terms of tillage, leveling and fertilization. The field area was 18 m long and 6 m wide. It was divided into terraces, with a distance of 30 cm between plants. Each experimental unit included 10 plants. The drip irrigation system was used to irrigate the plant. The field was divided into 3 replicates, each of which included 7 experimental units. The experimental unit length was 3 meters with a width of 80 cm. Each experimental unit contained a planting reciprocal line. The seedlings were planted according to the specified distance. The remaining agricultural processes, including bush removal, irrigation, etc., were carried out to serve the crop as needed (Matloub *et al*., 1989).

Study Factors and Design Used

The seeds of kale (Brassica oleracea L. var. acephala) used in this experiment were obtained from a local supplier. The seeds were exported by a company that sourced them from the American company Baker Creek Heirloom Seeds. The experiment included six kale varieties: V1 Scarlet Kale, V2 Dazzling Blue Kale, V3 Dwarf Siberian Kale, V4 Blue Curled Scotch, V5 Tronchuda Kale, and V6 Nero di Toscana. The varieties were arranged in a Randomized Complete Block Design (RCBD) with three replicates for each treatment, resulting in a total of 18 experimental units (Al-Rawi & Khalafallah, 2000). Prior to planting, the field was prepared using conventional agricultural practices, including plowing, leveling, and soil preparation to ensure uniform conditions for germination and plant growth.

Studied Traits

Throughout the study, the following traits were studied, whose data were taken from 5 plants for each experimental unit, as follows:

Plant height (plant^{-1} cm): At the end of the experiment, a measuring tape was used to record the plant height from the point of stem-soil contact to its highest growing peak, as well as calculating its rate.

Stem diameter (mm): The main stem diameter was measured using the Vernier Caliper at the end of the experiment.

The Number of Leaves (Leaf^{-1}): The total number of plant leaves was calculated at the end of the growing season, as well as calculating their rate.

Leaf Length (cm): At the end of the experiment, the leaf length was recorded for three leaves of different sizes from each plant by using a measuring tape from the leaf-stem contact area to the leaf end, as well as calculating its rate.

Leaf Width (cm): The leaf width was recorded for three leaves of different sizes from each plant at the end of the experiment by using a measuring tape from the widest area of the leaf, as well as calculating its rate.

Percentage of Dry Matter for Vegetative Total

The fresh weight of five leaves of each plant for the experimental unit was calculated and measured using a sensitive scale with three ranks, then dried until the weight was stable (Al-Sahaf, 1989), and then weighed to record the dry weight. The percentage was extracted using the following equation:

$$dry\ matter\ percentage = \frac{dry\ weight}{fresh\ weight} \times 100$$

Statistical and Phenotypic Analysis

The data was statistically analyzed as a one-factor experiment by employing the RCBD design according to the model used by Al-Hamdani and Al-Laila (2017).

Yij = □+ Ri + Tj + eij

where i = 1,2,.... r

j= 1،2،.... t

The components of phenotypic variation (VP) were estimated on the hypothesis that there is no interference between genotype and environmental variation (VGE), according to the following equation:

VP= VG + VE

Where VG= genotype variation and VE= environmental variation

The genotype and environmental variations were measured using the arithmetic mean in the ANOVA tables for the design used in the experiment according to the equation model shown in table 1 (Singh & Ceccarelli, 1996):

Table 1: Heterogeneity analysis according to the RCBD design

Mean of expected square	Mean squares	Total squares	Degrees of freedom	Sources of heterogeneity
$\sigma^2 e + g\theta^2 R$	M3	SSR=$\frac{\sum Y.J^2}{g}$	(r-1)=2	Replicates
$\sigma^2 e + r\theta^2 G$	M2	SSG=$\frac{\sum Yi.^2}{r}$ - $\frac{Y...^2}{rg}$	(g-1)=5	Varieties
$\sigma^2 e + \theta^2 GR$	M1	SSe=SST-SSR-SSG	(r-1)(g-1)=10	Experimental error
		SST=$\sum Yij^2$-$\frac{Y...^2}{rg}$	(sgr-1)=17	Total

Where r = the number of replicates (3), and g = the number of varieties (6)

VG=M2-M1 / R

Where M2 = the mean squares of genetic structures (Varieties), M1 = the mean of the experimental error squares, where VE= M1, R = replicates.

The genetic variation coefficient (GCV) and the phenotypic variation coefficient (PCV) were estimated according to the following equations (Waheeb et al., 2017):

GCV% =(√ □2G/Ỹ) × 100

PCV% =(√□2^2P / Ỹ) × 100

Where Ỹ represents the arithmetic mean of the trait studied.

The degree of broad-sense heritability was estimated according to the equation below (Khattab *et al*., 2023):

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H2(b.s) = VG / VP

The following ranges were used to calculate the degree of heritability as reported by Bahu (1997) and Ali (1999):

More than 0.60 high

0.40-0.60 Medium

Less than 0.40 Low

The expected genetic advance (EGA) was also estimated as shown in the following equation (Kempthorne, 1969):

E.G.A. % = [(K $H^2_{bs}\sqrt{\sigma 2\ P}$) / Ỹ] ×100 .

Where E.G.A. represents theexpected genetic advance, K=2.06 represents selection intensity for 5% of plants (Hill & Mackay, 2004), $H^2_{b.s.}$ represents broad-sense heritability, √σ2 P is the square root of phenotypic variation, Ỹ represents the overall average of the trait.

The limits of expected genetic advance were adopted according to the following ranges (Robinson, 1966):

Less than 10% Low

10 - 30 % Medium

More than 30% high

The correlation between the studied traits was analyzed according to the following equation (Al-Sahoki & Waheeb, 1990):

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{(\sum Xi^2 - (\sum Xi)^2/n)(\sum Yi^2 - (\sum Yi)^2/n)}}$$

The ANOVA table was extracted, and the arithmetic means were compared according to Duncan's multiple range test at a significance level of 5%.

Results and Discussion

Table (2) shows the variance analysis for the studied traits of the kale plant varieties. The results clarified that the values of the mean squares of all traits studied were highly significant at the probability level of 0.01, indicating the extent of genetic differences between the varieties under study.

Table (2) Results of variance analysis for traits studied

Mean square					df	S.O.V
Leaf width	Leaf length	Leaves number	Stem diameter	Plant height		
0.4891	10.875	0.1354	0.0434	20.591	2	Replicates
20.693**	627.95**	54.791**	215.64**	299.52**	5	Varieties
0.461	8.281	1.636	1.976	6.701	10	Experimental error

(**) indicate that the difference is highly significant at the 0.01 level of significance.

Table (3) shows the averages of the studied traits of kale varieties. The results indicated that the varieties differed in terms of significance. Hence, the V2 variety significantly outperformed other varieties in the traits of plant height, stem

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diameter, leaf length, and leaf width, with values of 41.997 cm, 36.361 mm, 37.667 cm and 10.333 cm, respectively. The V3 variety excelled in the trait of number of leaves only, reaching 22.483 leaves^{-1}. While the V4 variety recorded the lowest values in plant height, stem diameter, leaf length and leaf width, with values of 24.720 cm, 11.639, 33.667 and 17.333, respectively. The V5 variety had the lowest values for the trait of number of leaves, reaching 10.000 leaves^{-1}.

Table (3) The effect of kale varieties on the growth traits of the kale plant

Leaf width cm	Leaf length cm	Leaves number plant leaf^{-1}	Stem diameter mm	Plant height cm	Varieties
10.000 e	23.000 e	11.000 c	16.332 E	19.000 e	V1 Scarlet kale
10.333 a	37.667 a	17.810 b	36.361 A	41.997 a	V2 Dazzling blue kale
12.667 c	69.000 c	22.483 a	24.574 C	48.337 c	V3 Dwarf siberina kale
17.333 f	33.667 f	17.700 b	11.639 F	24.720 f	V4 Blue Curle D Scotch
10.997 b	33.000 b	10.000 c	28.805 B	30.220 b	V5 Tronchuda kale
11.000 d	47.667 d	16.330 b	20.711 D	43.473 d	V6 Nero di Toscana

The different letters within means differ significantly according to Duncan's multiple range test at a probability of 0.05

Table (4) shows the mean and some genetic features of the studied traits of the kale plant. The results showed that the traits of plant height, stem diameter, number of leaves, and leaf length and width showed a wide range of genetic and environmental variations. This difference is attributed to that the studied traits are quantitative and are highly affected by the environment (Bashir, 2023). Accordingly, the selection depends on the values of external appearance. The analysis also showed that the values of genetic and phenotypic variations were high in the traits of plant height, stem diameter and leaf length; however, these values were low in the traits of the number of leaves and

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leaf width. This genetic and phenotypic difference leads to a difference in the broad-sense heritability ratio as a result of the difference in the varieties included in this study.

The coefficient of genetic and phenotypic variation was high in the traits of stem diameter and leaf length, but it was low in the leaf width trait, and medium in the traits of stem height and number of leaves. The high values of the genetic variation coefficient for some traits may be due to the great dispersion among the studied traits; Accordingly, selection based on phenotypic characteristics can be considered an effective approach. (Brito *et al*. 2020).

The ratio of broad-sense heritability of the varieties included in the study according to the ranges proposed by Bahu (1997) and Ali (1999) was high in all traits studied, namely plant height, stem diameter, number of leaves, and leaf length and width, reaching 91.55, 97.30, 96.15, 93.58, and 93.60, respectively. The degree of expected genetic advance was high according to the ranges proposed by Robinson (1966) in all traits studied, reaching 53.82, 71.71, 50.29, 67.71 and 42.04, respectively.

The previous results of the high heritability ratio are due to the high values of genetic variation and the decrease in the values of phenotypic variation (Rout *et al*., 2019). This indicates the importance of the additional and non-additional effects of the genes that control the heritability of these traits (Wudneh, 2020). The high heritability ratio indicates that there is a relation between the individual's external appearance and genetic structure. This suggests the possibility of direct improvements to these traits in the subsequent seasons through breeding programs, which also help select the proper method of breeding (Bashir, 2023).

Table (4) Some genetic parameters of kale varieties

Leaf width	Leaf length	Leaves number	Stem diameter	Plant height	Varieties
12.312	42.875	16.498	23.913	36.578	Mean
6.744	206.556	17.718	71.221	97.607	VG
7.205	214.838	19.354	73.196	104.308	VP
0.461	8.281	1.636	1.976	6.701	VE
21.093	33.521	25.514	35.292	27.010	GCV
21.802	34.186	26.666	35.778	27.922	PCV
93.60	93.58	96.15	97.30	91.55	H
42.038	67.709	50.289	71.714	53.824	EGA

Table (5) clarifies the analysis of the correlation between the studied traits of the Kale plant varieties. The results clarified that the plant height trait has a positively highly significant correlation with the number of leaves and leaf length traits, and

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has a positively significant correlation with the stem diameter trait. Additionally, the trait of the number of leaves has a positively highly significant correlation with the leaf length trait. The results of the correlation analysis showed that the stem diameter trait has a highly negative and significant correlation with the leaf width trait. While the other correlation values were positive and negative; however, they did not reach the level of significance, as there was a positively insignificant correlation between the traits of stem diameter and leaf length and the traits of the number of leaves and leaf width. Moreover, there was a negatively insignificant correlation between the traits of the plant height and leaf width, the traits of the stem diameter and the number of leaves, and the traits of leaf length and leaf width. The positive correlations indicate that trait selection based on the result of the correlation for one of them will lead to an indirect positive response to the other trait (Bashir *et al.*, 2023). These correlations can guide the selection of patterns of promising genetic structures correctly. The genetic and environmental factors, indicated by the phenotypic or genetic correlations, are among the most important issues by which these correlations are evaluated (CRUZ *et al.*, 2012).

Table (5) Correlation analysis of the studied traits of kale varieties

Leaf width	Leaf length	Leaves number	Stem diameter	Plant height	Varieties
				1.00	Plant height
			1.00	0.47677*	Stem diameter
		1.00	-0.05862	0.61802**	Leaves number
	1.00	0.74983**	0.08450	0.81448**	Leaf length
1.00	-0.01401	0.30514	-0.71945**	-0.37439	Leaf width

(**) indicate that the difference is highly significant at the 0.01 level of significance

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